Silver Lake

Vilas County, Wisconsin

Comprehensive Management Plan

February 2023

Official First Draft for Agency and Public Review

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

Silver Lake Planning Committee

Jon Cook	Lon Fisk	Lou Gallo
Evette Gallo	Rita Krupka	Steve Haagen

Organization

Eagle River Silver Lake Association
City of Eagle River
Town of Washington

Wisconsin Dept. of Natural Resources

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1.0 INTRODUCTION

Silver Lake is an approximate 57-acre, oligo-mesotrophic, deep headwater drainage lake located in Eagle River (Vilas County), Wisconsin (Map 1). Water from Silver Lake flows north through an unnamed outlet into Yellow Birch Lake of the Eagle River Chain of Lakes. Silver Lake's watershed encompasses an area of approximately 217 acres (0.3 square miles). The lake has a shoreline perimeter of 1.4 miles, a maximum depth of 19 feet, and a mean depth of 8 feet.

Assessments completed in 2021 indicate that the lake has excellent water quality for a deep headwater drainage lake. The lake supports a species-rich aquatic plant community with 43 native species recorded since 2005, of which wild celery, Braun's stonewort, large-leaf pondweed, and common waterweed were the most frequently encountered in 2021. Four native aquatic plant species listed as special concern due to their uncommon occurrence in Wisconsin have been recorded in Silver Lake and include Robbins' spikerush, water-thread pondweed, Vasey's pondweed, and northeastern bladderwort.

Lake at a Glance - Silver Lake

Morphometry	
LakeType	Deep Headwater Drainage
Surface Area (Acres)	57.0 (WDNR definition)
Max Depth (feet)	19.0
Mean Depth (feet)	8.0
Perimeter (Miles)	1.4
Shoreline Complexity	1.9
Watershed Area (Acres)	217
Watershed to Lake Area Ratio	3:1
Water Quality	
Trophic State	Oligo-mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer Phosphous (μg/L)	15.2
Avg Summer Chlorophyll-α (μg/L)	3.6
Avg Summer Secchi Depth (ft)	10.2
Summer pH	7.0
Alkalinity (mg/L as $CaCO_3$)	< 20
Vegetation	
Number of Native Species	44
Endangered/Threatened/Special Concern Species	4
Exotic Species	3
Average Conservatism	7.2 (2005-2021 avg.)
Floristic Quality	30.1 (2005-2021 avg.)
Simpson's Diversity (1-D)	0.86 (2005-2021 avg.)

Descriptions of these parameters can be found within each respective section of this report
NHI = WDNR Natural Heritage Inventory Program

The conservation of Silver Lake has largely been undertaken by a partnership between the City of Eagle River, Town of Lincoln, and the Eagle River Silver Lake Association (ERSLA). A comprehensive management plan was completed for Silver Lake in 2013 and focused primarily on the management of Eurasian watermilfoil (EWM). In an effort to manage the lake's growing EWM population, a whole-lake 2,4-D treatment was completed in 2016. While this treatment was considered successful, in the subsequent five years, the lake has seen a resurgence in the EWM population. In an effort to not only understand the current state of the lake's EWM and native aquatic plant populations, these groups elected to move forward with creating an updated management plan for Silver Lake to assess and protect valuable areas of Silver Lake and its shoreline.

The City of Eagle River along with the ERSLA and Town of Lincoln were awarded a Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant to aid in funding the development of the management plan. The goal of this management plan update is to evaluate the management actions taken since the original plan development, their outcomes, and to create updated management goals and actions. The ultimate goal is to provide a framework for the conservation and enhancement of the Silver Lake ecosystem for current and future generations.

The management plan development included a comprehensive assessment of Silver Lake through baseline studies completed by Onterra over the course of 2021 and 2022. These baseline studies were designed to evaluate the lake's water quality, watershed, and aquatic plant community. Data regarding the health of the lake's immediate shoreland zone were collected by the WDNR in 2017. In addition, sociological data were collected from Silver Lake riparian property owners and stakeholders through the distribution of an anonymous stakeholder survey.

The data collected as part of this project in combination with available historical data were used to determine the current ecological state of Silver Lake and aid in the development of management goals to conserve and enhance this important natural resource. A detailed discussion of these study results can be found in sections 2.0 and 3.0 of this report. The assessments completed in 2021 indicate that Silver Lake is of exceptional quality, harboring a species-rich native aquatic plant community comprised of a number of rare and uncommon species. Approximately 3.6 acres of the lake was found to contain valuable emergent and floating-leaf aquatic plant communities. The surveys in 2021 and 2022 found that the lake's population of Eurasian watermilfoil has increased to the highest level recorded since surveys began in 2005. In addition, a few purple loosestrife plants were located along the lake's northern shore.

Minimal historical water quality data exists for Silver Lake, but water quality data collected as part of this project indicate water quality is excellent for a deep headwater drainage lake in Wisconsin. The lake has low phosphorus and algal levels, and it has high water clarity. The shoreland assessment completed by the WDNR found that the lake supports large tracts of natural shoreline with some smaller areas with a higher degree of development.

2.0 STAKEHOLDER PARTICIPATION

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

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

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results.

Kick-off Meeting

On August 4, 2021, a project kick-off meeting took place at the Eagle River City Hall. Participants also had the opportunity to attend the meeting through an online virtual program. An approximate one-hour presentation was given by Todd Hanke, an aquatic ecologist with Onterra. Mr. Hanke'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 meeting was recorded for future viewing by other interested persons and was also shared with other Lake Association members.

Project Wrap-up Meeting

Has not yet occurred.

Committee Level Meetings

Planning Committee Meeting I

On April 11, 2022, Onterra staff met with volunteer members from around Silver Lake comprising the Planning Committee for this project. During this approximate two and a half hour meeting, Onterra presented the results of the studies that have taken place and answered questions about Silver Lake. Following the meeting, committee members were tasked with reviewing the stakeholder survey results and compiling challenges they see facing the lake and the groups' ability to manage it.

Planning Committee Meeting II

On April 18, 2022, Onterra staff met once again with members serving on the Planning Committee for this project. During this approximately two and a half hour meeting, discussions revolved around meeting the challenges facing Silver Lake and developing a framework of management goals meant to meet these challenges. Specific actions were considered and facilitators were selected to oversee the completion of the action steps that were developed.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to Silver Lake riparian property owners and ERSLA members. The survey was designed by Onterra staff and the Silver Lake Planning Committee and reviewed by a WDNR social scientist. In October-November of 2021, the eight-page, 34-question survey was posted online through Survey Monkey for respondents to answer electronically. If requested, a hard copy was sent to the respondent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis.

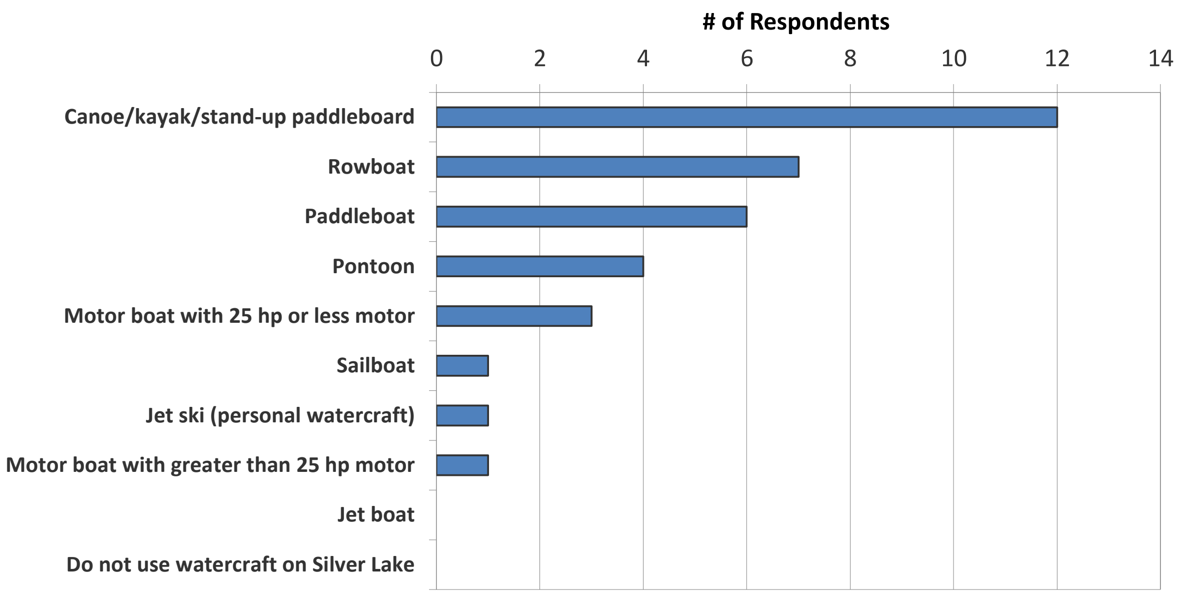
Of the 27 surveys distributed, 13 surveys (48%) were completed. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed in this section.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Silver Lake. Sixty-two percent of survey respondents indicated they are year-round residents, while 23% own a property that is used seasonally, and 15% own a property that is used on weekends and vacations (Appendix B Question #3). Thirty-eight percent of respondents indicated they have owned their property on Silver Lake for over 25 years, 38% for 11 to 25 years, and 23% for 0 to 5 years (Appendix B Question #2).

The Results and Discussion Section (Section 3.0), which discusses Silver Lake's water quality, watershed, paleoecology, aquatic plant communities, and fisheries data integration, also contains information from the stakeholder survey data as they relate to these particular topics. Figures 2.0-1 and 2.0-2 highlight results from more general questions found within this survey. The survey indicated that the top three types of watercraft utilized by Silver Lake survey respondents are non-motorized watercraft such as canoes, kayaks, or standup paddleboards (92%), rowboats (54%), and paddleboats (46%) (Figure 2.0-1). Survey respondents indicated that their top three activities that are important reasons for owning their property on Silver Lake are relaxing/entertaining, nature viewing, and canoeing/kayaking/ or paddleboarding (Figure 2.0-1).

When asked to rank their top three concerns regarding Silver Lake, survey respondents indicated that aquatic invasive species introduction, water quality degradation, and excessive aquatic plant growth (excluding algae) were the top three concerns (Figure 2.0-2). Shoreline development, excessive watercraft traffic, and unsafe watercraft practices were also marked as top concerns on Silver Lake.

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



Question 8: Please rank up to three activities that are important reasons for owning your property on or near Silver Lake.

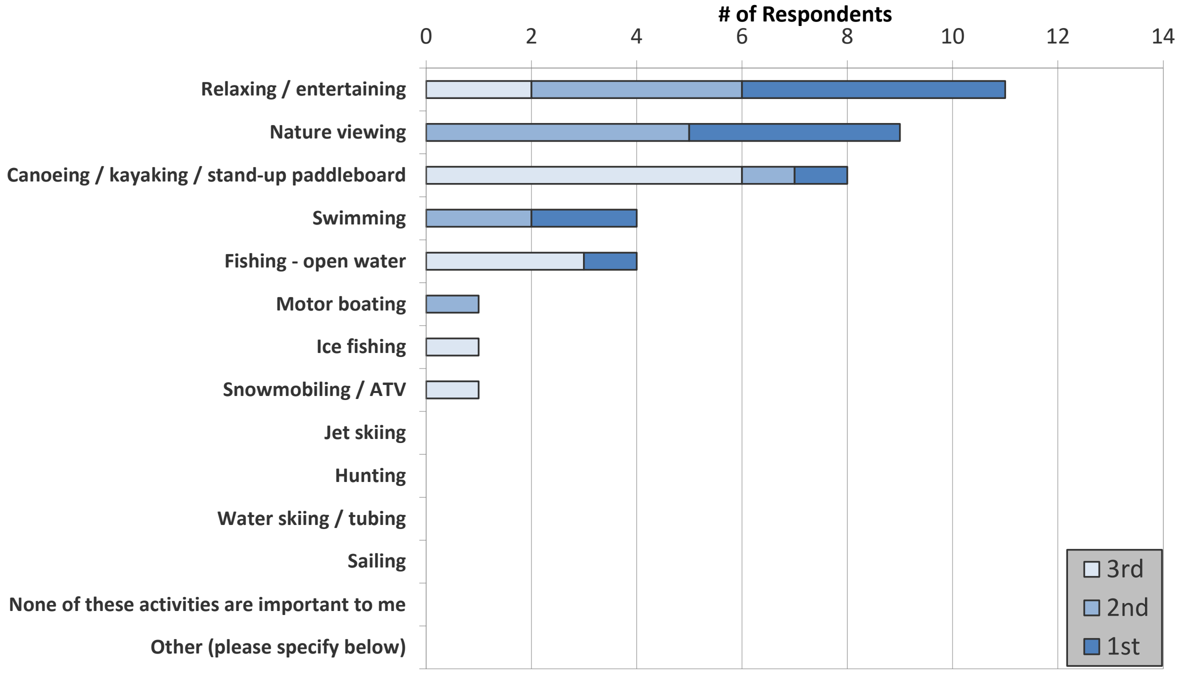


Figure 2.0-1. Select survey responses from the Silver Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 16: Please rank your top three concerns regarding Silver Lake.

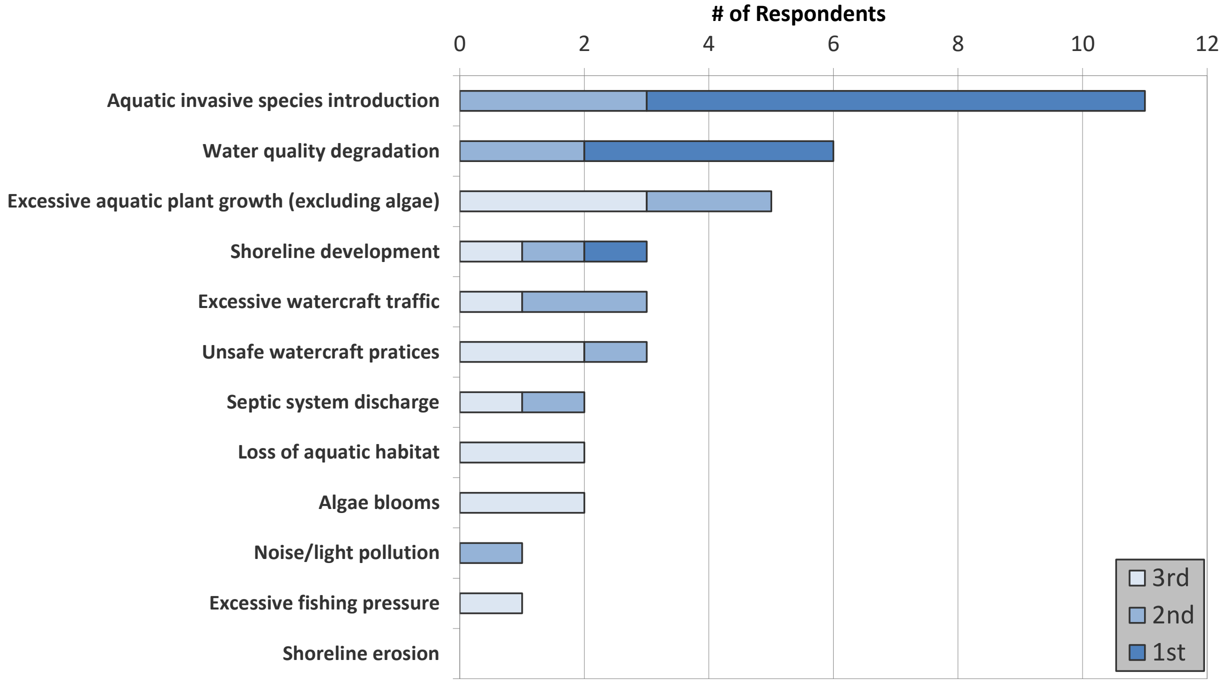


Figure 2.0-2. Select survey responses from the Silver Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

On December 5, 2022, a draft of the Implementation Plan was sent to the Planning Committee for review. The Committee submitted comments after which Onterra made edits and updates to the draft. A second draft of the Implementation Plan was issued to the Committee on January 13, 2023. The Planning Committee accepted the Implementation Plan in early-February 2023.

The Official First Draft of the Management Plan was compiled in February 2023 and distributed to WDNR, County, ERSLA, and other local project partners for official review.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

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 analyses 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). 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 primary water quality parameters are focused upon in the water quality analysis:

> **Phosphorus** is the primary nutrient that regulates the growth of planktonic algae and some larger, vascular plants (macrophytes) in the vast majority of Wisconsin lakes. 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 frequently employed 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 quadrants (a Secchi disk) into the water and recording the depth just before it disappears from sight.

These three parameters are often correlated with one another. 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, Nelson, & Everett, 1994); (Dinius, 2007); (Smith, Cragg, & Croker, 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. Oligotrophic lakes have the lowest amounts of nutrients and biological productivity, and are generally characterized by having high water clarity and a lower abundance of aquatic plants. Mesotrophic lakes have moderate levels of nutrients and biological productivity and generally support more abundant aquatic plant growth. Eutrophic lakes have higher levels of nutrients and biological productivity, and generally have a high abundance of aquatic plants.

Most lakes will naturally progress through these states under natural conditions (i.e., not influenced by the activities of humans), but this process can take tens of thousands of years. Unfortunately, human development of watersheds and the direct discharge of nutrient-rich effluent has accelerated this natural aging process in many Wisconsin lakes, and this is termed cultural eutrophication. The excessive input of nutrients through cultural eutrophication has resulted in some lakes becoming hypereutrophic. Hypereutrophic lakes have the highest levels of nutrients and biological productivity. These lakes are typically dominated by algae, have very poor water clarity, and little if any aquatic plant growth.

It is important to note that both natural factors and human activity can affect a lake's trophic state, and that some lakes can be naturally eutrophic. 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.

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and Secchi disk depth values that represent the lake's position within the eutrophication process. This allows for a clearer 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 larger vascular plants 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, they need 16 of each ingredient. If they are short two eggs, they will only be able to make three cakes even if they have 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 often need to be managed differently than lakes that do not. Normally, deep lakes stratify to some extent, while shallow lakes (less than 17 feet deep) do not.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills 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 processes that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Lake stratification occurs when temperature and density gradients are developed with depth in a lake. During stratification, the lake can be broken into three layers: The ***epilimnion*** is the surface layer with the lowest density and has the warmest water in the summer months and the coolest water in the winter months. The ***hypolimnion*** is the bottom layer the highest density and has the coolest water in the summer months and the warmest water in the winter months. The ***metalimnion***, often called the thermocline, is the layer between the epilimnion and hypolimnion where temperature changes most rapidly with depth.

Internal Nutrient Loading

In general, lakes tend to act as phosphorus sinks, meaning they tend accumulate phosphorus over time and export less phosphorus than the amount that is loaded to the lake from its watershed. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates over time. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel, 2001). If this phosphorus remains bound within bottom sediments, it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available. This release of phosphorus (and other nutrients) from bottom sediments into the overlying water is termed *internal nutrient loading*. While phosphorus can be released from bottom sediments under a few varying conditions, it occurs most often when the sediment-water interface becomes devoid of oxygen, or anoxic.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson, 1998). Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density.

As surface waters warm in late-spring/early summer, it becomes less dense and floats atop the colder, denser layer of water below. The large density gradient between the upper, warm layer of water (*epilimnion*) and lower, cold layer of water (*hypolimnion*) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper, dimictic lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton at the surface. Dimictic lakes are those which remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall. In dimictic lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate cyanobacterial (blue-green algae) blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in polymictic lakes, or lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes, and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms at the surface.

Phosphorus from bottom waters can also be mobilized to the surface in polymictic lakes through entrainment, or the continual deepening of the epilimnion and erosion of the metalimnion below (Wetzel, 2001). Wind-driven water generates turbulence across the thermal barrier between the epilimnion and the metalimnion and the metalimnion is eroded, mixing sediment-released nutrients into the epilimnion above. Both periodic mixing and entrainment act as "nutrient pumps" in polymictic lakes, delivering sediment-released nutrients in bottom waters to surface waters (Orihel, et al., 2015).

While a continuum exists between dimictic and polymictic lakes, the Osgood Index (Osgood, 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake's mean depth to its surface area. Lakes with an Osgood Index of less than 4.0 are deemed polymictic. Silver Lake's Osgood Index is 5.1, indicating the lake is considered intermediate between polymictic and dimictic. The temperature and dissolved oxygen data from 2021 indicate the lake remained stratified during the summer, showing that Silver Lake is most likely dimictic.

To determine if internal nutrient loading occurs and has a detectable effect on Silver Lake's water quality, the dynamics of near-surface phosphorus concentrations over the course of the growing season were examined. In dimictic lakes that experience internal nutrient loading, near-surface concentrations will often be highest in the fall following fall turnover when the phosphorus-rich bottom waters are mixed throughout the water column. In shallower lakes that experience internal loading and periodic mixing throughout the growing season, near-surface phosphorus concentrations will often increase over the course of the growing season as sediment-released phosphorus is periodically mobilized to the surface. In addition, near-bottom phosphorus concentrations are also measured during periods of stratification to determine if significant levels of phosphorus are accumulating in bottom waters.

Finally, watershed modeling was used to determine if measured phosphorus concentrations were similar to those predicted based on watershed size, land cover, and precipitation. If predicted phosphorus concentrations are significantly lower than those measured, this indicates that source(s) of phosphorus are entering the lake that were not accounted for in the model. This unaccounted source of phosphorus is often attributable to the internal loading of phosphorus.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR, Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM), 2018) 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 is compared to lakes in the state with similar physical characteristics.

The WDNR classifies Wisconsin's lakes into ten natural communities based on size, hydrology, and depth (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, and hydrology. An equation developed by (Lathrop & Lillie, 1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

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

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

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

Using these criteria, Silver Lake is classified as a deep (stratified) headwater drainage lake (category 3). The water quality from Silver Lake will be compared to water quality of other deep headwater drainage lakes in Wisconsin.

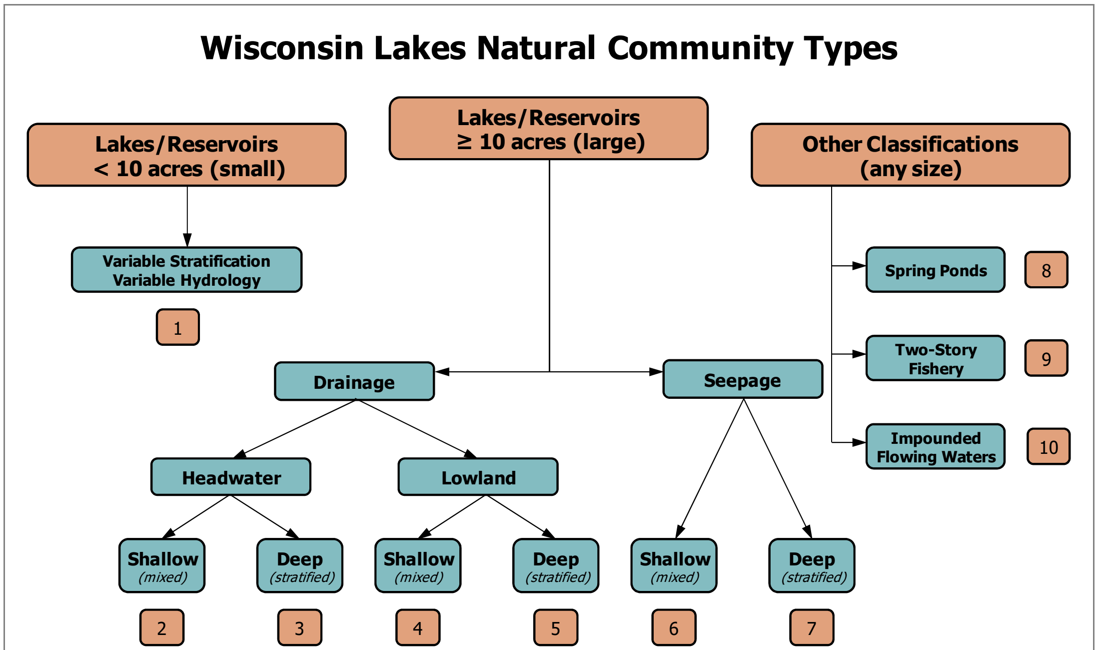


Figure 3.1-1. Wisconsin Lake Natural Communities. Silver Lake is classified as a deep (stratified) headwater drainage lake. Adapted from WDNR 2017.

(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 (NLF) ecoregion of Wisconsin (Figure 3.1-2).

The Wisconsin 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.

These data along with data corresponding to statewide natural lake means, historical, current, and average data from Silver Lake are displayed and discussed in the subsequent section. *Growing season* refers to data collected at any time between April and October, while *summer* refers to data collected in June, July, or August. Most of the data were collected from near-surface samples as these represent the depths at which algae grow. Most of the data presented in the following section were collected by ERSLA volunteers and Onterra. All data presented in this section were collected at the lake's deep hole sampling location.

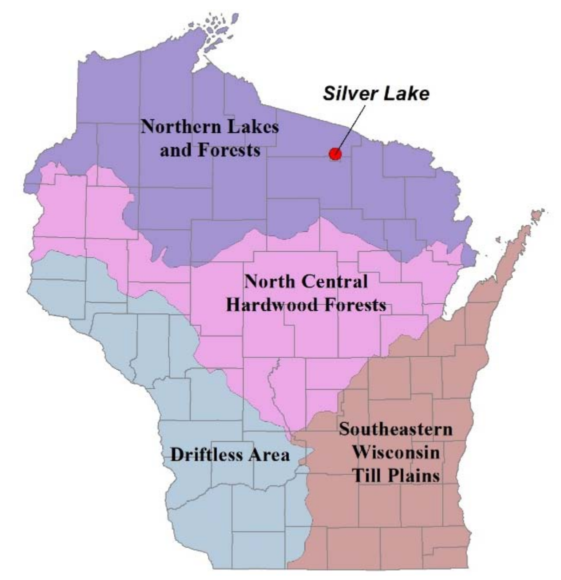


Figure 3.1-2. Location of Silver Lake within the ecoregions of Wisconsin. After Nichols 1999.

Silver Lake Water Quality Analysis

Total Phosphorus

Using 2021 mid-summer nitrogen and phosphorus concentrations from Silver Lake, a nitrogen:phosphorus ratio of 30:1 was calculated. This indicates that Silver Lake is phosphorus limited, as are most of Wisconsin's lakes. In general, this means that phosphorus is the primary nutrient regulating algal growth within the lake, and increases in phosphorus will likely result in increased algal production and lower water clarity. Conservation of Silver Lake's water quality means limiting anthropogenic sources of phosphorus to the lake (i.e., shoreland development and runoff).

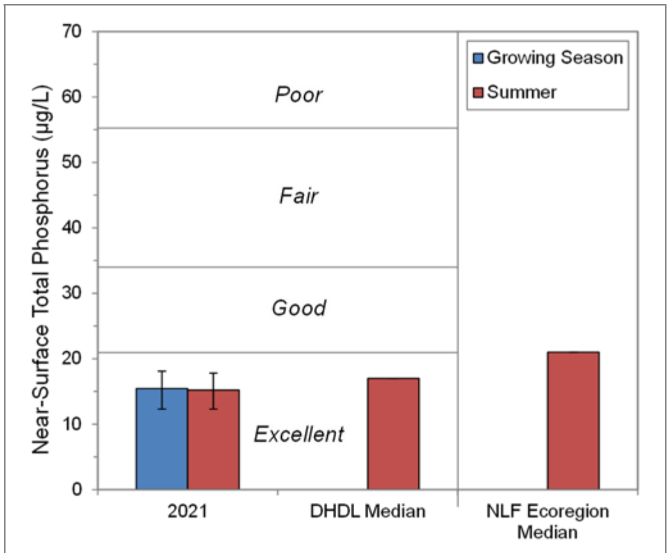


Figure 3.1-3. Silver Lake 2021 average near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Near-surface total phosphorus (TP) data from Silver Lake are only available from 2021 in Silver Lake (Figure 3.1-3). The average summer near-surface TP concentration in 2021 was 15.2 µg/L. falling into the *excellent* category for Wisconsin's deep headwater drainage lakes. The summer TP concentration is similar to the median concentration (17.0 µg/L) for other deep headwater drainage lakes in Wisconsin and lower than the median TP concentration (21.0 µg/L) for all lake types within the NLF ecoregion (21.0 µg/L). Given 2021 was the first year TP data were collected, it cannot be determined if and how TP concentrations may have or may be changing over time.

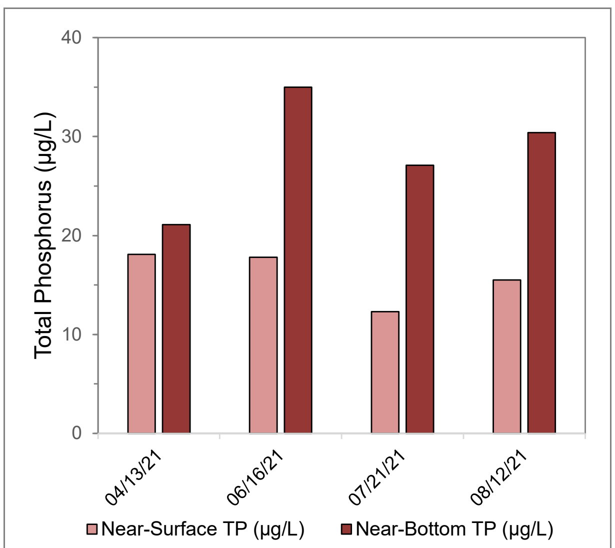


Figure 3.1-4. Silver Lake 2021 near-surface and near-bottom total phosphorus concentrations. While near-bottom concentrations are slightly higher than at the surface, these data indicate internal phosphorus loading is not a significant source of phosphorus to the lake.

Examination of Silver Lake's average near-bottom TP concentrations shows that concentrations during summer stratification are slightly higher than those at the surface (Figure 3.1-4). This typically occurs when dying algae and other organic matter sink to the bottom, elevating TP concentrations. If TP concentrations were 100-200 µg/L or greater, this may indicate internal nutrient loading. Internal nutrient loading is not a significant source of phosphorus to Silver Lake at this time.

Chlorophyll

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Silver Lake from 1979, 2015-2017, and 2021 (Figure 3.1-5). The weighted summer average chlorophyll-*a* concentration over this period is 3.6 µg/L, indicating the lake's chlorophyll-*a* concentrations are *excellent* for Wisconsin's deep headwater drainage lakes, and fall below the median concentration for statewide deep headwater drainage lakes (5.0 µg/L) and the median concentration for all lake types within the NLF ecoregion (5.6 µg/L). Summer 2021 chlorophyll-*a* concentrations were below average at 2.2 µg/L. Like total phosphorus, given the limited chlorophyll-*a* data, it cannot be determined if any trends are occurring over time, but they appear stable between the period between 2015 and 2021.

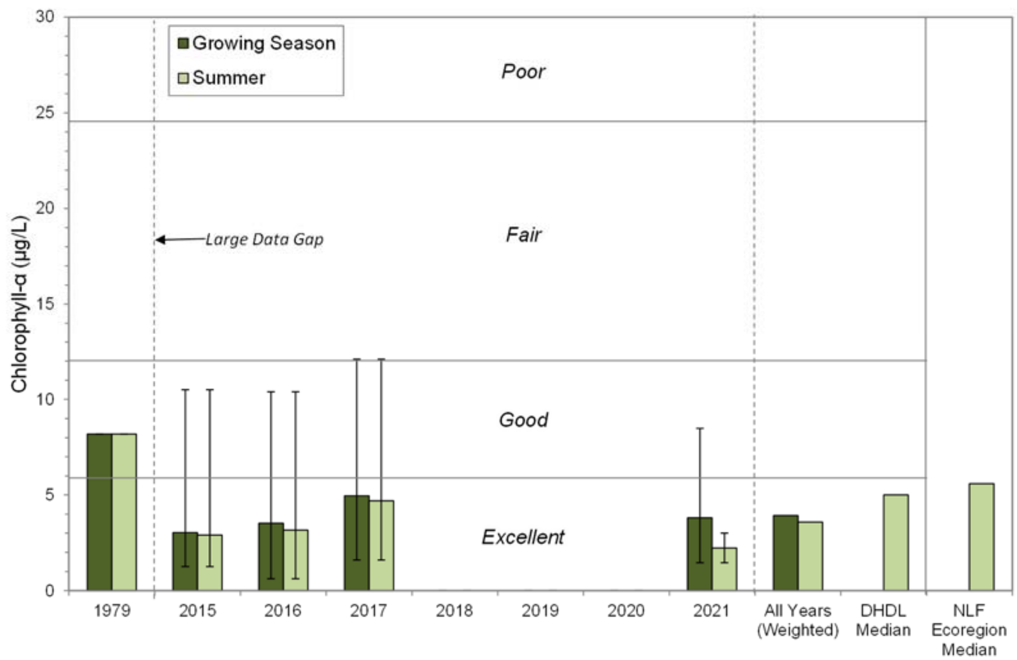


Figure 3.1-5. Silver Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Water Clarity

Water clarity monitoring using Secchi disk depths has been conducted at Silver Lake's deep hole sampling location from 1979, 1993-1998, 2010, and 2021 (Figure 3.1-6). Average summer Secchi disk depths have ranged from 12.5 feet in 2021 to 7.5 feet in 1993. The weighted summer average Secchi disk depth over this time period is 10.2 feet, indicating Silver Lake's water clarity is considered *excellent* for Wisconsin's deep headwater drainage lakes. Summer Secchi disk depths in 2021 were above the long-term average. Silver Lake's average Secchi disk depths are slightly lower than the median depth for other deep headwater drainage lakes in Wisconsin (10.8 feet) and higher than the median depth for all lake types within the NLF ecoregion (8.9 feet).

The two most important factors affecting water clarity in Wisconsin's lakes are algal abundance and water color, or true color. True color is a measure of water clarity once all particulates (i.e., algae, sediments, etc.) have been filtered out and only dissolved compounds remain. Dissolved organic matter (DOM) causes the water in lakes, particularly in northern Wisconsin, to be brown in color, or stained. This DOM originates from decaying plant matter in forests and wetlands in the lake's watershed.

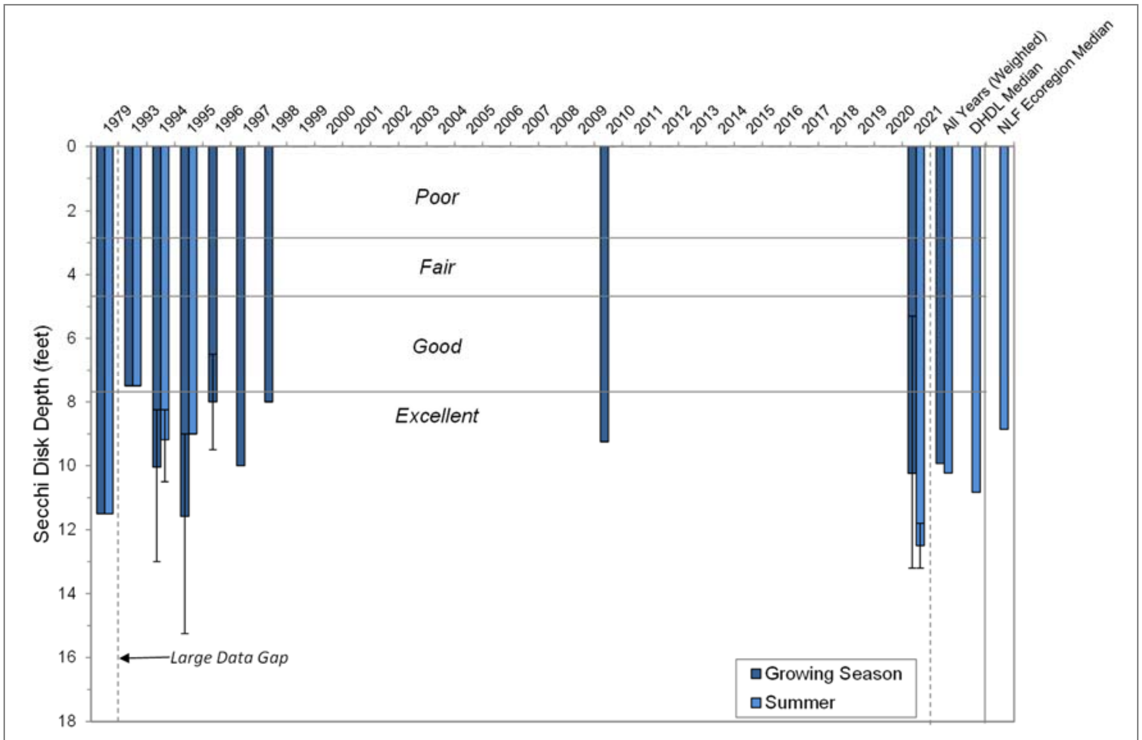


Figure 3.1-6. Silver Lake average annual Secchi disk depth measured at the deep hole sampling location and median Secchi disk depth for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Water clarity in Silver Lake is slightly lower than expected based on chlorophyll-*a* concentrations, indicating that another factor apart from algae is influencing water clarity. True color measurements taken in 2021 indicated that Silver Lake's water was *slightly tea-colored* due to the presence of DOM. As is discussed in the Watershed Assessment Section (Section 3.2), an approximate 17-acre complex of wetlands drain north into Silver Lake, and likely deliver enough DOM to slightly stain or darken the lake's water. In years with higher precipitation, these wetlands may flush, increasing DOM input and decreasing water clarity (e.g., 1993).

Silver Lake Trophic State

The Trophic State Index (TSI) values for Silver Lake were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figure 3.1-7). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae.

The weighted average TSI value for Secchi disk depth is slightly higher than chlorophyll, another indicator of the influence of DOM on the lake's water clarity. The weighted average TSI values indicate that Silver Lake is currently in an oligo-mesotrophic state. Silver Lake's productivity is lower when compared to other deep headwater drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

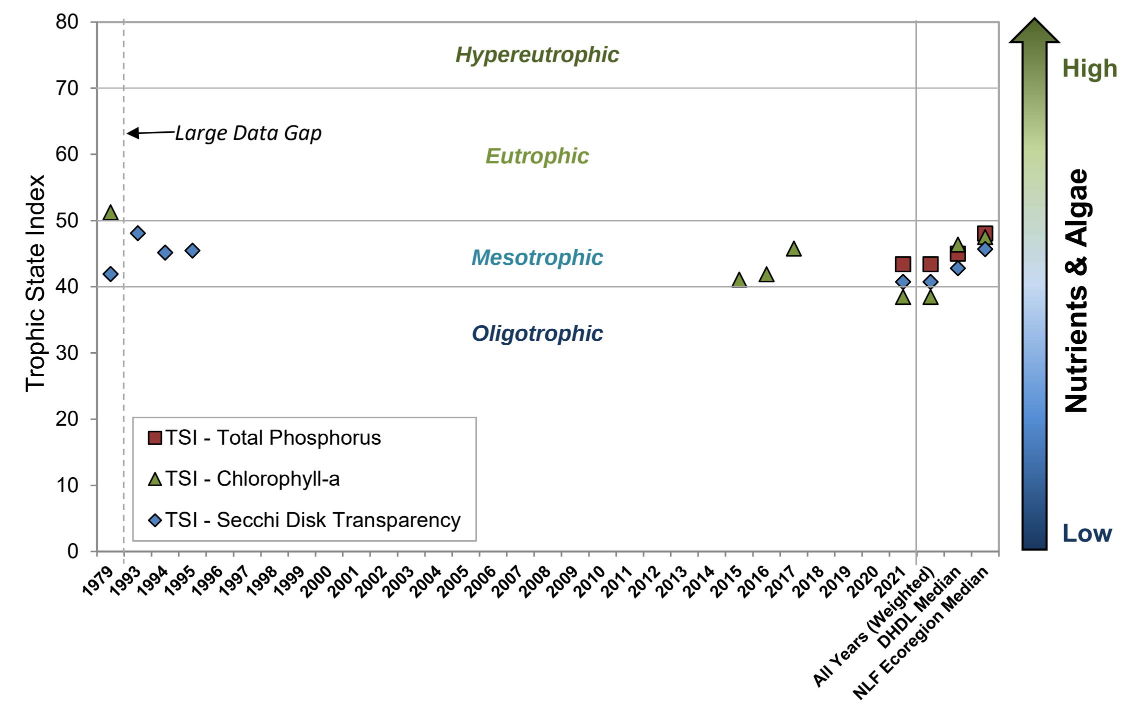


Figure 3.1-7. Silver Lake, state-wide deep headwater drainage lakes (DHDL), and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Silver Lake

Dissolved oxygen and temperature were measured during the growing season of 2021 by Onterra. A profile was also collected through the ice by Onterra in February of 2022. Profiles depicting these data are displayed in Figure 3.1-8. As discussed previously, Silver Lake is dimictic, meaning that the lake remains stratified during the summer (and inversely stratified in winter) and completely mixes, or turns over, once in spring and again in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Silver Lake straddles the boundary between deep and shallow lakes, and the 2021 data show that the lake developed weaker thermal stratification where the temperature gradient was not great as would be observed in deeper lakes. As surface temperatures cooled later in summer, the lake experienced mixing by mid-September. Dissolved oxygen was present throughout the majority of the water column during the summer of 2021. Dissolved oxygen concentrations in June and July were higher immediately above the bottom, likely due to photosynthesis of aquatic plants at these depths.

During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39°F, while oxygen gradually declines once again towards the bottom of the lake. In February 2022, Silver Lake was found to support sufficient levels of dissolved oxygen under the ice throughout most of the water column. This indicates that winter fish kills are not a concern on Silver Lake.

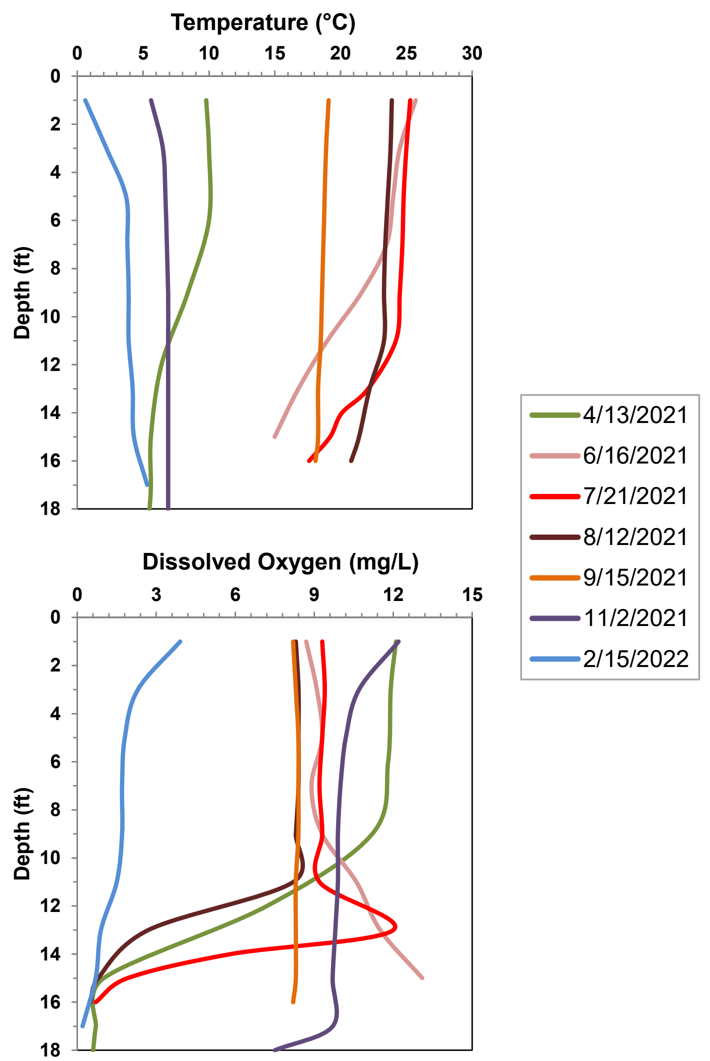


Figure 3.1-8. Silver Lake 2021 growing season and winter 2022 temperature and dissolved oxygen profiles. Collected by Onterra ecologists from the deep hole sampling location.

Additional Water Quality Data Collected at Silver Lake

The previous sections were largely centered on parameters related to lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of 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 (Figure 3.1-16). 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 & Nimphius, 1985). The mid-summer pH of the water in Silver Lake was found to be just neutral with a value of 7.0 and falls within the normal range for Wisconsin 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^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3)_2$). 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 low alkalinity have lower pH due to their inability to buffer against acid inputs. The near-surface alkalinity in Silver Lake was found to be below the limit of detection (< 20 mg/L as $CaCO_3$), indicating Silver Lake is moderately sensitive to acid rain. Alkalinity measured in near-bottom waters was detectable at just above 20 mg/L as $CaCO_3$, indicating alkalinity in surface waters is likely just below the detectable limit.

Similar to alkalinity is water hardness. While alkalinity is a measure of a lake's capacity to resist acidic changes in pH, water hardness is the combined concentration of dissolved calcium and magnesium in the water. Lakes in Wisconsin range from soft water lakes with little to no dissolved minerals to very hard water lakes with high concentrations of dissolved minerals. As is discussed in the Aquatic Plant Section (Section 3.3), alkalinity and associated water hardness are the most important factors driving aquatic plant community composition. Water hardness in Silver Lake in 2021 was 29.8 mg/L, falling below 60 mg/L and indicating that Silver Lake is considered a softwater lake.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Silver Lake's pH of 7.0 falls inside this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Silver Lake was found to be 7.7 mg/L, falling below the optimal range for zebra mussels.

Stakeholder Survey Responses to Silver Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figure 3.1-9 displays the responses of members of Silver Lake stakeholders to questions regarding water quality and how they believe it has changed over their years visiting Silver Lake. When asked what was the most important aspect regarding water quality, 46% responded that aquatic plant growth (not including algae) was the most important aspect, followed by water clarity (31%), algae blooms (15%), and smell/odors (8%) (Figure 3.1-9).

When asked how to describe Silver Lake's current water quality, 0% of respondents indicated the current water quality was *excellent*, 54% indicated it was *good*, and 38% indicated it was *fair*, 7%

indicated it is *poor*, and 0% indicated it is *very poor* (Figure 3.1-9). As is discussed earlier in this section, all of the parameters measured to assess Silver Lake's water quality were in the *excellent* category for Wisconsin's deep headwater drainage lakes. There is a discrepancy between the water quality parameters and the stakeholders' perception of Silver Lake's water quality.

This discrepancy is likely due to the fact that most respondents indicated aquatic plant growth was the most important aspect of water quality. As is discussed in the Aquatic Plant Section (Section 3.5), the majority of Silver Lake supports aquatic plant growth, including a population of Eurasian watermilfoil which was dense in a few areas. The water quality parameters assessed did not include the lake's aquatic plant community and looked at water chemistry and clarity. While water quality does influence aquatic plant growth, most of the aquatic plants in Silver Lake obtain phosphorus and other nutrients from the sediment and not the water column. The abundant growth of plants in Silver Lake is likely aiding in creating clearer water by providing structure for periphyton (algae and other organisms that grow on the plants) which absorb nutrients from the water. In addition, aquatic plants stabilize bottom sediments and provide habitat for zooplankton which graze on algae.

Respondents were also asked how they believe Silver Lake's water quality has changed since they first visited the lake. Forty-six percent indicated that the lake's water quality has *somewhat degraded*, 38% indicated the water quality has *remained the same*, 8% indicated it has *severely degraded*, and 8% believe it has *greatly improved* (Figure 3.1-9). While the water quality data do not indicate any signs of degradation, it is possible that an increase in aquatic plant growth may account for most respondents indicating water quality as *somewhat* degraded.

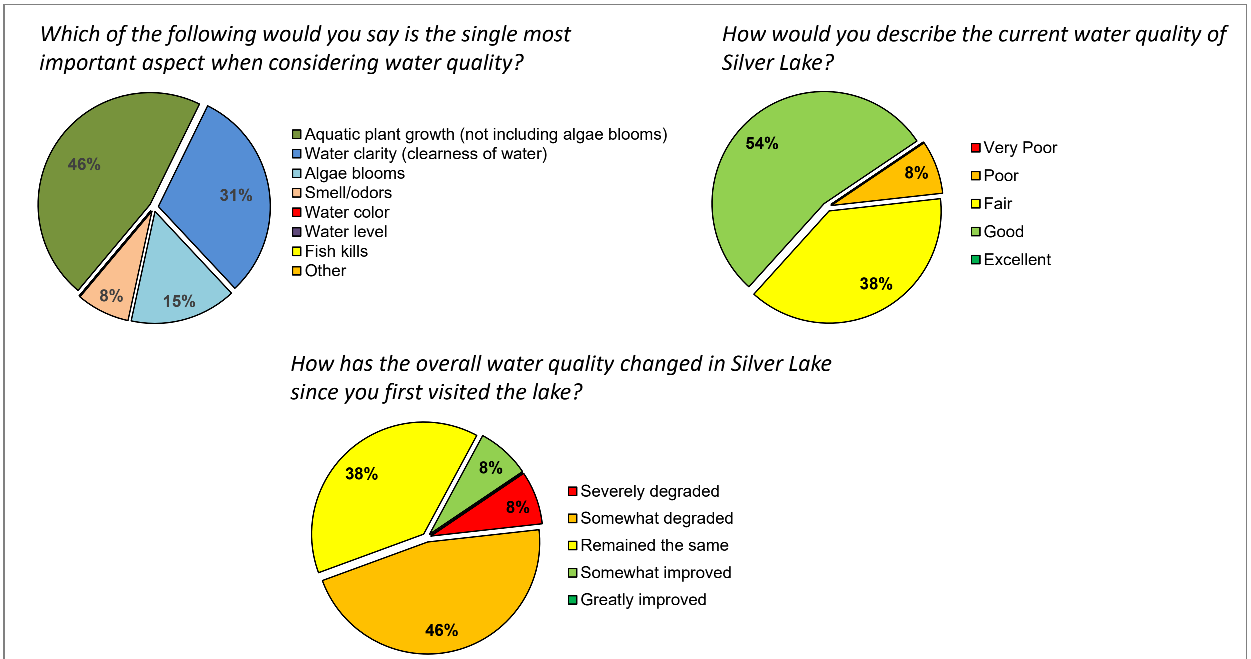


Figure 3.1-9. Silver Lake Stakeholder survey responses to water quality.

Silver Lake stakeholders were also asked what impact they believe, if any, certain anthropogenic factors have on water quality (Figure 3.1-10). Approximately 70% of respondents indicated that failing septic systems are having a large to small negative impact on Silver Lake's water quality.

 Onterra LLC Lake Management Planning

As is discussed in the subsequent Watershed Assessment Section (Section 3.2), there is no evidence to suggest that riparian septic systems are impacting Silver Lake's water quality. Stakeholders also believed runoff from impervious surfaces around Silver Lake impact water quality. While these areas are likely impacting Silver Lake to some extent, their impact was not detectable in the baseline water quality studies completed as part of this project. The Shoreland Condition Section (Section 3.4) discusses the impacts these developments can have on lakes and ways to mitigate their impacts.

Silver Lake stakeholders also indicated that they believe large-scale removal of native aquatic plants, rain gutters and downspouts draining toward the lake, and removal of nearshore vegetation are having negative impacts on Silver Lake's water quality. While these actions likely damage and have negative impacts to Silver Lake's ecology in terms of habitat loss, the water quality assessment indicates that Silver Lake's water quality is excellent for a deep headwater drainage lake in Wisconsin.

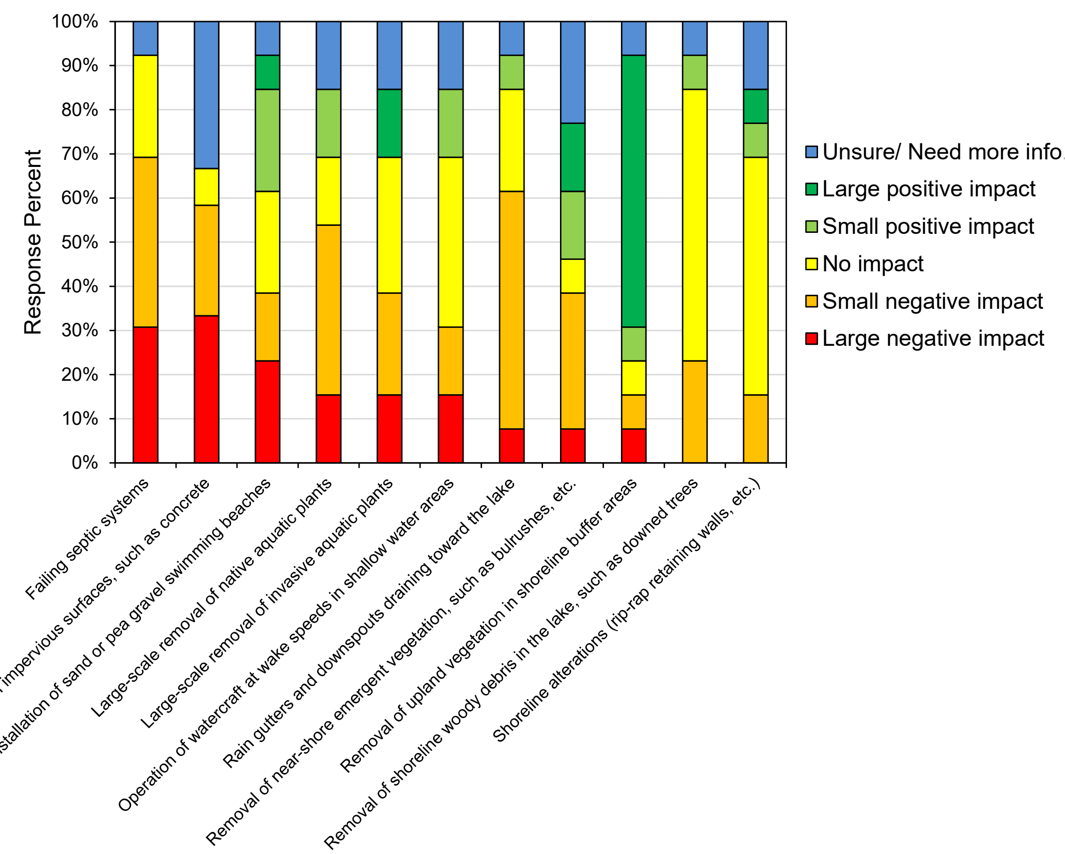


Figure 3.1-10. Silver Lake stakeholder survey response to question #20. *What impact, if any, do you believe each of the following practices have on the water quality of Silver Lake*?

3.2 Watershed Assessment

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 land cover (land use) within the watershed and 2) the size of the watershed. The type of land cover and the amount of that land cover that exists in the watershed is largely going to determine 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. Areas within a lake's watershed that are naturally vegetated (e.g., forests, grasslands, and wetlands) strongly influence the way water behaves on the land surface after it falls as precipitation or is released by the melting of snow (Silk & Ciruna, 2005).

Runoff is slowed down in areas with denser vegetation and increases the time it takes for precipitation from a storm event to reach the lake. This allows more water to soak into the soil and reduces the potential for flooding. Intact wetlands within a lake's watershed have been likened to the "kidneys of the landscape" as they filter out nutrients, sediments, and other pollutants from water which passes through them (Silk & Ciruna, 2005). The water quality within a lake is largely a reflection of the health of its watershed, and maintaining natural land cover within a lake's watershed is essential for maintaining good water quality.

Among the largest threats to a lake's water quality is the conversion of natural areas to agriculture and urban development. Conversion of natural areas to agriculture disrupts the hydrologic regime and increases surface runoff due to increased soil compaction and reduced water infiltration. Wetlands which were drained and converted to farmland were shown to increase runoff by 200-400% (Silk & Ciruna, 2005). Agriculture accounts for 60% of the pollutants in lakes and rivers in the United States due to increased runoff in combination with the application of fertilizers, pesticides, and manure.

Similar to agriculture, urban development can significantly alter the hydrologic regime within a watershed, primarily through the installation of impervious surfaces (e.g., roads, driveways, roof-tops) which decrease water infiltration and increase runoff. As impervious surface cover increases, the time it takes water from a storm event to reach the lake decreases. With the increase in water velocity and volume entering the water body, nutrient and sediment input also increase, degrading water quality. Nutrient input can also increase from urban areas as the result of fertilizer application, wastewater treatment facilities, and other industrial activities.

In addition to land cover within the watershed, the size of the watershed relative to the water volume within the lake also influences water quality. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drain 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. 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 grasslands 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 primary 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 measurable changes in primary 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 of 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 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.

Watershed Modeling

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 watershed is relatively small, encompassing just 217 acres (0.3 square miles) (Figure 3.2-1 and Map 2). A complex of forested and non-forested wetlands in the southern portion of the watershed drains northward into the lake. The lake is drained via an outlet on the lake's northeast side which flows north into Yellow Birch Lake (Eagle River Chain). The 2016 land cover data indicate that Silver Lake's watershed is comprised upland forests (30%), the lake itself (27%), urban areas of medium density (19%), forested and non-forested wetlands (8%), rural open space (8%), and rural residential areas (8%) (Figure 3.2-1 and Map 2).

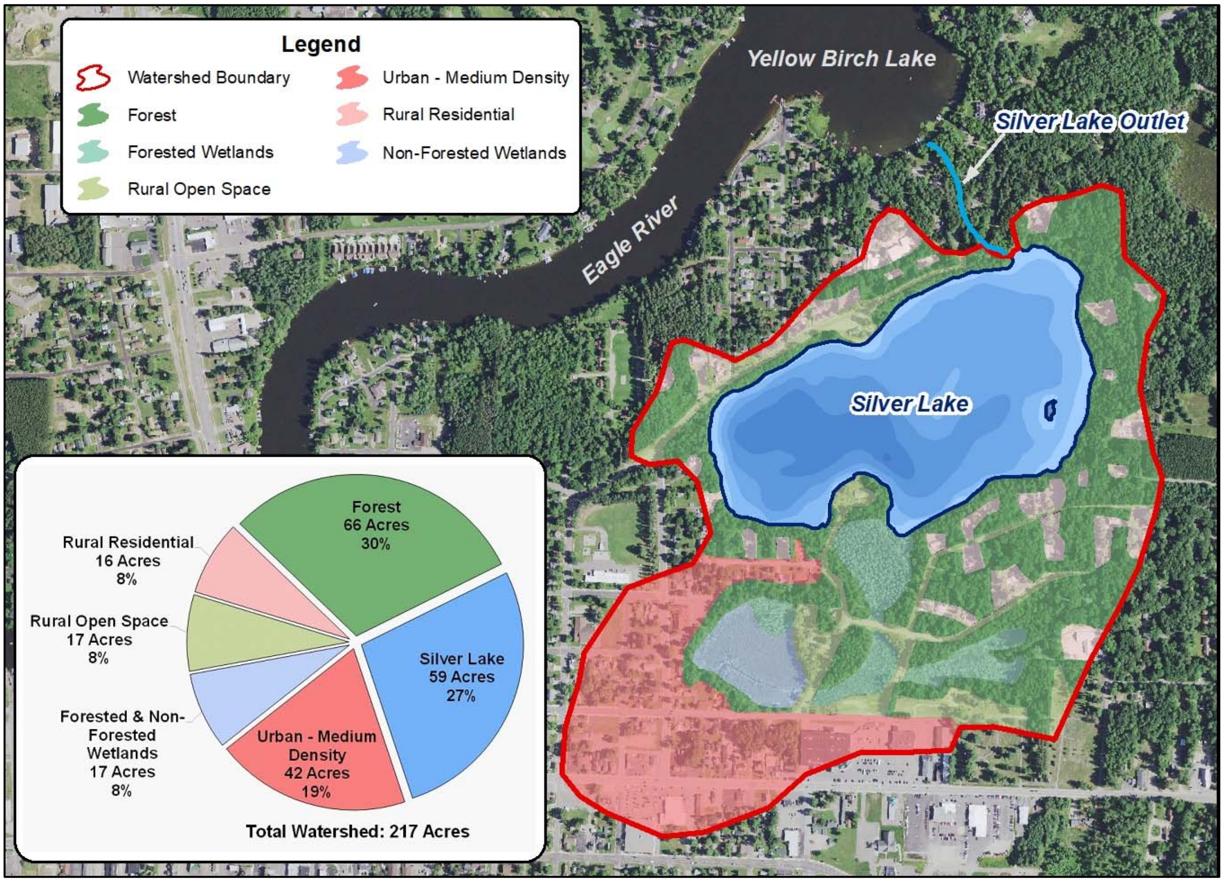


Figure 3.2-1. Silver Lake watershed and land cover types. Based upon National Land Cover Database (USGS 2016).

Using the land cover types and their acreages within Silver Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Silver Lake from its watershed. In addition, using data obtained from the 2021 stakeholder survey, an estimate of potential phosphorus loading to the lake from riparian septic systems was also incorporated into the model. The WiLMS model estimated that approximately 53 pounds of phosphorus are delivered to Silver Lake from its watershed on an annual basis (Figure 3.2-2).

Approximately 39% of the annual loading (20 lbs) was predicted to originate from medium density urban areas, 31% (15 lbs) from atmospheric deposition, 9% (4 lbs) from both rural open space and upland forests, 4% (2 lbs) from both wetlands and rural open space (Figure 3.2-2). WiLMS estimated that potentially 4 pounds (8%) of phosphorus originate from riparian septic systems. Using the predicted annual phosphorous load of 53 pounds, WiLMS predicted an in-lake average growing season total phosphorus concentration of 30 µg/L, a concentration nearly 100% higher than the measured growing season concentration of 15.5 µg/L.

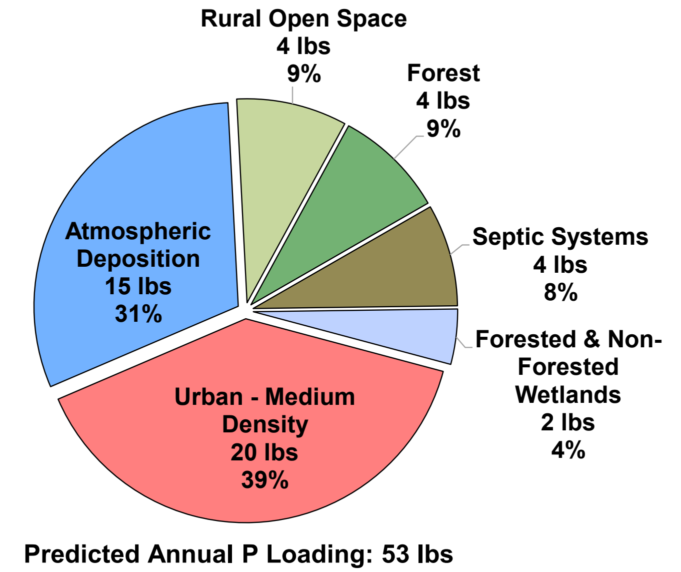


Figure 3.2-2. Silver Lake WiLMS model estimated annual watershed phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates. Measured concentrations of phosphorus in Silver Lake indicate that annual loading is likely closer to <20 pounds per year.

The discrepancy between the predicted and measured phosphorus concentrations indicates that the WiLMS watershed model is over-predicting the amount of phosphorus being loaded to Silver Lake. Given measured concentrations of phosphorus in 2021, it is likely that less than 20 pounds of phosphorus are being loaded to Silver Lake annually. While approximately 19% of Silver Lake's watershed is comprised of urbanized development, these urban areas drain to the 17-acre wetland complex on the south side of the lake. These wetlands are likely intercepting and retaining a significant portion of the phosphorus runoff from these urban areas, or acting as filters and removing phosphorus and other pollutants. Maintaining the integrity of these wetlands into the future will ensure protection of Silver Lake's water quality.

The WiLMS model estimated that Silver Lake has a water residence time of approximately 2.3 years. In other words, on average, the water in Silver Lake is completely replaced once every two and half years. This is a relatively long water residence time, meaning that pollutants entering the lake will not leave the system very quickly and may accumulate over time. Given the urbanized development in Silver Lake's watershed, the ERSLA may want to consider testing for and monitoring chloride concentrations.

Chloride occurs naturally in Wisconsin's waters at low levels (2-3 mg/L). Higher levels of chloride or trends in increasing chloride levels have been associated with the application of chloride-based road salts (typically sodium chloride) within the lake's watershed (Dugan, 2017). Studies have shown that ecological impacts are often observed when chloride concentrations increase into the 100-1000s mg/L (Dugan, 2017), and the Canadian government considers concentrations within this range to be chronically toxic (exposure to elevated concentrations over extended time periods) (Evans M., 2001). While the aquatic plant data collected from Silver Lake do not suggest any impacts from chloride, the ERSLA may want to consider periodically measuring chloride concentrations and can take actions if they find concentrations are increasing over time.

3.3 Shoreland Condition

Lake Shoreland Zone and its Importance

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 reduces many forms of habitat for wildlife.

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however, the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers' itch. Development such as rip rap or 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 aim to enhance and protect shorelands. Additionally, counties, townships and other municipalities have developed their own (often more comprehensive or stronger) policies. At the state level, the following shoreland regulations exist:

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized 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. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

- 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 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- 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. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

Mitigation requirements: 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. Mitigation requirements are county-specific and any such projects should be discussed with local zoning to determine the requirements.

Wisconsin Act 31

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

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk, Hunt, Greb, Buchwald, & Krohelski, 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. Groundwater 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 & 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, Gillum, & Meyer, 2002). And studies on shoreland development and fish nests show that undeveloped shorelands are preferred as well. In a study conducted on three Minnesota lakes, researchers found that only 74 of 852 black crappie nests were found near shorelines that had any type of dwelling on it (Reed, 2001). The remaining nests were all located along undeveloped shoreland.

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

Photograph 3.3-1. Example of coarse woody habitat in a lake.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging area, as well as spawning habitat (Hanchin, Willis, & St. Stauver, 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey, Bozek, Jennings, & Cook, 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 many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. (Newbrey, Bozek, Jennings, & Cook, 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 such as 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.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings, E., Hatzenbeler, Edwards, & Bozek, 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, E., Hatzenbeler, Edwards, & Bozek, 2003), (Radomski & 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 & Schindler, 2004).

Photograph 3.3-2. Example of a bio-log restoration site.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function. Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.4-1).

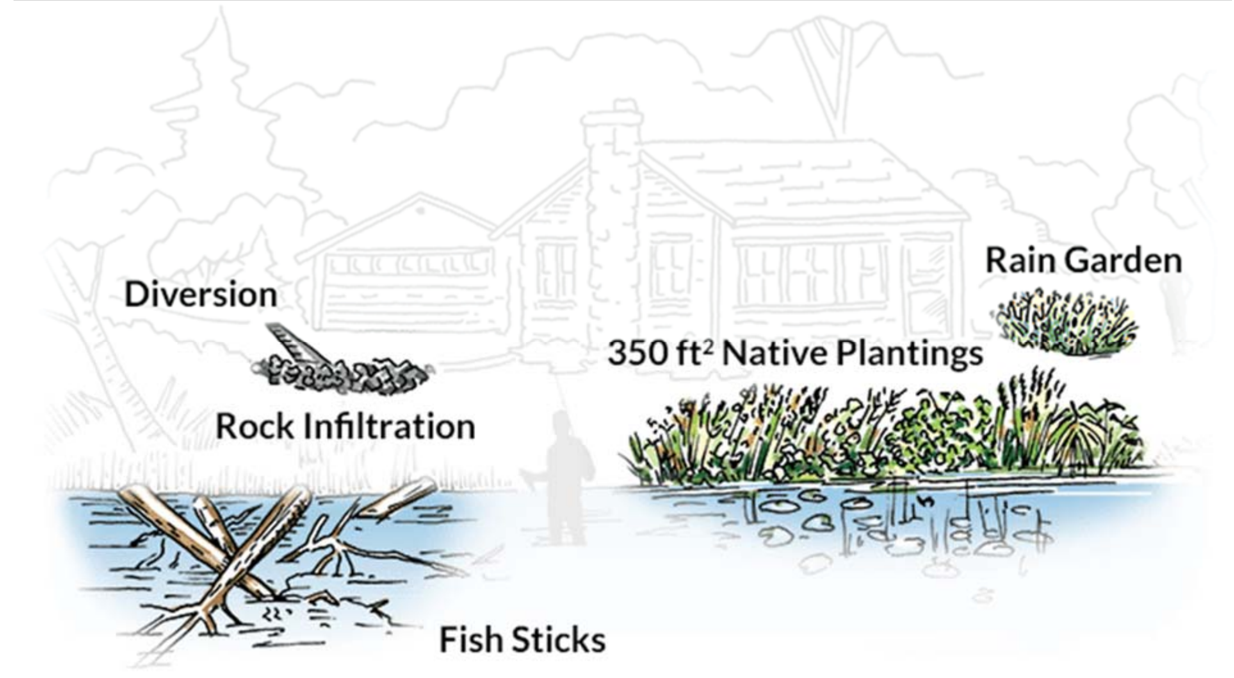


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

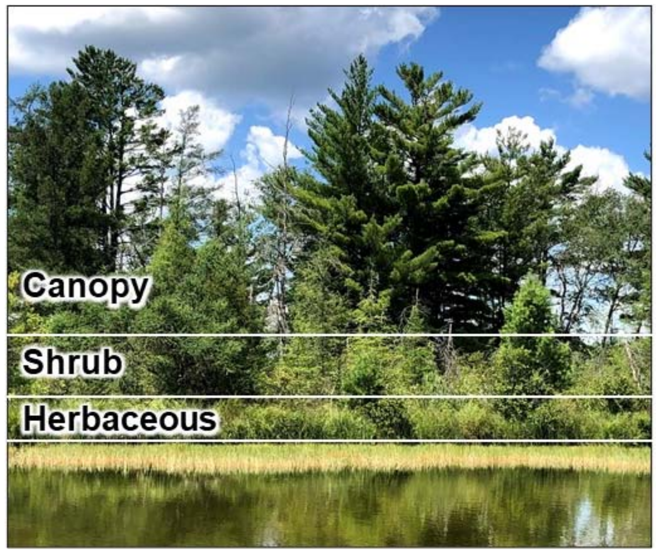
The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here: https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

Silver Lake Shoreland Zone Condition

Shoreland Development

Silver Lake's 1.4-mile shoreline was surveyed in 2017 by WDNR staff, and the data presented in this section were provided by the WDNR. A draft WDNR protocol (WDNR, 2016) was utilized to evaluate the shoreland zone on a parcel-by-parcel basis beginning at the estimated high-water level mark and extending inland 35 feet. Within the shoreland zone the natural vegetation (canopy cover, shrub/herbaceous) was given an estimate of the percentage of the plot which is dominated by each category (Photo 3.3-3). Human disturbances such as impervious surface, manicured lawn, agriculture, number of buildings, boats on shore, piers, boat lifts, sea wall length, were also recorded by number of occurrence or percentage during the survey.



Photograph 3.3-3. Example of lake shoreland natural canopy, shrub, and herbaceous layers. Photo credit Onterra.

For this management plan, the percent canopy cover, percent shrub/herbaceous, percent manicured lawn, and percent impervious surfaces are primarily focused upon to assess the shoreline for development and determine a need for restoration. In general, developed shorelands impact a lake ecosystem in a negative manner, while definite benefits occur from shorelands that are left in their natural state or a near-natural state. Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.4-3). Forty-eight 333percent (0.7 miles) of the Silver Lake shoreline contains a canopy that covers between 81-100% of the parcel, 43% (0.6 miles) contains 61-80% canopy cover, 3% (0.04 miles) contains 41-60% canopy coverage, 1% (0.02 miles) contains 21-40% canopy coverage, and 5% (0.07 miles) contains 0-20% (Figure 3.3-3 and Map 3).

Shrub and herbaceous layers are small trees and plants without woody stems less than 16 feet tall (Photograph 3.3-3). Twenty percent (0.27 miles) of the Silver Lake shoreline contains a shrub/herbaceous layer that covers between 81-100% of the parcel, 34% (0.48 miles) contains 61-

80%, 20% (0.28 miles) contains 41-60%, 17% (0.24 miles) contains 21-40%, and 9% (0.13 miles) contains 0-20%. (Figure 3.3-2 and Map 4).

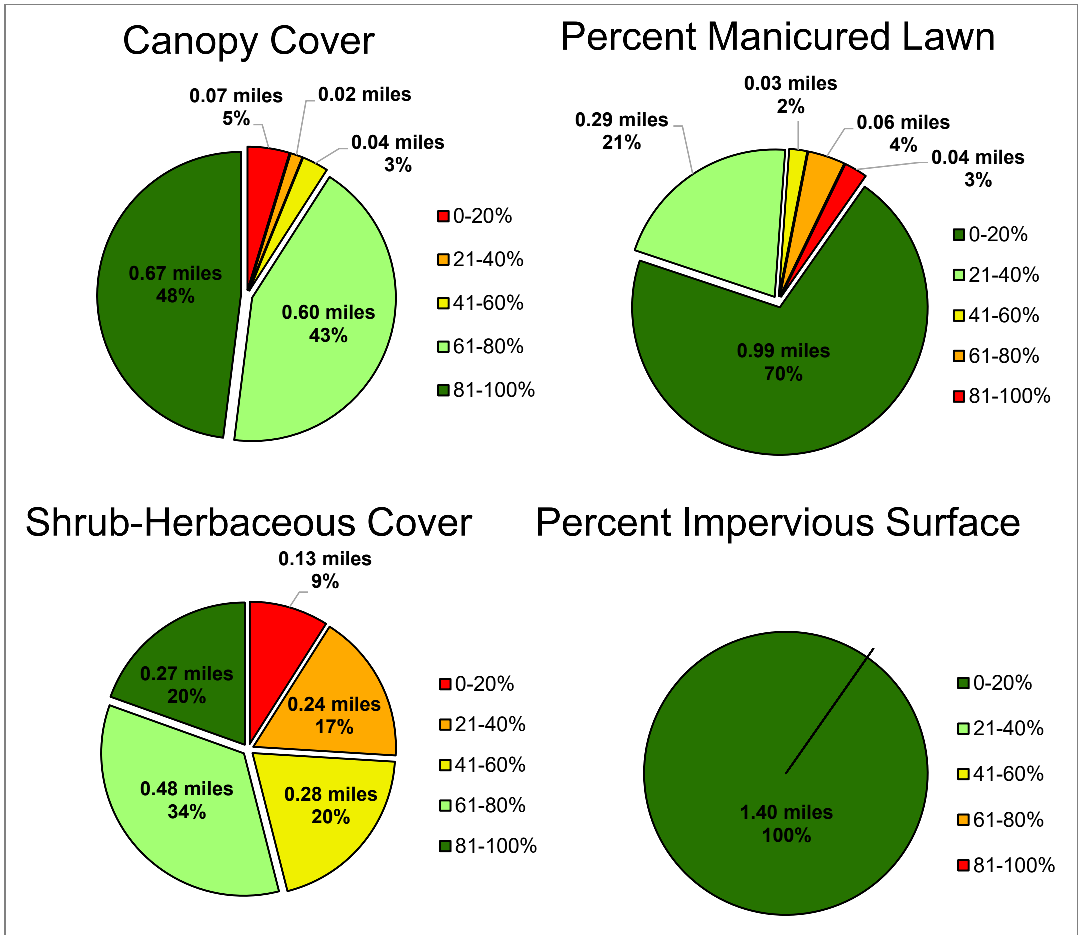


Figure 3.3-2. Silver Lake 2017 shoreland parcel canopy cover, shrub-herbaceous cover, manicured lawn, and impervious surface. Created using data provided by Wisconsin Dept. of Natural Resources.

A manicured lawn is defined as grass that is mowed short and is direct evidence of urbanization. Having a manicured lawn poses a risk as runoff will carry pollutants, such as lawn fertilizers, into the lake. Seventy percent (0.99 miles) of shoreline contained manicured lawn coverage of 0-20%, 21% (0.29 miles) contained 21-40% coverage, 2% (0.03 miles) contained 41-60% coverage, 4% (0.06 miles) contained 61-80% coverage, and 3% (0.04 miles) contained 81-100% coverage (Figure 3.3-3 and Map 5). Impervious surface is an area that releases all or a majority of the precipitation that falls onto it (e.g., rooftops, concrete, stairs, boulders, and boats flipped over on shore). One hundred percent of Silver Lake's shoreline (1.4 miles) was found to contain impervious surface coverage of 0-20%, indicating minimal coverage by impervious surfaces (Figure 3.3-3 and Map 6).

Coarse Woody Habitat

As part of the WDNR's shoreland condition assessment, Silver Lake was also surveyed to determine the extent of its coarse woody habitat. All wood greater than 4 inches in diameter, at least 5 feet long and located between the high-water level (HWL) mark and 2-foot contour line was marked with a GPS waypoint. The coarse woody habitat was then given a complexity ranking (no branches, a few branches, or a full crown), noted if it touched shore, and whether or not it was mostly submerged in water. 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 (Newbrey, Bozek, Jennings, & Cook, 2005).

During the survey, a total of 208 total pieces of coarse woody habitat were observed along 1.4 miles of shoreline (Figure 3.3-4 and Map 7), yielding a course woody habitat pieces per shoreline mile of 143:1. Of the 208 pieces located, 136 (65%) had no branches, 60 (29%) had a few branches, and 12 (6%) had a full crown. Onterra has completed coarse woody habitat surveys on 129 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Silver Lake was the highest recorded of the 129 lakes (Figure 3.3-3). Please note that based on the WDNR protocol, all Silver Lake coarse woody habitat was collected between the 2-foot contour line and the high-water level mark. The Onterra protocol, which all data from Onterra project lakes was collected from, only records data on coarse woody habitat which crosses the high-water level mark.

Figure 3.3-3. Silver Lake coarse woody habitat survey results. Based upon a WDNR 2017 survey. Locations of Silver Lake coarse woody habitat can be found on Map 7.

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.

Photograph 3.4-1. Example of emergent and floating-leaf plant community.

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 watermilfoil (*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 species will be discussed further in depth in the Aquatic Invasive Species section. 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.

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 techniques applicable to Silver Lake are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

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

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

Manual Removal (Hand-Harvesting & DASH)

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.

Photograph 3.4-2. Example of aquatic plants that have been removed manually.

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,500 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,500 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

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

Bottom Screens

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

Cost

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

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

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends

Photograph 3.4-3. Mechanical harvester.

traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Cost

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

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

Herbicide Treatment

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

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in Appendix F of (Gettys, 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: 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. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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.

Table 3.4-1. Common herbicides used for aquatic plant management.

	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; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen -benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with 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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • Herbicides can be economical at certain scales compared with other management options. • Herbicide type and application timing can increase selectivity towards target species. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil 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 watermilfoil 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 watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on 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 aquatic plant species, both native and non-native, that were located during the surveys completed in Silver Lake since 2005. The list also contains the growth-form of each plant found (e.g., submergent, emergent, etc.), its scientific name, common 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 growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Silver Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

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 surveys (equation shown below). This assessment allows the aquatic plant community of Silver Lake to be compared to other lakes within the region and state.

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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.

The Simpson's Diversity Index value from Silver Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Silver Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

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 exotic species, curly-leaf pondweed and Eurasian watermilfoil are the primary targets of this extra attention.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). Eurasian watermilfoil 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 watermilfoil 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 and instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil 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.

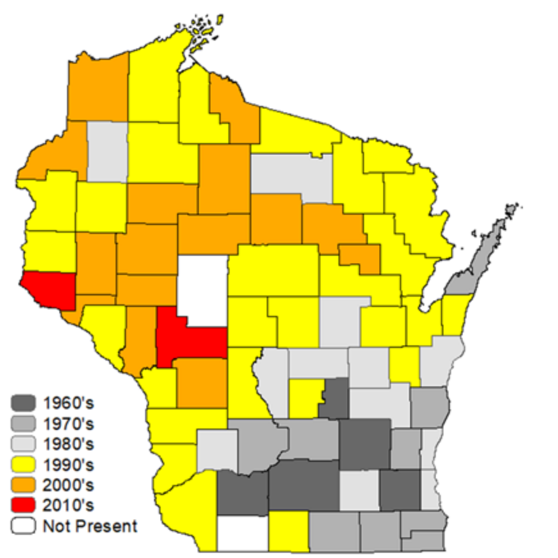


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties over time. Most recent infestations are colored in Red, Orange, and Yellow. WDNR Data 2021 mapped by Onterra.

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 watermilfoil, 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.

Due to its odd life-cycle, a special survey is conducted early in the growing season to account for and map curly-leaf pondweed occurrence within the lake. Although Eurasian watermilfoil 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.

Silver Lake Aquatic Plant Survey Results

The first survey completed on Silver Lake in 2021 was the Early-Season Aquatic Invasive Species (ESAIS) Survey completed on June 23, 2021. The goal of this survey was to identify and assess any new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists did not observed any occurrences of curly-leaf pondweed or pale-yellow iris. Eurasian watermilfoil, which is present in Silver Lake, was also mapped during this survey to aid in mapping it in later summer when it is near or at its peak growth. Purple loosestrife and narrow-leaved cattail, non-native wetland plant species, were also found on the shoreline of Silver Lake in 2021. These non-native plants will be discussed in detail in the subsequent Non-Native Aquatic Plant Section.

Silver Lake is one of the WDNR's long-term trends monitoring lakes for aquatic plants, and whole-lake point-intercept surveys have been completed almost annually between 2005 and 2021. Over the course of these surveys, a total of 44 native aquatic plant species have been identified (Table 3.4-2). In addition to Eurasian watermilfoil and purple loosestrife mentioned above, reed canary grass has been the only other non-native species documented in Silver Lake, observed by the WDNR in 2019.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the WDNR's 2021 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake. These data indicate that 92% of the point-intercept locations contained organic sediments, 41% contained sand, and 17% contained rock (Figure 3.4-2). Areas of sand or rock were primarily located in near-shore areas around the lake, while the majority of sampling locations with soft organic substrate were located in the northern basin.

The combination of both soft and hard substrates in Silver Lake creates habitat types which support different aquatic plant community assemblages, resulting in higher species richness.

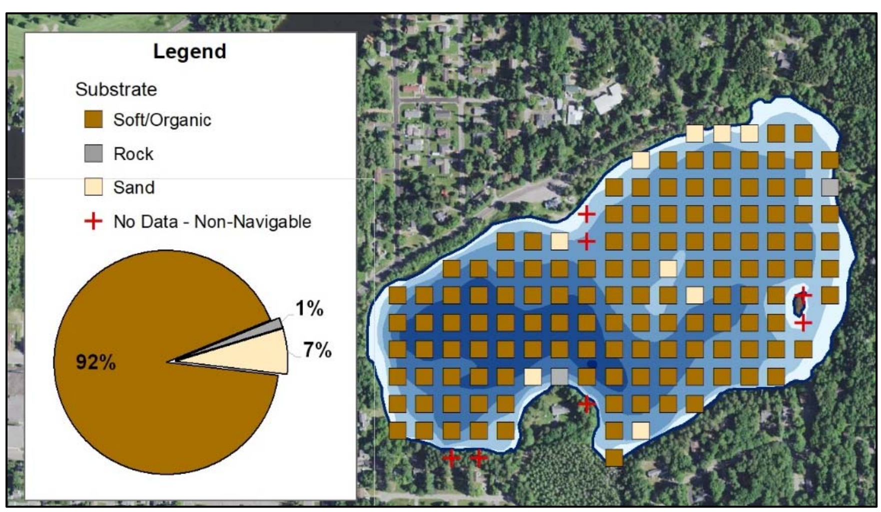


Figure 3.4-2. Silver Lake 2020 substrate types in areas ≤ 15 feet deep. Created from data collected during the 2020 whole-lake point-intercept survey.

Table 3.4-2. Aquatic plant species located in Silver Lake from 2005-2021.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Emergent	*Calla palustris*	Water arum	Native	9																I
	Decodon verticillatus	Water-willow	Native	7				I												I
	Dulichium arundinaceum	Three-way sedge	Native	9	I													I		I
	Eleocharis palustris	Creeping spikerush	Native	6	X		X	I	X	X	X							X		I
	Eleocharis robbinsii	Robbins' spikerush	Native - Special Concern	10			X										X			
	Juncus effusus	Soft rush	Native	4														I		I
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A																I
	Phalaris arundinacea	Reed canary grass	Non-Native - Invasive	N/A														I		
	Sagittaria rigida	Stiff arrowhead	Native	8	X	I	X	I				X								I
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4														I		I
	Sparganium eurycarpum	Common bur-reed	Native	5	X															
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A																I
FL	*Nuphar variegata*	Spatterdock	Native	6		X	I	I				X						X	I	I
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9		X	X	I		X	X	X	X	X				I	I	I
	Sparganium fluctuans	Floating-leaf bur-reed	Native	10																I
FL/E	*Sparganium sp.*	Bur-reed sp.	Native	N/A					X											
Submergent	*Ceratophyllum demersum*	Coontail	Native	3			X													
	Chara & Nitella	Charophytes	Native	7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Chara spp.	Muskgrasses	Native	7		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Elatine minima	Waterwort	Native	9		X	X			X										
	Elodea canadensis	Common waterweed	Native	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Elodea nuttallii	Slender waterweed	Native	7											X					
	Eriocaulon aquaticum	Pipewort	Native	9		X														
	Heteranthera dubia	Water stargrass	Native	6										X						
	Isoetes spp.	Quillwort spp.	Native	8	X	X	X	X	X	X	X	X		X		X	X	X	X	
	Lobelia dortmanna	Water lobelia	Native	10	X		X			X	X	X	X	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X		I					X	X	X			X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Najas flexilis	Slender naiad	Native	6	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
	Nitella spp.	Stoneworts	Native	7	X	X	X	X	X	X	X	X	X	X	X	X			X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton diversifolius	Water-thread pondweed	Native - Special Concern	8					X	X	X	X	X	X				X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6															X	
	Potamogeton gramineus	Variable-leaf pondweed	Native	7															X	
	Potamogeton pusillus	Small pondweed	Native	7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X		X			X		X						X		X
	Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10											X		X		X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A				X											X	X
	Stuckenia pectinata	Sago pondweed	Native	3													X			
	Utricularia cornuta	Horned bladderwort	Native	10		X														
	Utricularia resupinata	Northeastern bladderwort	Native - Special Concern	9			X	X	X	X	X	X	X				X	X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	Native	5			X	X	X	X	X	X	X	X		X	X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	Native	8						X	X	X	X				X		X	
	Sagittaria graminea	Grass-leaved arrowhead	Native	9														X		
	Schoenoplectus subterminalis	Water bulrush	Native	9	X															
FF	*Lemna trisulca*	Forked duckweed	Native	6											X					

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; FL/E = Floating-leaf & Emergent; S/E = Submergent & Emergent; FF = Free-floating

The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. The maximum depth of aquatic plant growth in Silver Lake has ranged from 19.0 feet in 2016, 2017, and 2020 to 12.0 feet in 2019 (Figure 3.4-3). The average maximum depth of aquatic plant growth between 2005 and 2021 has been 16.7 feet. Unfortunately, Secchi disk data within this period are only available from 2010 and 2021, but the changes in the maximum depth of aquatic plant growth indicate that water clarity in Silver Lake has fluctuated over this period. As is discussed in the Lake Water Quality Section (Section 3.1), Silver Lake's water is slightly stained due to the input of dissolved organic matter. Many lakes in northern Wisconsin have seen declines in water clarity within the past 5-10 years due to higher precipitation and a higher input of dissolved organic matter. The reduction in the maximum depth of plant growth in Silver Lake in 2018 and 2019 is likely the result of reduced water clarity from higher inputs of dissolved organic matter.

The littoral frequency of occurrence of vegetation in Silver Lake has ranged from 77% in 2021 to 99% in 2010, with an average occurrence of 89% (Figure 3.4-4), indicating the vast majority of Silver Lake's littoral zone supports aquatic plant growth. Total rake fullness (TRF) data collected in all years with the exception of 2005 were primarily comprised of TRF values of 1 and 2, indicating that where vegetation is present its density or biomass is low to moderate. There were very few TRF ratings of 3 across all 16 datasets. There was a larger proportion of TRF ratings of 2 in 2021 compared to previous years, indicating aquatic plant biomass/density may have been above average in 2021. The littoral occurrence of vegetation was below average in 2020 and 2021 at 81% and 77%, respectively. These fluctuations in occurrence have been seen in other long-term data lakes, and it is believed these changes are largely a function of changes in water clarity, water levels, length of the growing season, etc.

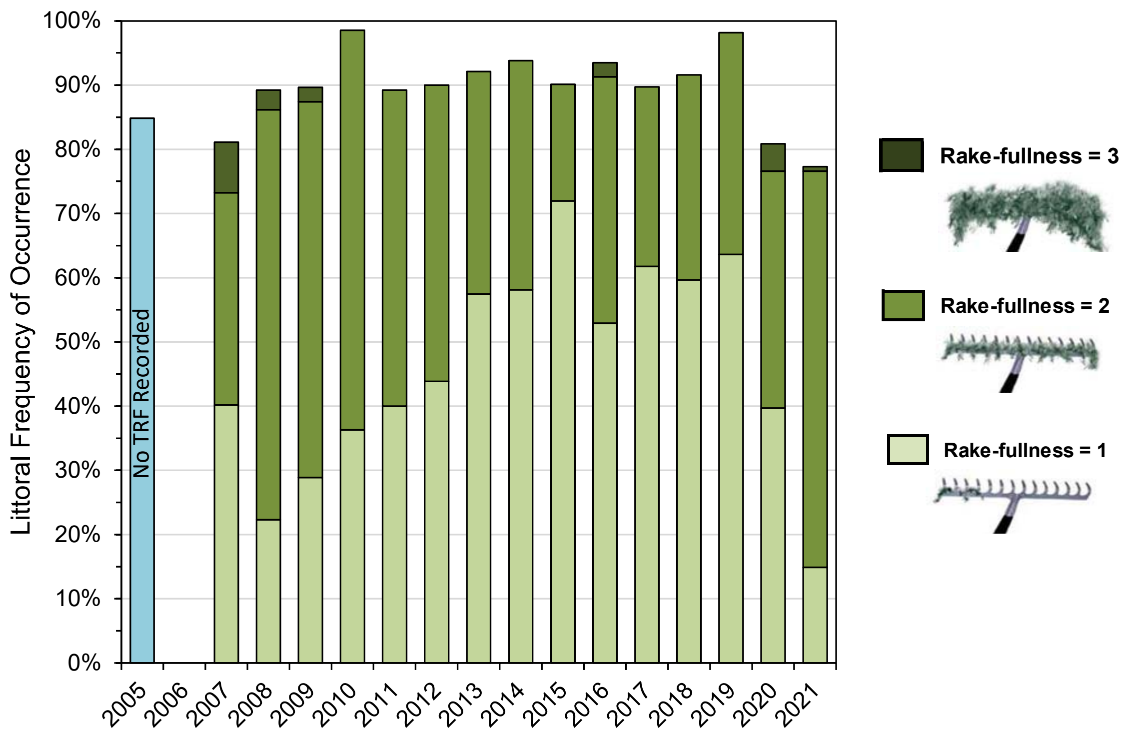


Figure 3.4-4. Silver Lake littoral frequency of occurrence of vegetation and total rake fullness (TRF) ratings from 2005-2021. Please note TRF ratings were not recorded in 2005.

The data collected from the whole-lake point-intercept survey is also used to quantify the abundance of individual plant species within the lake. Of the 45 aquatic plant species that have been recorded in Silver Lake since 2005, 18 were encountered directly on the rake during the 2021 whole-lake point-intercept survey (Figure 3.4-5). In addition to these 18 species, 11 additional species were recorded as incidental during the emergent and floating-leaf community mapping survey. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are rare within the plant community. Of the 18 species directly sampled with the rake during the point-intercept survey, wild celery, Braun's stonewort, large-leaf pondweed, and common waterweed were the four-most frequently encountered (Figure 3.4-5). Eurasian watermilfoil had a littoral occurrence of 9% in 2021. The Eurasian watermilfoil in Silver Lake is discussed in detail in the subsequent *Non-Native Aquatic Plants* sub-section.

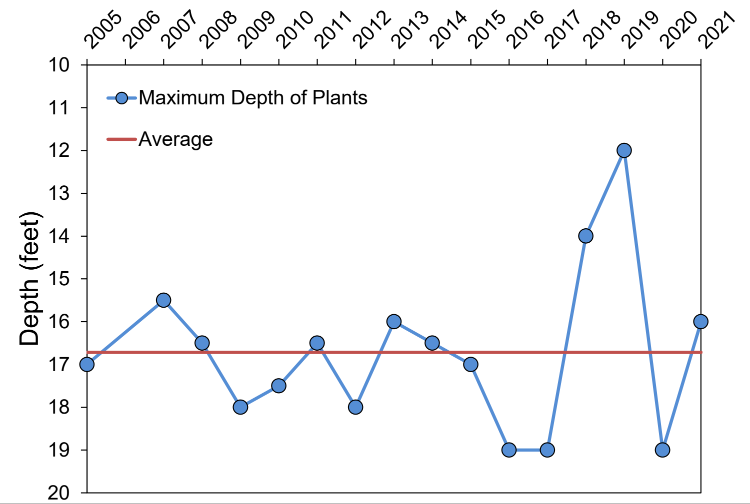


Figure 3.4-3. Silver Lake recorded maximum depth of aquatic plant growth from 2005-2021.

Four native aquatic plant species located during these studies are currently listed as special concern by the WDNR Natural Heritage Inventory Program due to "a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Wisconsin Natural Heritage Program 2016). These species include Robbins' spikerush, water-thread pondweed, Vasey's pondweed, and northeastern bladderwort (Photograph 3.4-6). All four of these species require high-quality conditions to survive, and their presence in Enterprise Lake is indicative of high-quality environmental conditions.

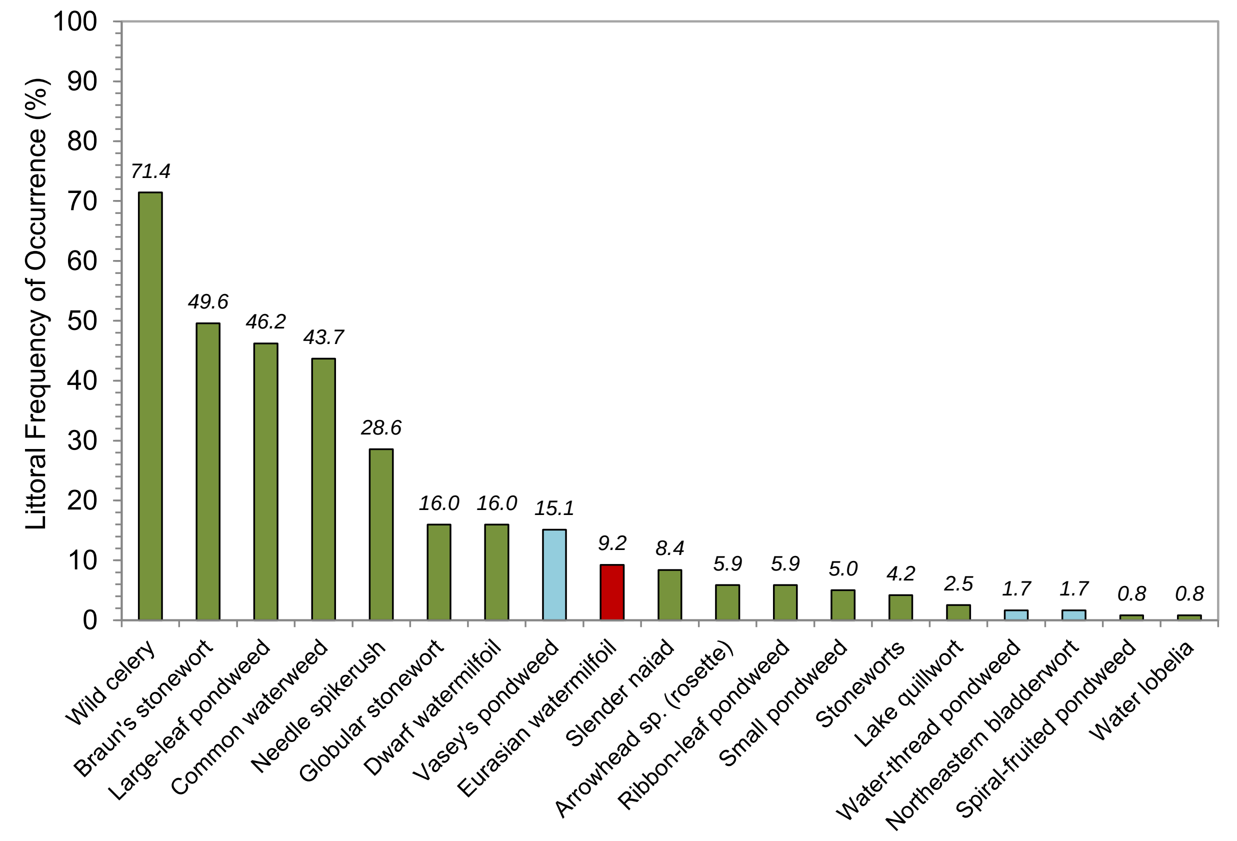


Figure 3.4-5. Silver Lake 2021 littoral frequency of occurrence of aquatic plant species. Created using data from 2021 whole-lake point-intercept survey. Native species indicated in green; native species listed as special concern indicated in light blue; non-native species indicated in red.

A Chi-Square Test was utilized to determine if changes in the littoral occurrences between surveys from 2005-2021 are statistically valid ($\alpha = 0.05$). The nine most frequently-encountered native aquatic plants were included in this analysis. The littoral occurrences of all species recorded from 2005-2021 in Silver Lake can be found in a table in Appendix D. Some of the following littoral frequency of occurrence charts also include the littoral occurrences of these species from four other northern Wisconsin lakes which have point-intercept data over this time period. These include Big Sand Lake, Little Bearskin Lake, Boot Lake, and Mid Lake.

Photograph 3.4-4. Rare native aquatic plant species listed as special concern located in Silver Lake. Photo credits Onterra.

Wild celery was most frequently encountered aquatic plant species in Silver Lake in 2021 with a littoral occurrence of 71% (Figure 4.2-5). Wild celery, or tape grass, produces long linear leaves which originate from a basal rosette. Later in summer, numerous seeds are produced which serve as an important source of food for migratory waterfowl and other wildlife. The plants extensive network of rhizomes stabilizes bottom sediments. The occurrence of wild celery in Silver Lake has increased markedly over the time period between 2005 and 2021, increasing from an initial occurrence of around 20% to between 60-85% in the most recent five years (Figure 3.4-6). Wild celery has been increasing by 3% per year on average between 2005 and 2021. The cause(s) of this increase is unknown; however, it corresponds to a decreasing trend in common waterweed, and wild celery may be expanding in areas where common waterweed has receded. As is discussed further, common waterweed has been declining in a number of northern Wisconsin lakes over this period.

Braun's stonewort, one of several macroalgae or charophyte species found in Wisconsin, was the second-most frequently encountered aquatic plant in Silver Lake in 2021 with a littoral occurrence of 50% (Figure 3.4-5). Given multiple charophyte species (both *Chara* and *Nitella*) have been recorded in Silver Lake and their morphological similarity, the occurrences of all species have been combined for this analysis. Trends analysis shows that the occurrence of charophytes in Silver Lake like wild celery has increased between 2005 to 2021, increasing by 1% per year over this period (Figure 3.4-7). Like wild celery, charophytes may be expanding in areas where common waterweed has receded.

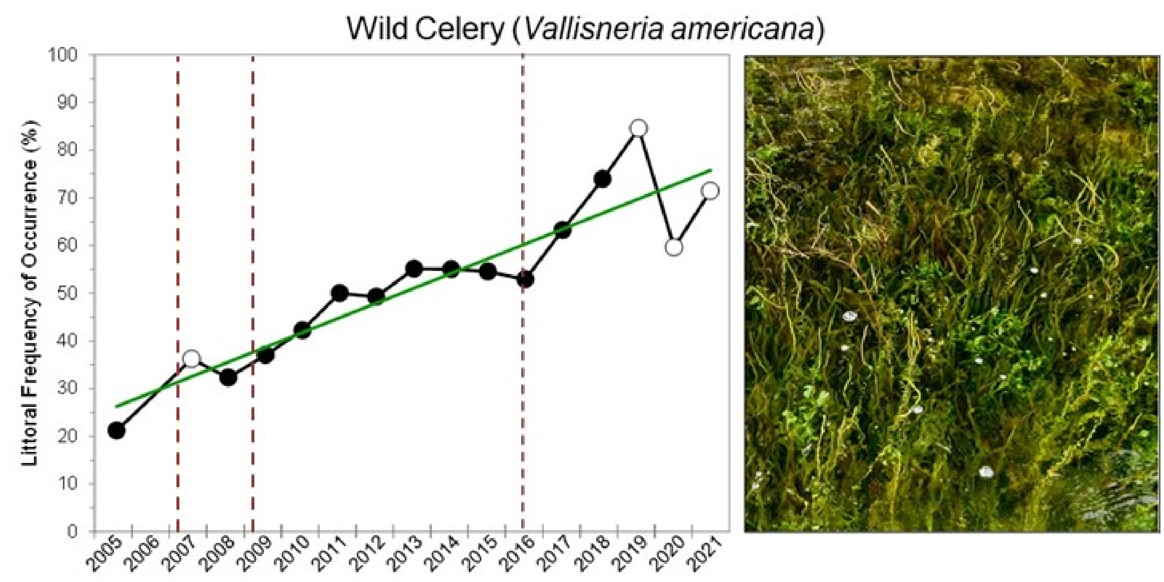


Figure 3.4-6. Littoral frequency of occurrence of wild celery in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square $\alpha = 0.05$). Dashed red lines indicate 2,4-D herbicide treatment.

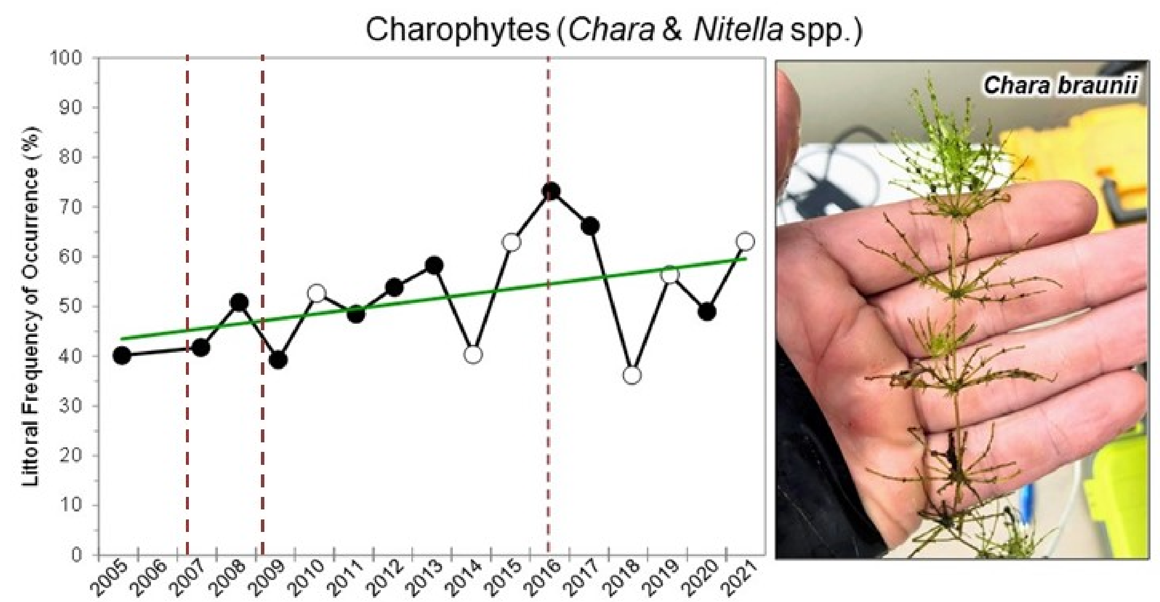


Figure 3.4-7. Littoral frequency of occurrence of charophytes in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square $\alpha = 0.05$). Dashed red lines indicate 2,4-D herbicide treatment.

Large-leaf pondweed, the largest pondweed species found in Wisconsin, was the third-most frequently encountered aquatic plant in Silver Lake in 2021 with a littoral occurrence of 46% (Figure 3.4-5). While the leaves of this species are large, colonies of large-leaf pondweed create habitat that provides both structure and larger spaces for apex fish predators to access and search for prey. This species is usually found growing in organic substrates, and in Silver Lake was most abundant between 7 and 12 feet of water. While the occurrence of large-leaf pondweed has fluctuated somewhat from 2005-2021, trends analysis indicates no statistically valid trend is present over this time period (Figure 3.4-8). The highest occurrence of large-leaf pondweed in Silver Lake was recorded in 2021.

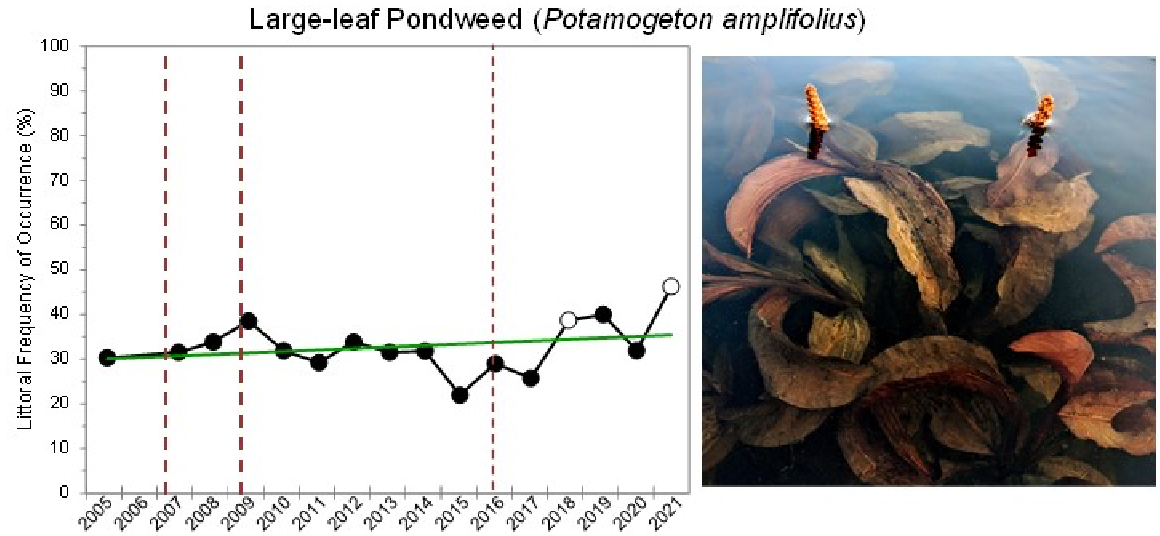


Figure 3.4-8. Littoral frequency of occurrence of large-leaf pondweed in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed red lines indicate 2,4-D herbicide treatment.

Common waterweed was the fourth-most frequently encountered aquatic plant in Silver Lake in 2021 with a littoral occurrence of 44% (Figure 3.4-5). Common waterweed can be found in waterbodies across Wisconsin, obtains much of its nutrients directly from the water, and provides valuable structural habitat. The occurrence of common waterweed in Silver Lake as declined slightly over the period from 2005-2021 at a rate of approximately 1% per year. Common waterweed saw a steep decline following the 2016 whole-lake 2,4-D treatment, and this species has been shown to be sensitive to this type of herbicide treatment strategy. However, its occurrence rebounded to pre-treatment levels in 2017, one year following the treatment. The declining trend in common waterweed occurrence was also recorded in the other four northern Wisconsin lakes over this period, indicating the decline of common waterweed in Silver Lake is likely related to regional changes in environmental factors.

Needle spikerush, a small aquatic sedge, was the fifth-most frequently encountered aquatic plant species in Silver Lake in 2021 with a littoral occurrence of 29% (Figure 3.4-5). Needle spikerush is an inconspicuous plant which produces short, grass-like stems, colonies of which form a carpet along the lake bottom. This plant is generally found growing in sandier substrates, but can also be found growing in organic sediments in areas where it is not out-shaded by taller plants. Like other spikerush species, needle spikerush produces a spike of flowers or fruits at the apex of the plant, but needle spikerush will only flower during periods of lower water levels when the plants are exposed. In Silver Lake, the occurrence of needle spikerush has seen larger fluctuations from year to year, ranging from undetected in some years to nearly 30% like in 2021 (Figure 3.4-10). Despite these fluctuations, there has been an overall increasing trend in occurrence over the period from 2005-2021.

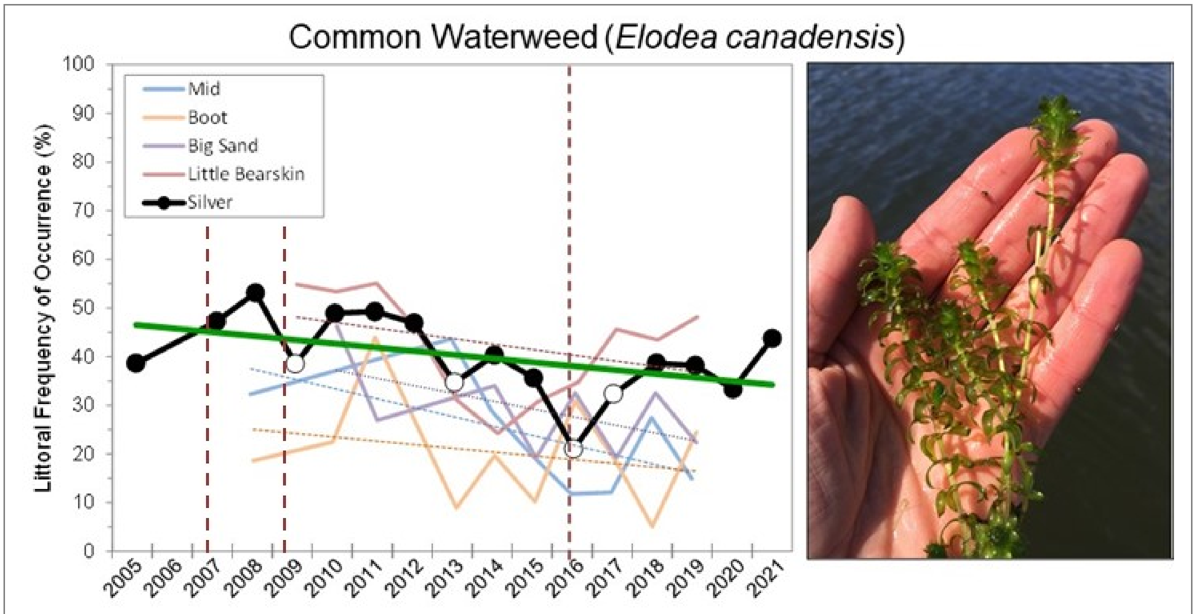


Figure 3.4-9. Littoral frequency of occurrence of common waterweed in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square $\alpha = 0.05$). Dashed red lines indicate 2,4-D herbicide treatment.

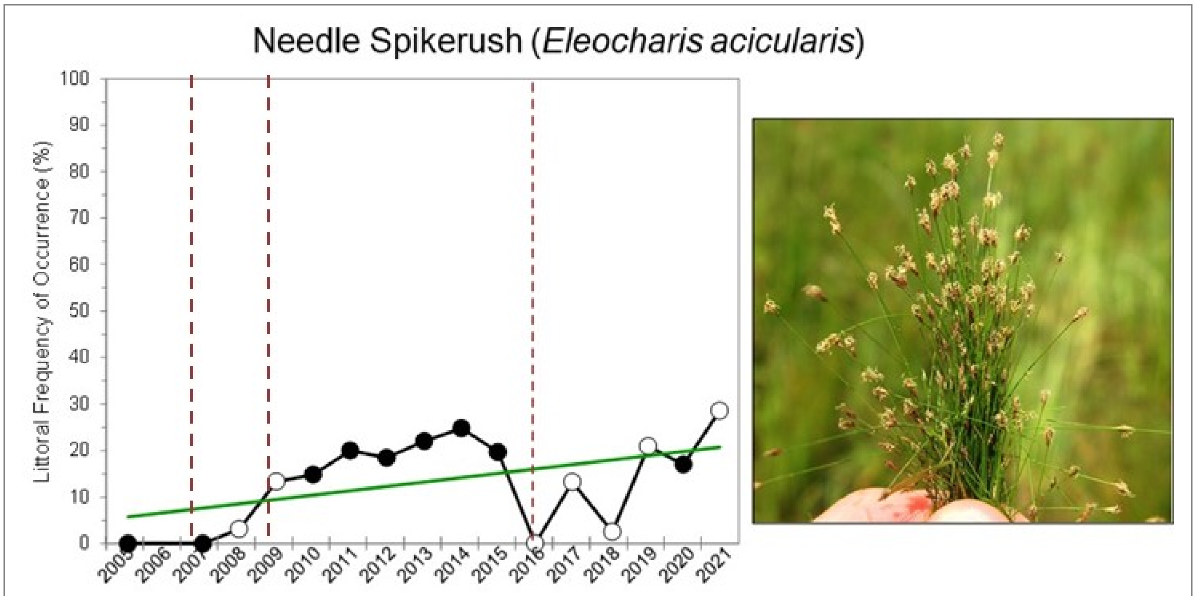


Figure 3.4-10. Littoral frequency of occurrence of needle spikerush in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square $\alpha = 0.05$). Dashed red lines indicate 2,4-D herbicide treatment.

Dwarf watermilfoil, a milfoil species more similar in appearance to needle spikerush than the other milfoil species found in Wisconsin, was the sixth-most frequently encountered aquatic plant in Silver Lake in 2021 with a littoral occurrence of 16% (Figure 3.4-5). Like needle spikerush, dwarf watermilfoil is inconspicuous, producing small stems with reduced, scale-like leaves. Dwarf watermilfoil is typically found in lakes with lower nutrients in sandy substrates; however, it can also be found in more organic substrates if taller plants are not present to out-shade it. This plant will produce small pink flowers when water levels recede and it becomes exposed. In Silver Lake, there has been a slight decreasing trend in the occurrence of dwarf watermilfoil from 2005-2021 (Figure 3.4-11).

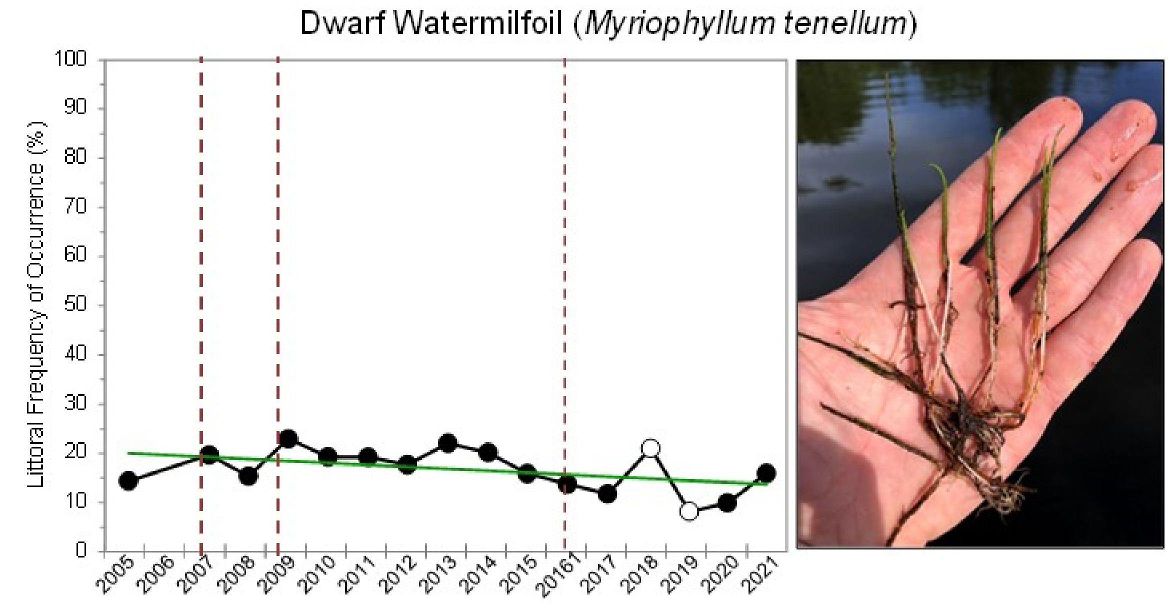


Figure 3.4-11. Littoral frequency of occurrence of dwarf watermilfoil in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed red lines indicate 2,4-D herbicide treatment.

Vasey's pondweed, a native species listed as special concern in Wisconsin as discussed earlier, was the seventh-most frequently encountered aquatic plant in Silver Lake in 2021 with a littoral occurrence of 15% (Figure 3.4-5). Vasey's pondweed is a submersed aquatic plant which produces hair-like leaves along a very slender stem. Upon reaching the surface, small floating-leaves no larger than a fingernail are produced which subtend a small spike of flowers above the water's surface. Vasey's pondweed was not detected in Silver Lake until 2016, and has been increasing in its occurrence since then (Figure 3.4-12). It is possible that this species has always been present in Silver Lake and has become more abundant in recent years due to changes in environmental conditions. It is also possible that this species was introduced to Silver Lake via watercraft (like non-native plants are) and it is becoming established. The nearby Eagle River Chain has a large population of Vasey's pondweed, and the population in Silver Lake could possibly have originated from here.

Slender naiad was the eighth-most frequently encountered native aquatic plant in Enterprise Lake in 2021 with a littoral occurrence of 8% (Figure 3.4-5). Slender naiad is one of five naiad species that can be found in Wisconsin and is also the most common. In Silver Lake, the occurrence of slender naiad was highest between 2008-2011, ranging from approximately 10-16%. There was a decreasing trend in its occurrence from 2012-2017, and there has since been an increase in its occurrence from 2018-2021 (Figure 3.4-13). Slender naiad is an annual, meaning it reproduces via seed each year. Ongoing monitoring of aquatic plant communities in Wisconsin is indicating that the occurrence of this species can be highly variable from year to year, likely due to changes in suitability for seed germination. This variability can be seen in the occurrence of slender naiad in the other lakes displayed in Figure 3.4-13. The numerous seeds produced by slender naiad have been shown to be an important food source for wildlife, including migratory waterfowl.

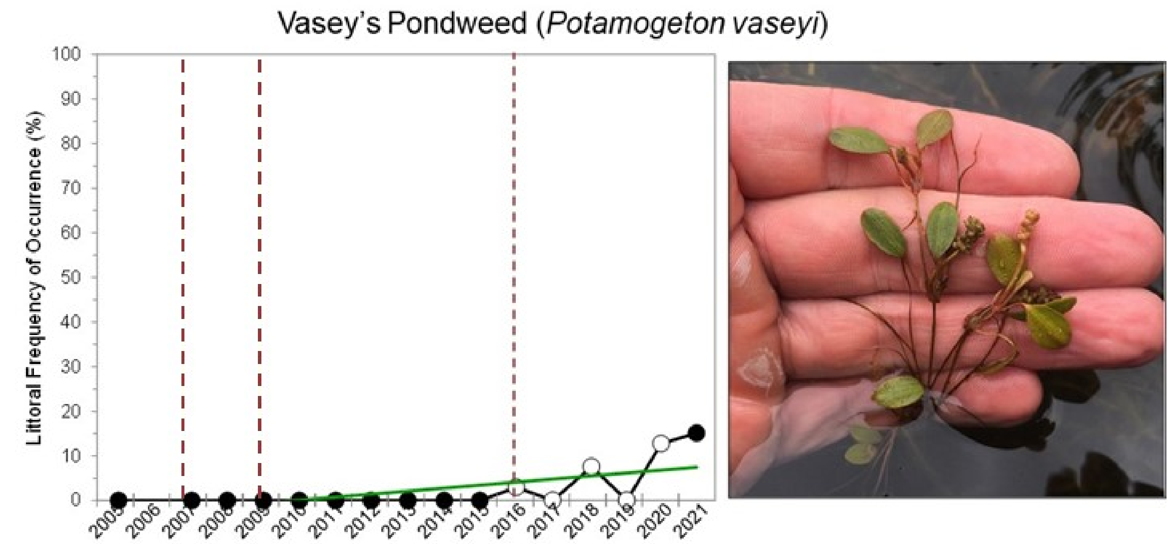


Figure 3.4-12. Littoral frequency of occurrence of Vasey's pondweed in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed red lines indicate 2,4-D herbicide treatment.

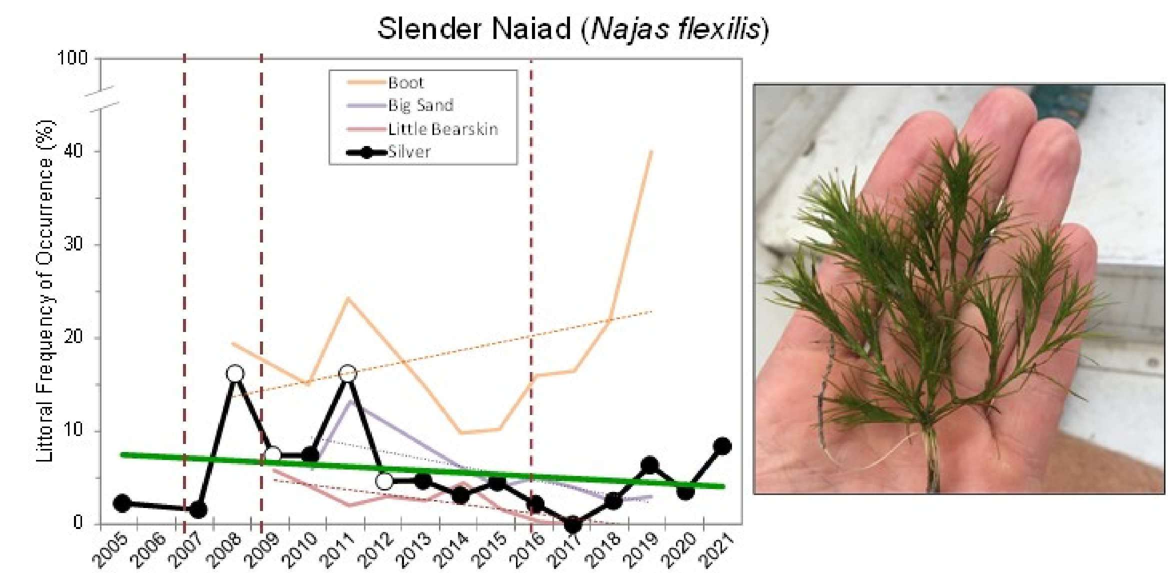


Figure 3.4-13. Littoral frequency of occurrence of slender naiad in Silver Lake. Closed circle denotes no statistical difference in occurrence from previous survey; open circle denotes statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Dashed red lines indicate 2,4-D herbicide treatment.

The calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. The native aquatic plant species located on the rake during the point-intercept surveys from 2005, 2013, and 2021 and their conservatism values were used to calculate the FQI for each year (Figure 4.2-14). Native species richness, or the number of native plant species recorded on the rake, has ranged from 21 in 2008, 2013, and 2020, to 12 in 2017. While species richness has fluctuated from 2005-2021, there is no detectable trend over this period. The species richness in 2021 was 17, which is the average for 2005-2021. This average species richness value falls slightly below the median value for lakes in the Northern Lakes and Forests ecoregion (21) and the median value for lakes statewide (19).

Between 2005-2021, average species conservatism in Silver Lake has ranged from 6.9 to 7.4 with an average of 7.2 (Figure 3.4-14). These conservatism values fall at or above the median values for lakes in the NLF ecoregion and the state. In other words, Silver Lake has a higher number of environmentally sensitive aquatic plant species when compared to the majority of lakes in the ecoregion and the state. Using the species richness and average conservatism to calculate the Floristic Quality Index for Silver Lake yielded values ranging from 24.5 to 33.7 with an average of 30.0, which falls near the median value for lakes in the NLF ecoregion and above the median value for lakes statewide.

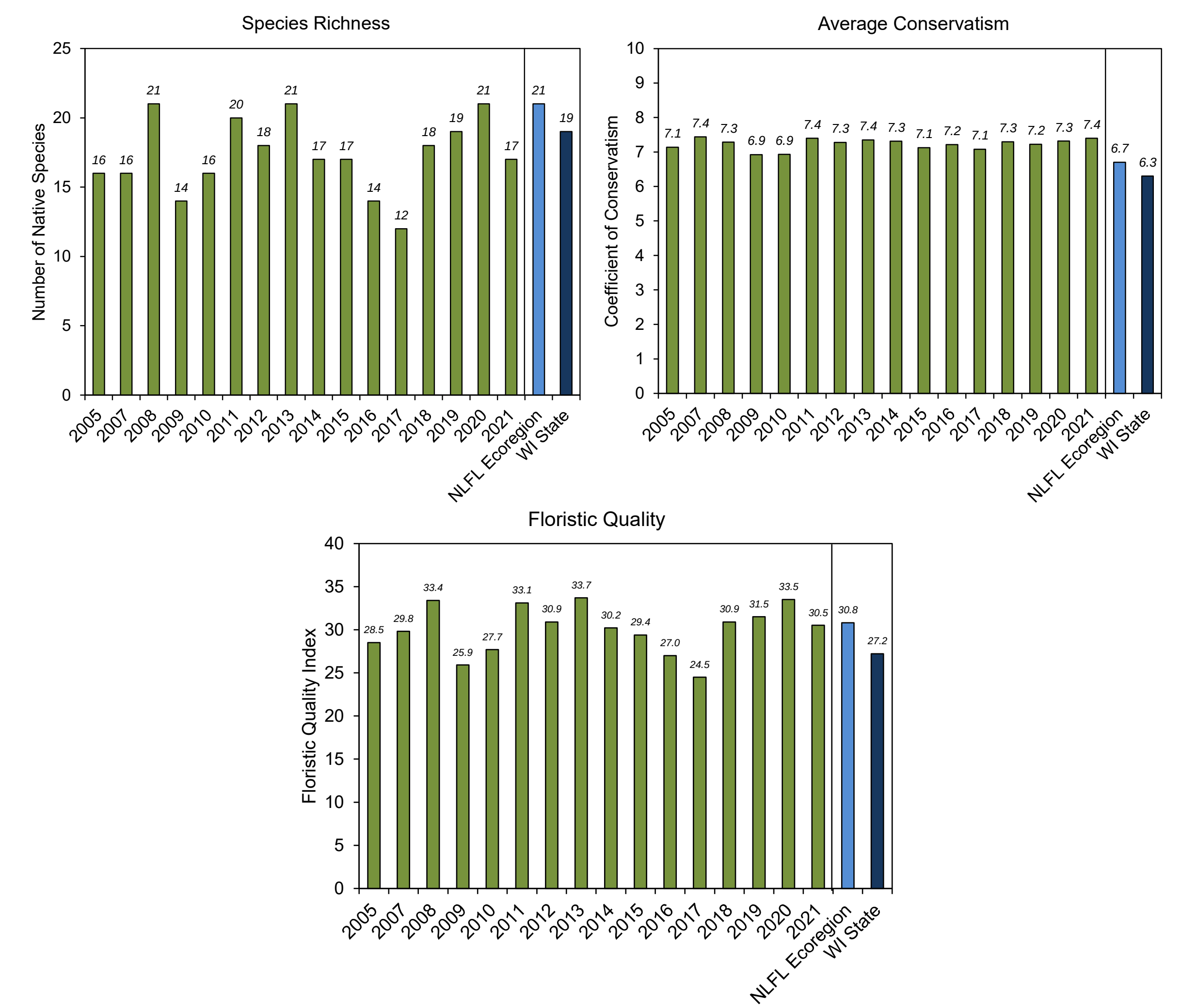


Figure 3.4-14. Silver Lake species richness, average conservatism, and Floristic Quality from 2005-2021. Includes native aquatic plant species physically encountered on the rake during the point-intercept survey and does not include incidentally-located species.

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 values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for

212 lakes within the NLFL Ecoregion (Figure 3.4-15). Using the data collected from the whole-lake point-intercept surveys, Silver Lake's aquatic plant species diversity has ranged from 0.89 to 0.80. The lake's diversity declined the year following the 2016 whole-lake 2,4-D treatment, a typical response often observed as some non-target native plants experience impacts from the treatment. Diversity increased from 2017-2020 before declining again in 2021. The average diversity value over the period from 2005-2021 was 0.86, slightly below the median value for lakes in the NLF ecoregion.

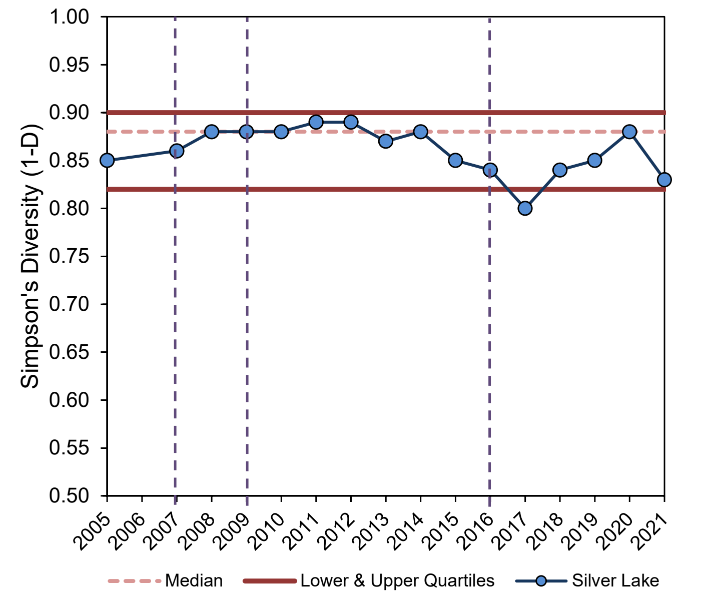
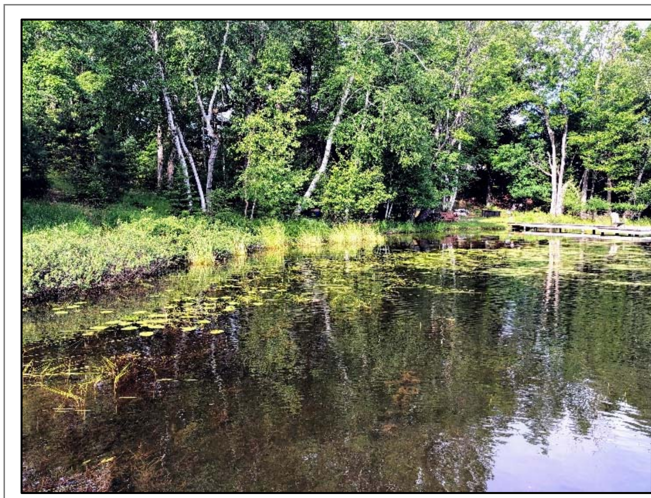


Figure 3.4-15. Simpson's Diversity Index for Silver Lake. Created using data from 2005-2021 point-intercept surveys. Purple dashed lines indicate 2,4-D herbicide treatments.

In 2021, Onterra ecologists also conducted a survey aimed at re-mapping emergent and floating-leaved plant communities in Silver Lake (Photograph 3.4-5). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plant communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosions control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

This is important to note because these communities are often negatively affected by recreational use and shoreland development. (Radomski & Goeman, 2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.



Photograph 3.4-5. Emergent and floating-leaf plant communities in Silver Lake. Photo credit Onterra 2021.

In 2010, approximately 4.5 acres of emergent and floating-leaf aquatic plant communities were delineated in Silver Lake compared to 3.6 in 2021 (Figure 3.4-16 and Map 8). This decline in acreage appears to be in communities that were dominated by narrow-leaved bur-reed (*Sparganium angustifolium*), a floating-leaf species. This retraction appears to have occurred in most communities throughout the lake, and it does not appear that one area of the lake in particular accounts for this loss in acreage.

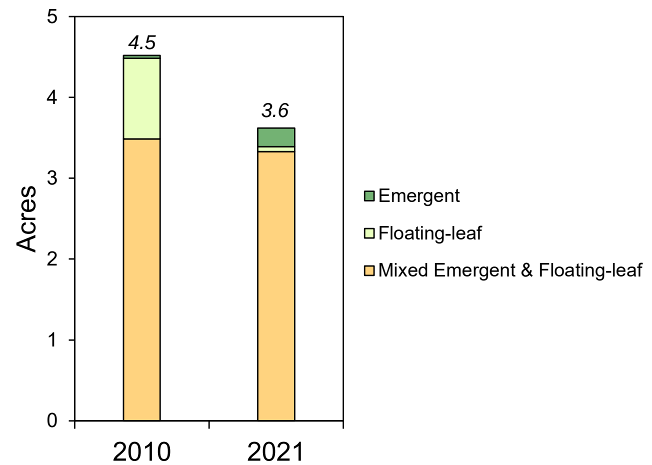


Figure 3.4-16. Acres of floating-leaf and emergent plant communities on Silver Lake. Data from 2010 and 2021 community mapping surveys conducted by Onterra.

Examination of the 2010 and 2021 data together shows that many of the emergent and floating- leaf communities retracted shoreward between the two surveys (Figure 3.5-17 and Map 8). Emergent and floating-leaf plant communities often recede or expand in response to changes in water levels. As water levels rise, these communities retract as water at their lakeward extent becomes too deep. In contrast, these communities often expand during periods of lower water levels. In 2010, many lakes were experiencing record low water levels, while in 2021 many lakes were experiencing record high water levels. Higher water levels in 2021 compared to 2010 are believed to be the primary reason for the retraction of these plant communities and reduced acreage.

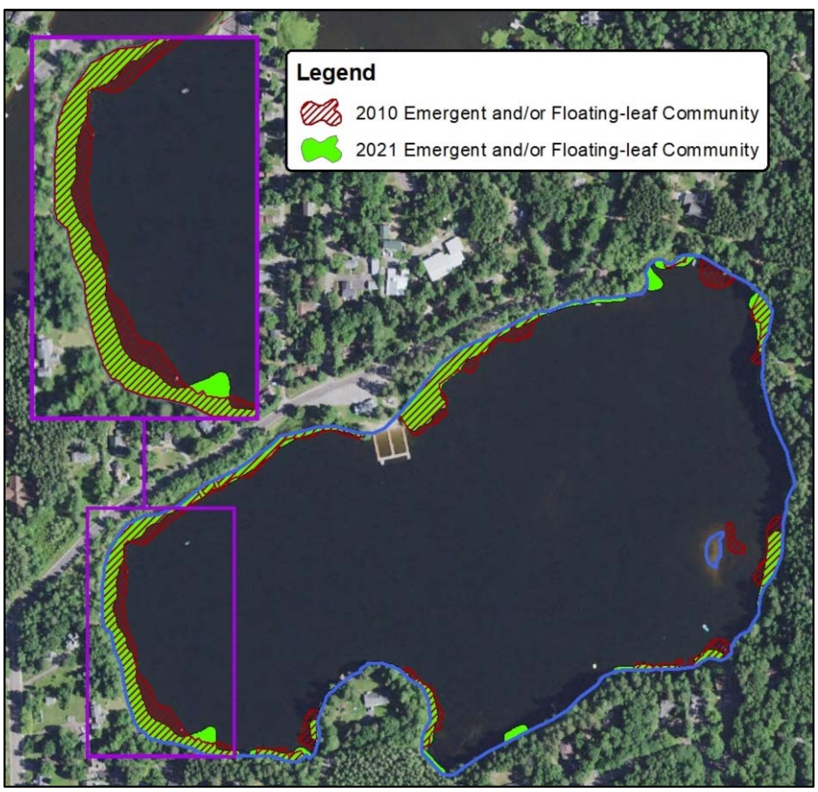


Figure 3.4-17. Emergent and floating-leaf plant communities Silver Lake in 2010 and 2021. This image illustrates the shoreward retraction of these communities between 2009 and 2021. This is likely due to water level fluctuations that have occurred over this period.

Non-Native Aquatic Plants in Silver Lake

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Because of their potential to upset the natural balance of an aquatic ecosystem, non-native species are paid particular attention to during the aquatic plant surveys. The non-native plant that is of primary concern in Silver Lake is Eurasian watermilfoil (EWM). Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties.

Eurasian watermilfoil 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, EWM 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 sometimes does not stop growing like most native plants and instead continues to grow along the surface creating a canopy that blocks light from reaching native plants.

Eurasian watermilfoil 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. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

EWM Research: WDNR Long-Term EWM Trends Monitoring

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are clearest for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.4-18). The upper frame of Figure 3.4-18 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected *unmanaged lakes* were moved into the *managed* category as the EWM populations were targeted for control by the local lake organization as populations increased.

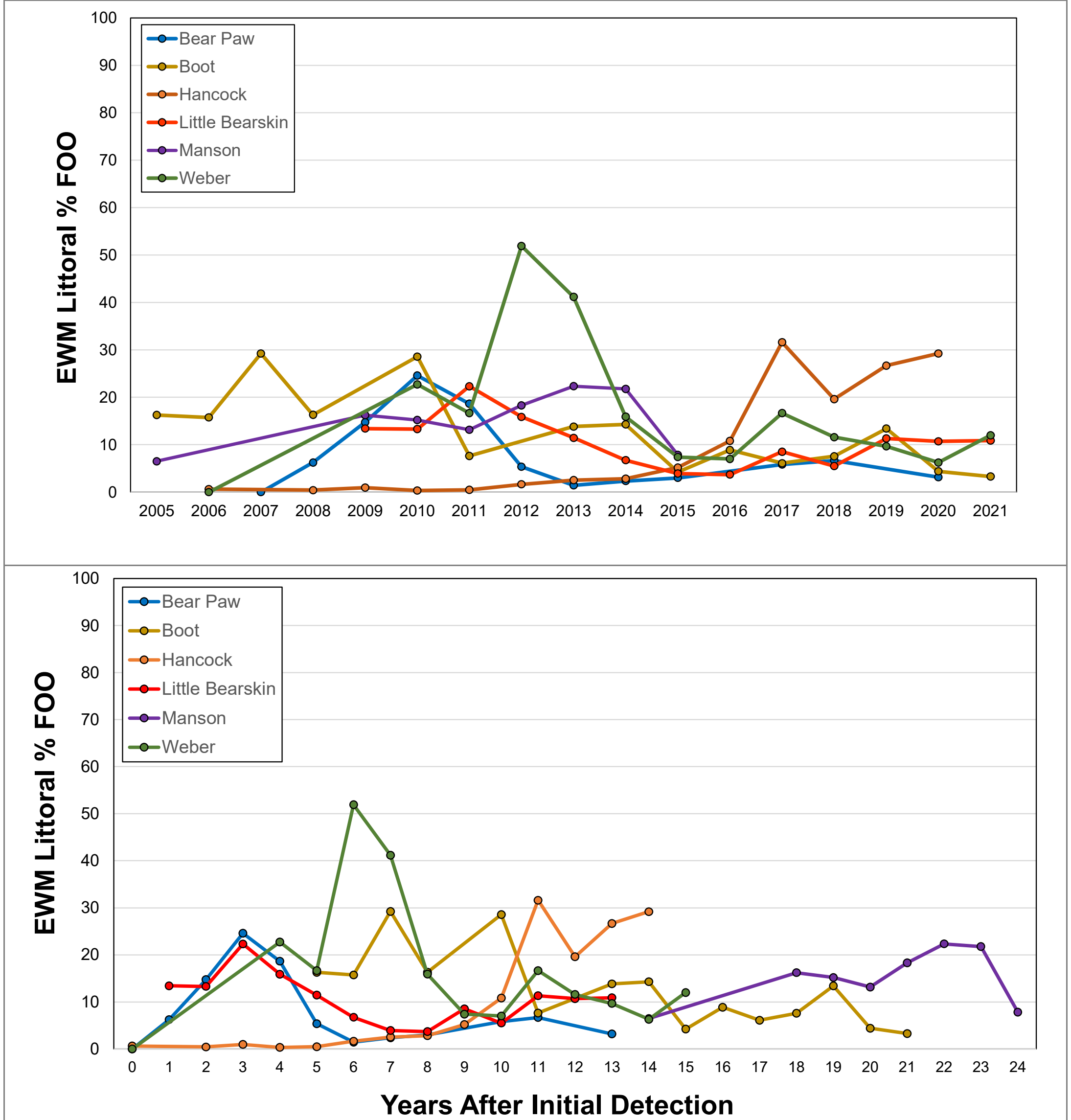


Figure 3.4-18. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from WDNR.

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years. Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault, 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake.

EWM Research: The Science Behind the "So-Called" Super Weed

In 2015, the WDNR investigated the most recent point-intercept data from almost 400 Wisconsin Lakes that had confirmed EWM populations (Nault, 2016). These data show that approximately 65% of these lakes had EWM populations of 10% or less (Figure 3.4-19). At these low population levels, there may not be impacts to recreation and navigation, nor changes in ecological function. While EWM can clearly become problematic in some lakes, it may not become a "super weed" in all lakes.

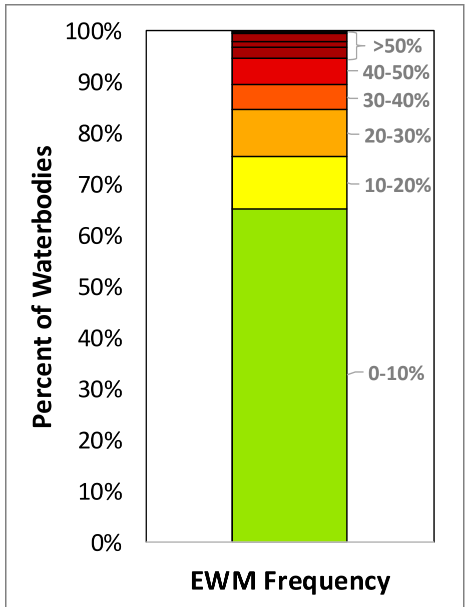


Figure 3.4-19. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

EWM Monitoring Methodologies

Almost all of the aquatic plant data discussed so far within this report were collected as part of whole-lake point-intercept surveys. The subsequent materials will also incorporate data from EWM mapping surveys.

Point-Intercept Surveys

The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations and using a rake sampler to identify all the plants at each location. The point-intercept survey can be applied at various scales. The point-intercept survey is most often applied at the whole-lake scale. These surveys and the data collected regarding native aquatic plants in Silver Lake were discussed previously in this section. If a smaller area is being studied, a modified and finer-scale point-intercept sampling grid may be needed to produce a sufficient number of sampling points for comparison purposes. This sub-sample point-intercept survey methodology is often applied over management areas such as herbicide application sites. This type of sampling method was utilized to monitor a 3.4-acre treatment completed in Silver Lake in 2009.

EWM Mapping Surveys

While completing the point-intercept survey, it is common to see a particularly plant species, such as EWM, very near the point-intercept sampling location but not yield it on the rake sampler. Particularly in low-density colonies such as those designated by Onterra as *highly scattered* and *scattered*, large gaps between EWM plants may exist resulting in EWM not being present at a particular pre-determined point-intercept sampling location in that area. While the point-intercept survey is a valuable tool to understand the overall plant population of a lake or a target area, it does not offer a full account (census) of where a particular species exists in the lake. A species-specific mapping survey, such as an EWM mapping survey, approximates a census of where that species exists in the surveyed boundaries.

Photograph 3.4-6. EWM mapping survey on a Waushara County, WI lake. Photo credit Onterra.

During an EWM mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 3.4-6). Field crews supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies greater than 40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (less than 40 feet in diameter), *clumps of plants*, or *single or few plants*. Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this overall project.

Invasive Watermilfoil Management

Field identification between pure strain EWM, hybrid watermilfoil (HWM), and certain native watermilfoil species can be difficult. Photograph 3.4-7 shows a cross-section of a whorl of four EWM leaves. One of the primary ways to distinguish between different species of watermilfoils is to count the number of leaflets on each leaf. As shown on Figure 3.4-20, northern watermilfoil (green triangles) typically has leaflet counts under 23, whereas EWM typically has leaflet counts over 25. Hybrid watermilfoil leaflet counts overlap with both these ranges, making field identification difficult. While leaflet counts can be a relatively definitive way to differentiate between EWM and northern watermilfoil, this method is less definitive in distinguishing HWM from EWM and northern watermilfoil. Genetic analysis in some cases, can be the only method for accurate determination of watermilfoil species. Genetic analysis of select watermilfoil plants from Silver Lake collected in 2011, 2013, and 2021 all were determined to be pure strain EWM, suggesting that the invasive watermilfoil population of Silver Lake is all comprised of pure-strain EWM.

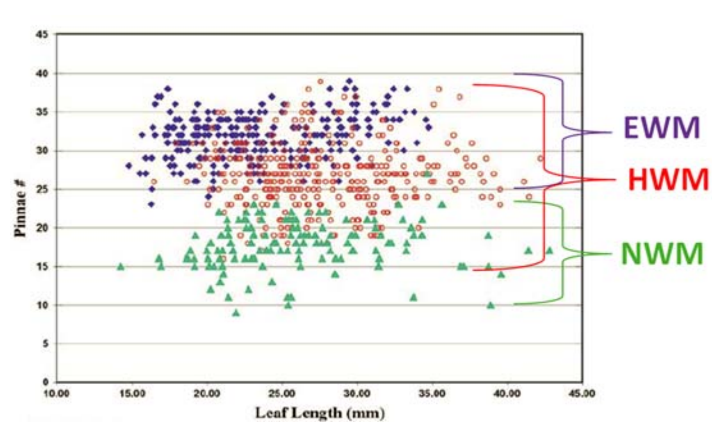
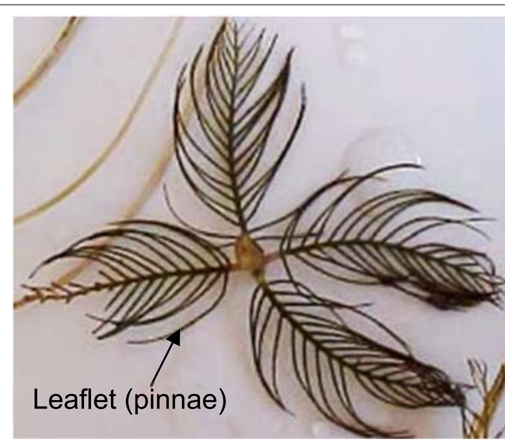


Figure 3.4-20. Pinnae (leaflet) counts from three watermilfoil species-types. Extracted and modified from (Moody & Les, 2007).



Photograph 3.4-7. EWM leaflet. Photo credit Onterra.

The goal of invasive watermilfoil management is to kill the plant. While sexual reproduction (seeds) and asexual reproduction (turions in some hybrid watermilfoil populations) do occur, their contribution to a lake-wide population is thought to be minimal. Often, one effective treatment is all that is needed for long-term control. As a perennial plant, EWM/HWM is difficult to kill with herbicides. Contact herbicides may eliminate the aboveground biomass of EWM/HWM, but extensive storage reserves in the root crown will allow resprouting and rebound. Therefore, systemic herbicides that translocate throughout the plant into the root crown are required.

The term Best Management Practice (BMP) is often used in environmental management fields to represent the management option that is currently supported by the latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. For example, granular herbicides historically were a BMP that is no longer supported in most instances. Emerging science demonstrated that liquid treatments provided more consistent results at a fraction of the cost of granular products, larger application areas appeared to retain herbicide concentrations and exposure times better, and attention needed to be paid to the addition of individual spot treatments that may cumulatively function as a whole-lake treatment.

From an ecological perspective, whole-lake treatments are those where the herbicide may be applied to specific sites, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water (of the lake, lake basin, or within the epilimnion of the lake or lake basin), it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume. A recent article by (Nault, et al., 2018) investigated 28 large-scale herbicide treatments in Wisconsin and found that “herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lake-wide low-concentration equilibriums were reached within the first few days after application.”

2,4-D is a weak-acid auxin mimic herbicide often used for invasive watermilfoil management. This herbicide gets translocated throughout the plant (acts systemically) and suppresses growth regulation hormones. Operationally, a lake-wide 2,4-D concentration above 0.1 ppm acid equivalent (ae) is considered by Onterra to represent a whole-lake treatment, assuming typical exposure time from herbicide degradation. Onterra has observed lake-wide impacts to some sensitive native plants when lake-wide concentrations were above 0.1 ppm ae; but being more durable, EWM impacts do not typically occur until lake-wide concentrations exceed 0.2 ppm ae. When prescribing whole-lake 2,4-D treatments, the traditional lake-wide target is 0.3 ppm ae with higher concentrations targeting more difficult populations.

Herbicide treatments using 2,4-D to target EWM have taken place in Silver Lake in 2007, 2009, and 2016 (Table 3.4-3). Treatment records showing the amount of herbicide applied in Silver Lake allowed for calculations to illustrate the potential whole-lake concentration of the 2,4-D active ingredient when lake-wide dispersion occurred. For lakes that maintain thermal stratification, the herbicide only mixes within the warmer, upper layer of water (epilimnion) and does not mix into the colder, bottom layer (hypolimnion). Silver Lake is dimictic and stratifies during the summer. The 2016 treatment was designed as a whole-lake (epilimnetic-wide) treatment, and the volume of the epilimnion calculated that year as determined from temperature profiles was used to calculate concentrations for 2007 and 2009.

Prior to 2010, the concept of whole-lake treatments was not yet realized, and thus both of these treatments were designed as spot treatments where impacts to plants were expected within and immediately adjacent to areas where herbicide water directly applied. However, it is clear from the calculations that the 2007 and 2009 treatments resulted in epilimnetic-wide concentrations that could have impacted sensitive native species at the lake-wide level. The 2007 treatment was near 0.3 ppm ae, indicating EWM may have been impacted lake-wide.

Table 3.4-3. Historical aquatic plant management activities on Silver Lake. Information provided by WDNR.

Date	Herbicide Applied	Acres Treated	Amount Used	Pounds of 2,4-D Active Ingredient	Whole-Lake 2,4-D ppm ae	Epilimnetic 2,4-D ppm ae
5/22/2007	2,4-D Granular (Navigate)	13.0	1,300 lbs	247	0.205	0.290
5/15/2009	2,4-D Granular (Navigate)	3.4	510 lbs	96.9	0.080	0.114
6/7/2016	2,4-D Liquid (DMA 4)	19.8	69 gallons	262	0.217	0.307 targeted; 0.112 actual

Whole-lake 2,4-D concentration calculated using entire lake volume (443 acre-feet as determined from 2015 acoustic survey)
Epilimnetic 2,4-D concentration calculated using volume of early summer epilimnion (314 acre-feet as determined from 0-7.5 feet based on temperature profiles and 2015 acoustic data)

EWM population of Silver Lake

Late-season EWM mapping surveys have been completed on Silver Lake in 2008-2010, 2012-2017, and 2021-2022 (Figure 3.4-21). Please note that this figure only represents only the acreage of mapped EWM polygons, not EWM mapped with point-based methodologies (*Single or Few Plants*, *Clumps of Plants*, or *Small Plant Colonies*). Said another way, EWM marked with point-based mapping methods do not contribute to colonized acreage as shown on Figure 3.4-21. Map 9 shows the entire EWM footprint over this period, including the point-based EWM occurrences. Map 10 shows the latest EWM mapping data from Silver Lake (2022).

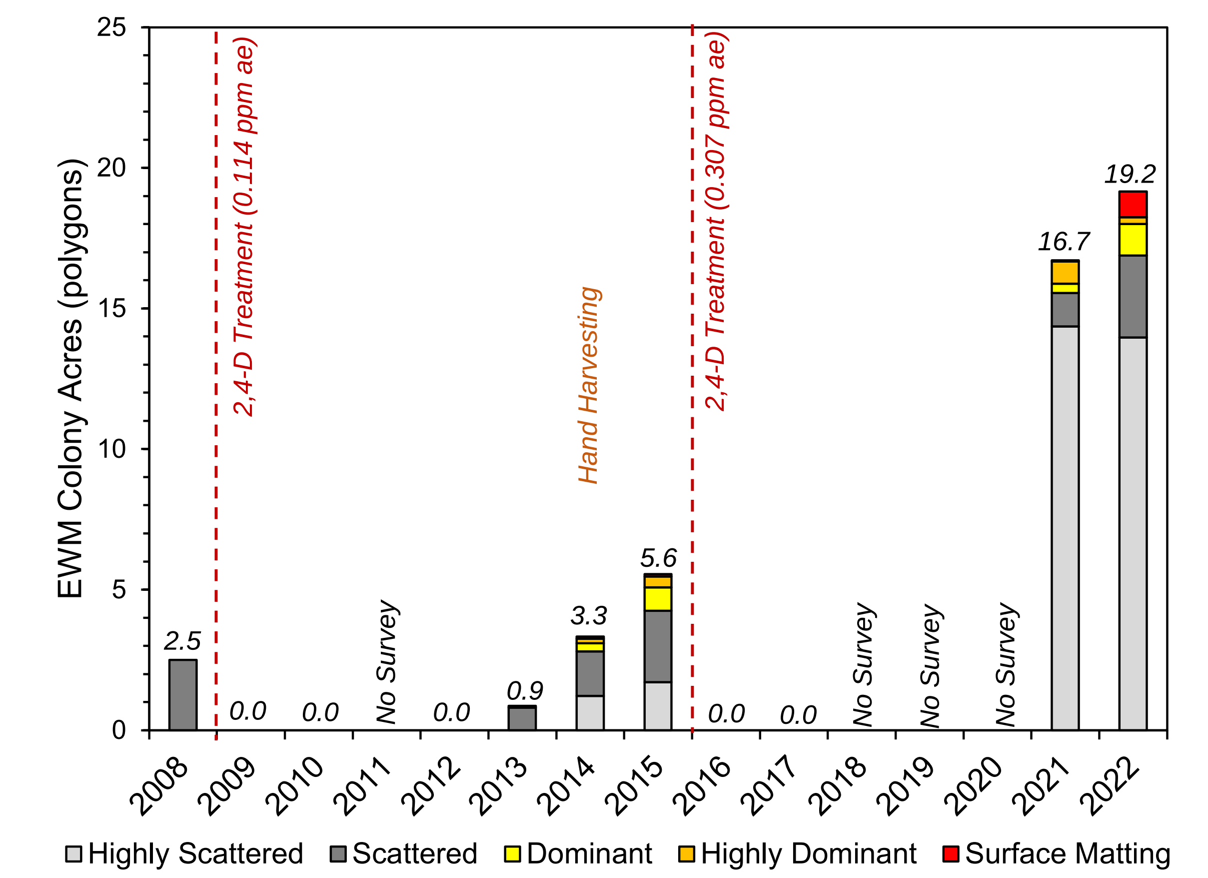


Figure 3.4-21. Acreage of colonized EWM in Silver Lake from 2005-2022. Created using data from Onterra late-season AIS mapping surveys.

Onterra first mapped the EWM population of Silver Lake in 2008, and 2.5 acres of *scattered* EWM were located. Following the 3.4-acre 2,4-D treatment in the spring of 2009, no colonized areas of EWM were mapped in 2009, 2010, or 2012. From 2013-2015, colonized acreage of EWM increased from 0.9 to 5.6 acres despite annual volunteer hand-harvesting. Given the increasing EWM population, a whole-lake 2,4-D treatment was designed and implemented in 2016.

Herbicide was applied over 19.8 acres of the lake where the densest areas of EWM were located, resulting in an epilimnetic concentration of 0.307 ppm ae. However, the initial concentration as determined from herbicide concentration monitoring was below the target level at 0.112 ppm. As is discussed in the 2017 report, the impacts to the EWM and native aquatic plants indicate the treatment was likely closer to the targeted 0.3 ppm ae, and it is believed the analysis method for measuring herbicide in the water samples may have delivered lower-than actual concentrations. No EWM was observed in 2016 following the treatment, while only point-based occurrences were located in 2017.

It is important to note that US EPA registration of aquatic herbicides typically requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). Therefore, only limited organismal toxicity data is available for concentrations and exposure times consistent with large-scale treatment use patterns (low concentrations, long exposure times).

With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D concentrations more relevant to what would be observed in large-scale treatments. The focus of their investigations was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows with one 2,4-D tradename (not with another), and uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose of one herbicide that was tested (no reduction at higher doses).

Researchers from UWSP and WDNR wanted to see if the impacts observed in the laboratory would be manifested in the field and commenced a cooperative research study titled: *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes*. Silver Lake was selected to participate in the six-lake study as one of three lakes that would receive a large-scale 2,4-D amine treatment. Typical whole-lake herbicide treatments occur when lake-wide EWM populations are much higher than existed on Silver Lake prior to the treatment, such as greater than 15%-20% littoral frequency of occurrence. However, the WDNR was amenable to allowing the treatment to move forward with agreement from the ERSLA for the benefit of the overall scientific exploration.

Participation in the study included researchers conducting aquatic plant point-intercept surveys, fisheries studies, and zooplankton studies occurring in 2015 (*year prior to treatment*), 2016 (*year of treatment*) and 2017 (*year following treatment*). The ERSLA also received a WDNR AIS-Education, Prevention, and Planning Grant (AEPP-46416) to assist with planning, reporting, and additional surveys on Silver Lake as it pertains to reaching aquatic plant management goals. More details on the planning and implementation of this treatment can be found in the *Silver Lake 2016 EWM Control & Monitoring Report.*

No mapping surveys were completed in 2018-2020, and mapping completed in 2021 as part of this project revealed the largest EWM footprint mapped to date with 16.7 acres and this increased further to 19.2 acres in 2022 (Figure 3.4-21). The point-intercept survey data show the littoral occurrence of EWM from 2005-2022 (Figure 3.4-22). The data show that EWM increased rapidly between 2020 and 2021, increasing from 2.8% in 2020 to 9.2% in 2021 representing a statistically valid increase between the two surveys. The EWM population increased further in 2022 with an occurrence of 13.2%, representing the highest occurrence since monitoring began in 2005.

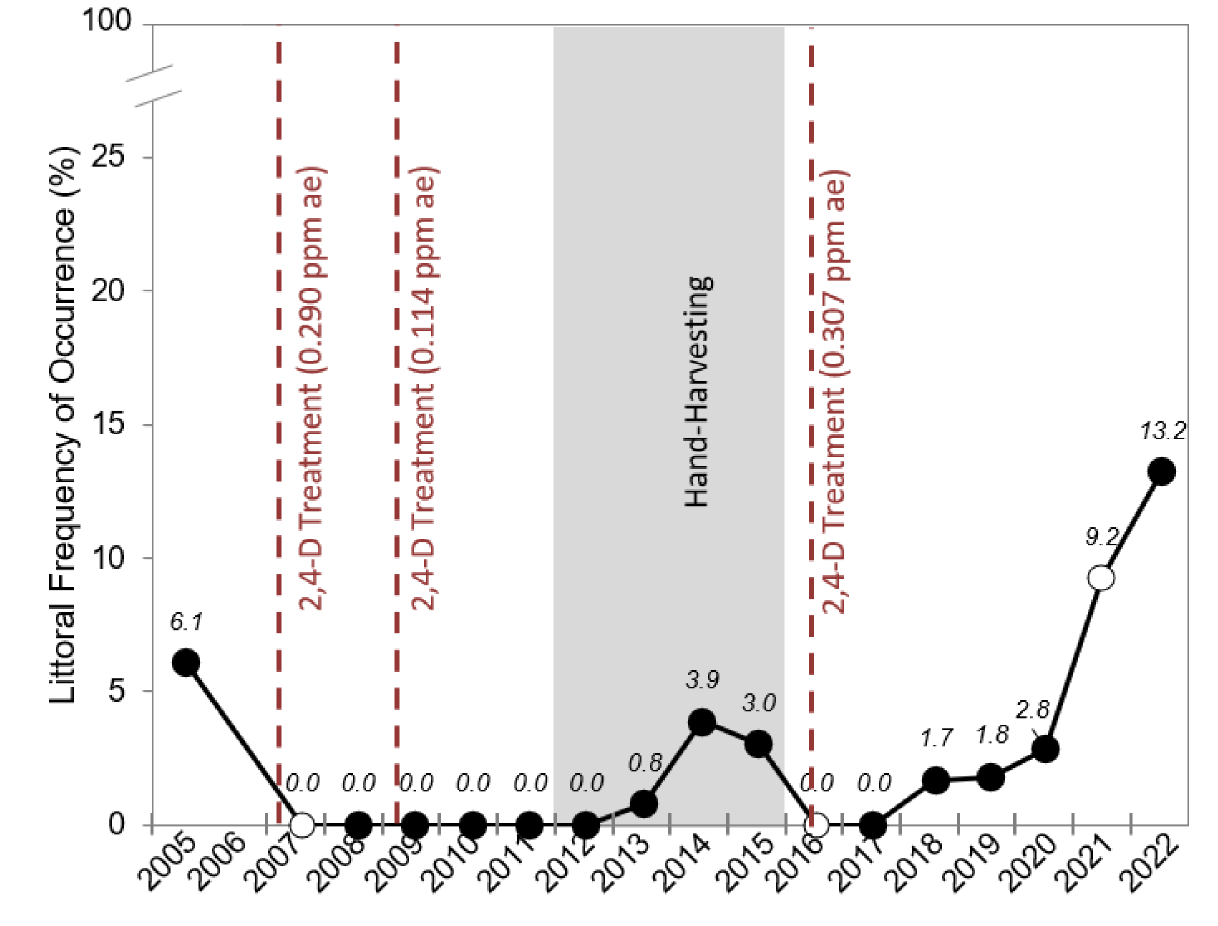


Figure 3.4-22. Littoral occurrence of EWM in Silver Lake. Created using data from whole-lake point-intercept surveys.

Future AIS Management Philosophy

During the Planning Committee meetings held as part of this project, three broad Eurasian watermilfoil management goals were discussed including a generic potential action plan to help reach each of the goals. During these discussions, conversation regarding risk assessment of the various management actions was also discussed. Onterra discussed relevant chapters from the WDNR's *APM Strategic Analysis Document (Appendix E)* to serve as an objective baseline for the ERSLA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Silver Lake ecosystem. The Planning Committee also reviewed these management perspectives in the context of perceived riparian stakeholder support, which is discussed in the subsequent sub-section.

1. Let Nature Take its Course: On some lakes, invasive plant populations plateau or reduce without active management. Some lake groups decide to periodically monitor the EWM population, either through an EWM mapping survey or a whole-lake point-intercept survey, but may not coordinate active management (e.g., hand-harvesting or herbicide treatments). Individual riparians could choose to hand-remove the EWM within their recreational footprint, but the lake group would not assist financially or by securing permits if necessary. In most instances, the lake group may select an EWM population threshold or trigger where they would revisit their management goal if the population reached that level.

2. Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with their AIS population is the reduced recreation, navigation, and aesthetics compared to before the AIS became established in their lake. Particularly on lakes with large EWM populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve the navigability within the lake. This is typically accomplished by targeting EWM populations in high-use parts of the lake through mechanical harvesting or spot herbicide treatments and allowing other areas of low use to remain unmanaged.

3. Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may mean to manage the EWM population at a reduced level with the perceived goal to allow the lake to function as it had prior to EWM establishment. Due to the inevitable collateral impacts from most forms of EWM management, lake managers and natural resource regulators question whether that is an achievable goal.

For newly introduced EWM populations, the entire population may be targeted through hand-harvesting or herbicide spot treatments. Herbicide spot treatments, particularly historical treatments with 2,4-D, generally lead to short term EWM population reductions with reductions largely being limited to a season or two. This type of strategy can be analogous to the "whack-a-mole" arcade game; where areas are targeted, rebound, and then are targeted again on an every-other year basis. As new areas emerge and get factored into the strategy, it becomes harder to manage all the areas. Typically, if management is withheld at this stage, the EWM will rebound to its full capacity within a year. The repeated need for exposing the same areas of the system to herbicides as is required when engaged in an annual spot treatment program has gone out of favor with some lake managers due to concerns over the non-target impacts that can accompany this type of strategy. In recent years, lake managers have sought actions that achieve multiyear EWM population suppression, such as whole-lake treatments or spot treatments with chemistries theorized to require shorter exposure times. The EWM population reductions are more commensurate with the financial costs and risks of the treatment.

To gain multi-year EWM suppression, future spot herbicide treatments would likely need to consider herbicides (diquat, florpyrauxifen-benzyl, etc.) or herbicide combinations (2,4-D/endothall, diquat/endothall, etc.) thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g., 2,4-D, triclopyr). At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike ™) are examples of herbicides with reported short exposure time requirements.

ProcellaCOR™ is currently the region's most popular spot-treatment strategy. In Onterra's experience monitoring many ProcellaCOR™ treatments within the state since 2019, EWM control has been high with almost no EWM being located during the summer post treatment. Some treated sites have shown EWM population recovery two-years after treatment, while most other sites have demonstrated three years and counting of continued EWM reductions to-date. Within these treatments, native plant impacts have been limited to some sensitive dicot species such as northern watermilfoil, coontail, water marigold, and white water crowfoot. Specific to Silver Lake, there are no native aquatic plant species present that have exhibited sensitivity to this herbicide in the field cases studied by Onterra. Native pondweed species seem to be generally not impacted by ProcellaCOR™.

That being said, lake managers continue to learn how to successfully implement this form of treatment after being registered for use in Wisconsin only a couple of years ago. ProcellaCOR™ has a high sediment/organic binding affinity (Koc) and relatively short persistence (half-life of < 6 days), so it is thought to stay where applied better than other chemistries. The active ingredient of ProcellaCOR™, florpyrauxifen-benzyl, is primarily degraded by photolysis (light exposure), with some microbial degradation. Preliminary research suggests that florpyrauxifen-benzyl may have a different or quicker breakdown pattern in waters with high pH and high biomass of aquatic plants. The primary breakdown product of florpyrauxifen-benzyl is florpyrauxifen acid. Florpyrauxifen acid has been shown to persist in the lake longer than the active ingredient. This chemical metabolite is reported to have activity as an herbicide on aquatic plants, albeit to a lower degree than the active ingredient. It is unclear at this time the exact role that the acid metabolite may play in contributing to EWM reductions, particularly in areas not located directly within the herbicide application area.

In many of the treatments Onterra has monitored, EWM impacts have been observed extending outside of the application area, as this chemical has shown activity at even low concentrations and exposure times as it dissipates.

Herbicide Resistance

While understood in terrestrial herbicide applications for years, tolerance evolution is an emerging topic amongst aquatic herbicide applicators, lake management planners, regulators, and researchers. Herbicide resistance is when a population of a given species develops reduced susceptibility to an herbicide over time, such that an herbicide use pattern that once was effective no longer produces the same level of effect. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that re-populate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population over time.

If genetic variation in the target population exists, particularly the presence of hybrid watermilfoils, repetitive treatments with the same herbicide may cause a shift towards increased herbicide tolerance in the population. Rotating herbicide use-patterns can help avoid population-level herbicide tolerance evolution from occurring. Onterra maintains concern for future use of 2,4-D in Silver Lake, as the sole use of this herbicide mode of action in the past may yield a cause for concern about potential herbicide resistance and therefore herbicide rotation away from this herbicide is recommended.

Stakeholder Survey Responses to Eurasian Watermilfoil Management

As discussed in Section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the 2021 survey was 48%. Because the response rate was below 60% in both instances, it is important to reiterate that the stakeholder survey results need to be understood in the context of the respondents to the survey, not to the overall population sampled.

In an effort to understand how EWM impacts Silver Lake stakeholders, the 2021 stakeholder survey asked if the Eurasian watermilfoil population ever had a negative impact on your enjoyment of Silver Lake. The categories with the highest number of respondents indicating *Yes* were aesthetics, swimming, and canoeing/kayaking/stand-up paddleboarding (Figure 3.4-23).

Question 28: Has the EWM population ever had a negative impact on your enjoyment of Silver Lake.

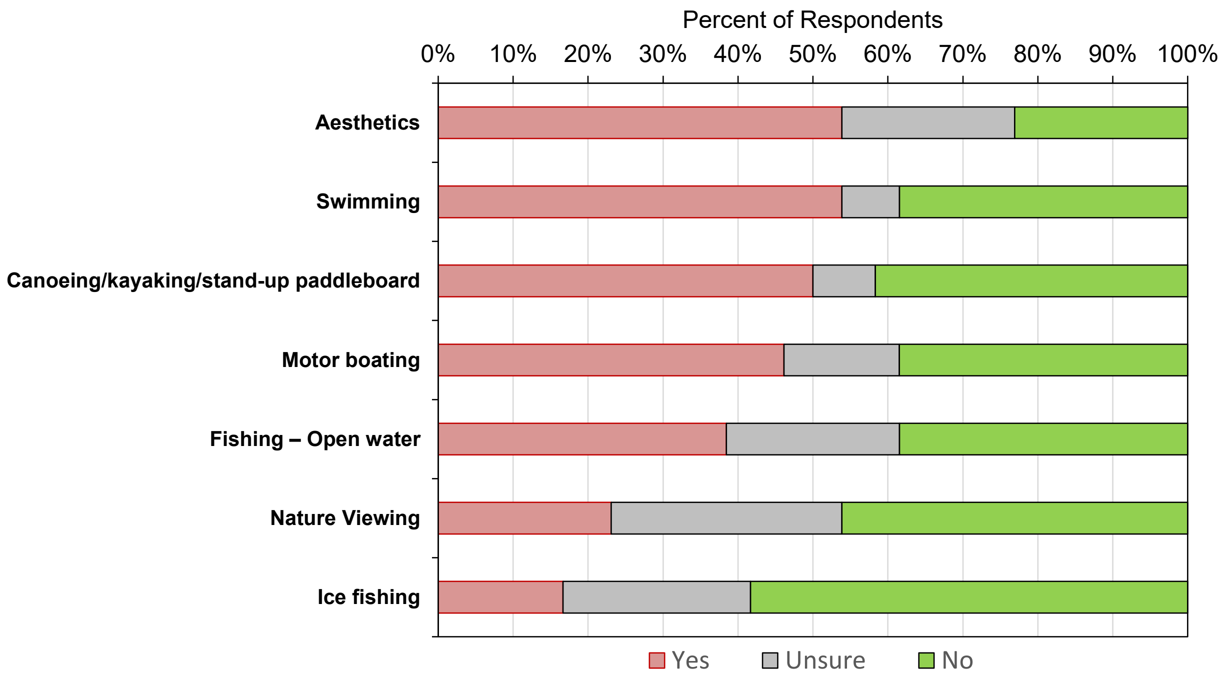


Figure 3.4-23. Select survey responses from the ERSLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B. Number of respondents = 13.

In 2021, ERSLA stakeholders were asked about their level of support or opposition for using herbicide treatments or hand-harvesting methodologies to manage EWM in Silver Lake. Stakeholders were asked if they knew that aquatic herbicides had been used in the past in Silver Lake to manage EWM. Ninety-two percent of respondents indicated that *yes* they were aware, 8% indicated *I think so but can't say for certain*, and 0% indicated *no* they were not aware. When asked what their level of support or opposition for the past use of aquatic herbicides to treat EWM in Silver Lake, 54% indicated *completely support*, 15% indicated *moderately support*, 23% indicated *neither oppose nor support*, and 8% indicated *completely oppose* (Figure 3.2-24).

When asked what their level of support or opposition was for the future use of aquatic herbicides to target EWM in Silver Lake, 46% indicated they *completely support* future use, 46% indicated they *moderately support* future use, while 8% indicated they *completely oppose* future use. The stakeholder who selected *completely oppose* indicated their reasons for opposing were *potential impacts to native aquatic plant species, potential impacts to native (non-plant) species (fish, insects, etc.), potential impacts to human health, future impacts are unknown,* and *ineffectiveness of herbicide strategy.*

Questions 25 & 26: What is your level of support or opposition for the past and future use of aquatic herbicides to target Eurasian watermilfoil in Silver Lake?

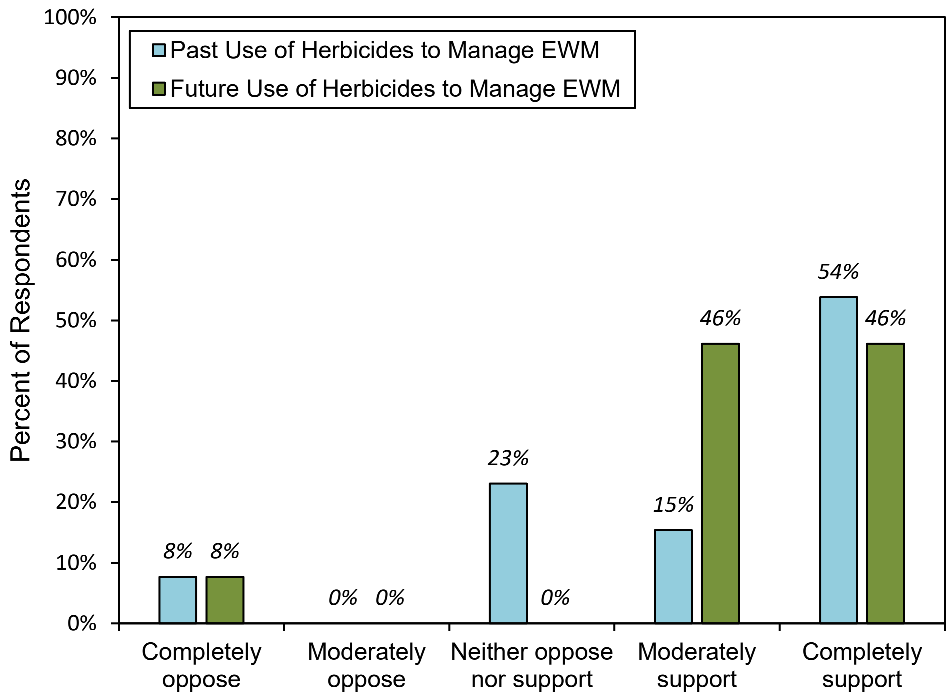


Figure 3.4-24. Select survey responses from the ERSLA Stakeholder Survey. Additional questions and response charts may be found in Appendix B. Number of survey respondents = 13.

Purple Loosestrife (*Lythrum salicaria*)

Photograph 3.4-8. Purple loosestrife. Photo credit Onterra.

Purple loosestrife (Photo 3.4-8) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. In 2021, four occurrences of purple loosestrife were located in isolated locations along the north shore of Silver Lake (Map 8).

Narrow-leaved Cattail (*Typha angustifolia*)

Photograph 3.4-9. Narrow-leaved cattail in Silver Lake. Photo credit Onterra.

Narrow-leaved cattail is a perennial invasive wetland plant which invades shallow marshes and other wet areas (Photograph 3.4-9). Like Wisconsin's native broad-leaved cattail (*T. latifolia*), narrow-leaved cattail produces tall, erect, sword-like leaves that can grow nearly 10 feet tall. The leaves are generally narrower than broad-leaf cattail, typically 0.15-0.5 inches wide. Unlike broad-leaf cattail in which the male and female flowers are typically touching, there is typically a gap of 0.5-4.0 inches between the male and female flowers of narrow-leaved cattail.

One colony of narrow-leaved cattail was located in shallow water on Silver Lake's southeast side in 2021 (colony J on Map 8). Given the isolated nature of this colony, the best method of control is likely the cutting of stems (both green and dead) in mid- to late-summer or early fall to below the water line. The following growing season, continually cut-back emerging stems to maintain them below the water for the remainder of the growing season. This process should be repeated until the plants do not reemerge.

Reed Canary Grass (*Phalaris arundinacea*)

Reed canary grass is a large, coarse perennial grass that can reach three to six feet in height (Photograph 3.4-10). Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed by WDNR staff during the 2019 point-intercept survey; however, its presence does not appear to have been officially verified. Its presence has not been noted in subsequent surveys and was not recorded during Onterra's 2021 community mapping survey.

Photograph 3.4-10. Reed canary grass. No reed canary grass was observed in 2021.

3.5 Aquatic Invasive Species in Silver Lake

To date, two non-plant, non-native species have been documented in Silver Lake (Table 3.5-1). These include the Chinese mystery snail (documented in 2008) and the banded mystery snail (documented in 2012). In the anonymous stakeholder survey distributed in 2021, respondents were asked which invasive species they believed were present in Silver Lake. One hundred percent of respondents indicated EWM was present, 70% indicated purple loosestrife was present, 15% believed banded mystery snails were present, and 8% indicated reed canary grass was present. Approximately 62% of respondents indicated they believed freshwater jellyfish, zebra mussels, curly-leaf pondweed, faucet snail, and/or common carp were present in Silver Lake – please note that none of these invasive species have been documented in Silver Lake as of this writing.

Table 3.5-1. Aquatic invasive species documented in Silver Lake as of January 2022.

AIS Type	Scientific Name	Common Name	Location in Report
Invertebrate	*Cipangopaludina chinensis*	Chinese Mystery Snail	Section 3.5
	Viviparus georgianus	Banded Mystery Snail	Section 3.5
Plant	*Lythrum salicaria*	Purple Loosestrife	Section 3.4
	Myriophyllum spicatum	Eurasian Watermilfoil	Section 3.4
	Phalarais arundinacea	Reed Canary Grass	Section 3.4

More information on these and other aquatic invasive species can be found at the following links:

- http://dnr.wi.gov/topic/invasives/
- https://nas.er.usgs.gov/default.aspx
- https://www.epa.gov/greatlakes/invasive-species

Aquatic Animals

Mystery snails

There are two types of invasive mystery snails found within Wisconsin waters: the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*) (Photo 3.6-1). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species can thrive in eutrophic waters with very little flow. They are bottom-dwellers, eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon, Olden, P.T.J, Dillion Jr., & Vander Zander, 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were

Photograph 3.5-1. Chinese mystery snail (left; credit Onterra) and banded mystery snail right (credit USGS).

present (Johnson, Olden, Solomon, & Vander Zanden, 2009). Rusty crayfish have to date not been documented in Silver Lake.

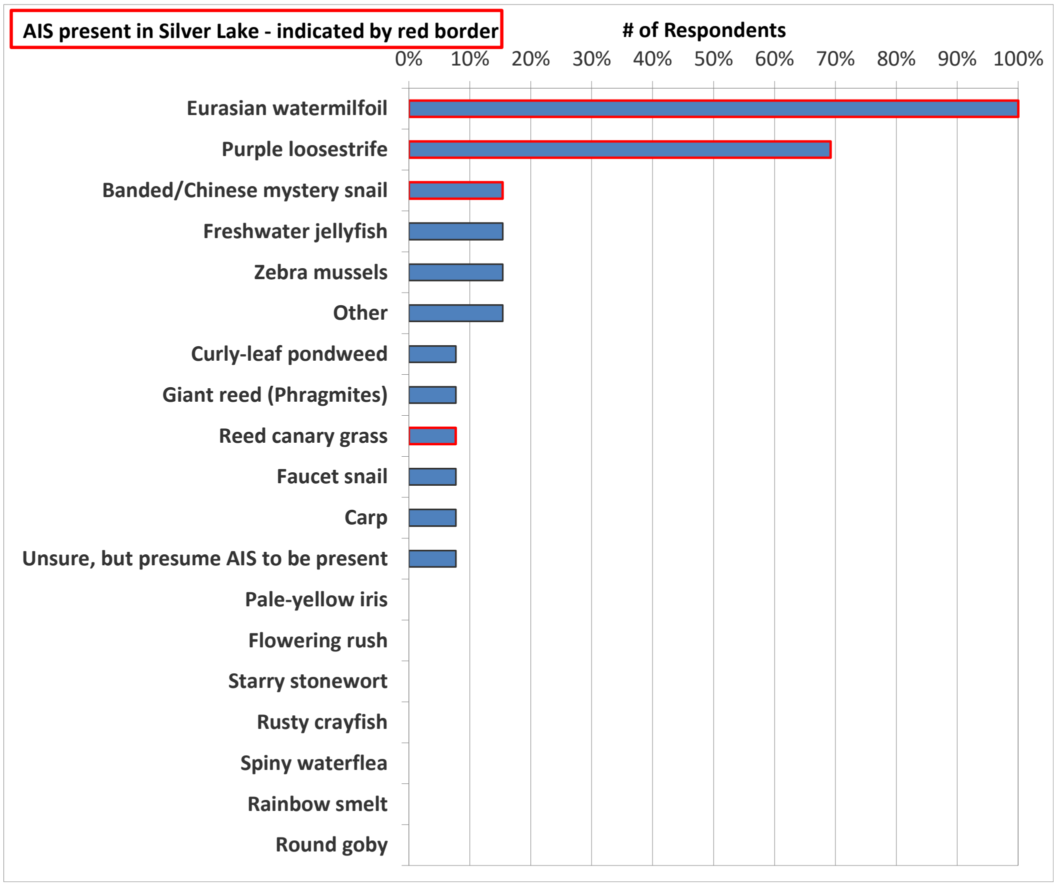


Figure 3.5-1. Silver Lake stakeholder survey response to question #23: Which aquatic invasive species do you believe are in Silver Lake? Red outline indicates species which have been documented in Silver Lake as of January 2022.

3.6 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 a 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 fisheries biologists overseeing Silver Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fisheries data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), and personal communications with DNR Fisheries Technician Jason Folstad.

Silver Lake Fishery

Energy Flow of a Fishery

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 plants and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.7-1.

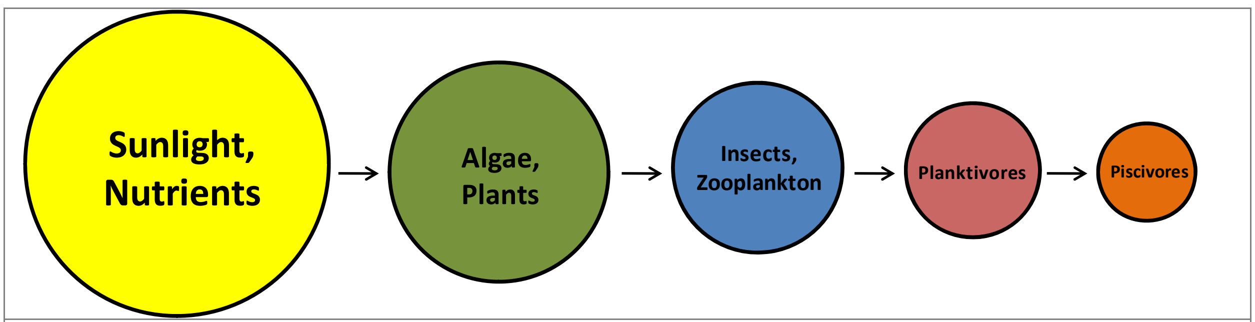


Figure 3.6-1. Aquatic food chain. Adapted from (Carpenter, Kitchell, & Hodgson, 1985).

As is discussed in the Lake Water Quality section (Section 3.1), Silver Lake is a mesotrophic system, meaning it has moderate nutrient levels, and thus a moderate level of primary productivity. In other words, Silver Lake is more productive relative to low-nutrient oligotrophic lakes, and less productive relative to high-nutrient eutrophic lakes. Simply put, this means Silver Lake should have sufficient primary productivity to support an appropriately sized population of predatory fish (piscivores) species. Table 3.7-1 shows the popular game fish species present in Silver Lake. Although not an exhaustive list of fish species in the lake, additional species documented in past WDNR surveys of Silver Lake include brown bullhead *(Ameiurus nebulosus)* and golden shiner *(Notemigonus crysoleucas).*

Table 3.6-1. Gamefish present in Silver Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements
Black Crappie *(Pomoxis nigromaculatus)*	7	May - June	Near Chara or other vegetation, over sand or fine gravel
Bluegill *(Lepomis macrochirus)*	11	Late May - Early August	Shallow water with sand or gravel bottom
Largemouth Bass *(Micropterus salmoides)*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation
Muskellunge *(Esox masquinongy)*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.
Northern Pike *(Esox lucius)*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves
Pumpkinseed *(Lepomis gibbosus)*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms
Yellow Perch *(Perca flavescens)*	13	April - Early May	Sheltered areas, emergent and submergent veg

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.7-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.7-1). This is often done at night by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released. The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

A survey of Silver Lake's fish population conducted by University of Wisconsin-Stevens Point graduate student Nick Rydell took place in June 2015. Aside from a fall electrofishing survey that took place in 1994, this 2015 survey was one of the only ones on record for Silver Lake (E. Wegleitner, personal communications)

Photograph 3.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.7-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Historically, Silver Lake had been stocked with muskellunge, walleye, and largemouth bass. No DNR stocking has been completed since 1974, however, when 100 fingerling muskellunge were released.

Photograph 3.6-2. Muskellunge fingerling.

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), Silver Lake stakeholders enjoy catching bluegill/sunfish and largemouth bass most. Approximately 78% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-2). Approximately 44% of respondents who fish Silver Lake believe the quality of fishing has remained the same or gotten better since they first started fishing the lake (Figure 3.6-3). The remaining 56% of respondents believe the fishing has gotten worse since they first started to fish the lake (Figure 3.6-4).

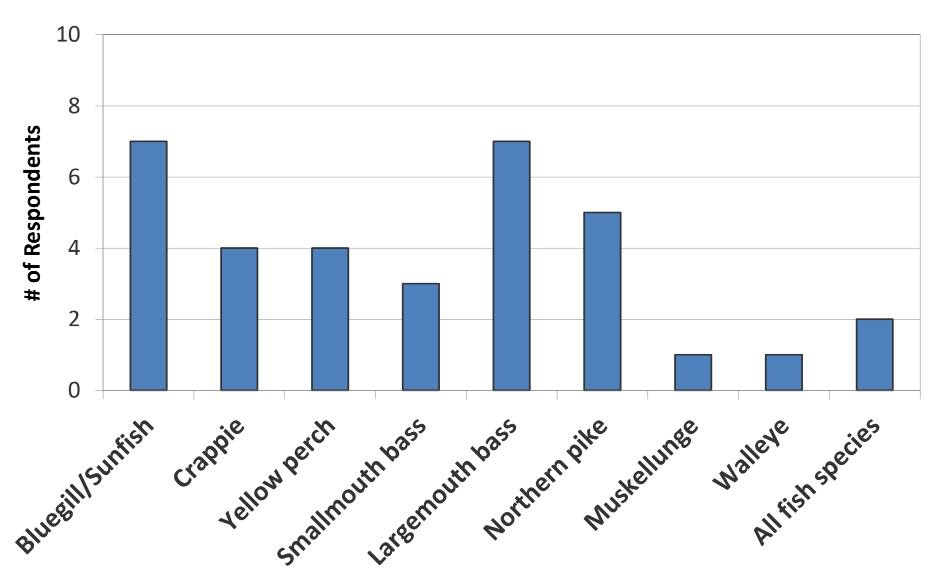


Figure 3.6-2. Stakeholder survey response Question #10. What species of fish do you like to catch on Silver Lake?

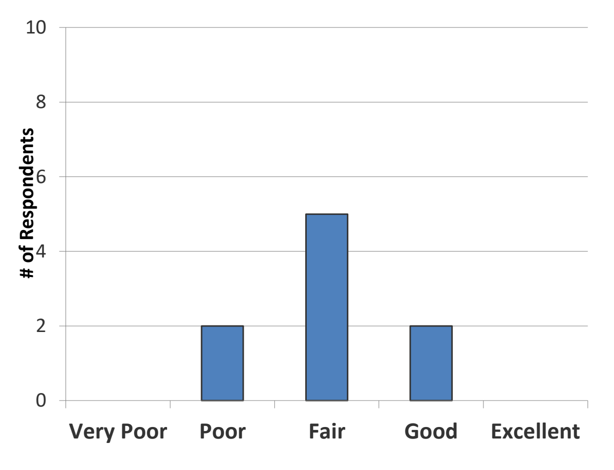


Figure 3.6-3. Stakeholder survey response Question #11. How would you describe the current quality of fishing on Silver Lake?

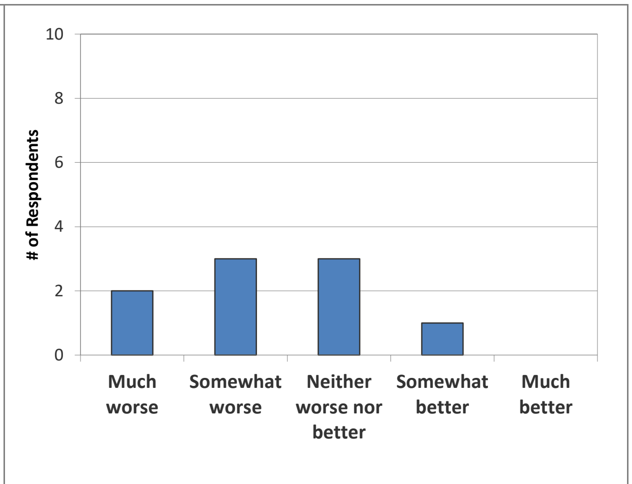


Figure 3.6-4. Stakeholder survey response Question #12. How has the quality of fishing changed on Silver Lake since you started fishing the lake?

Fish Populations and Trends

Gamefish

The gamefish present on Silver Lake represent different population dynamics depending on the species. The results for the stakeholder survey show anglers prefer to catch largemouth bass and northern pike on Silver Lake (Figure 3.7-2). Brief summaries of gamefish with fishable populations in Silver Lake are provided based off of the electrofishing survey completed in 2015.

Muskellunge were not captured during the 2015 survey but are present within Silver Lake. Silver Lake is considered a Class C water, meaning that muskellunge are present but are not of major importance to the overall fishery. In terms of muskellunge recruitment, Silver Lake is considered a Category one water, meaning the population is self-sustained through natural reproduction and no stocking occurs.

Largemouth bass are the most common gamefish found in Silver Lake. In the 2015 survey, 15 individuals were captured with the largest being a 17-inch fish.

Northern Pike are present in Silver Lake. In the 2015 survey, only two individuals were captured. These fish measured 19.8 and 21.0 inches. Electrofishing is not the most effective method for surveying northern pike and does not provide sufficient data to make conclusions regarding northern pike populations.

Walleyes have previously been stocked in Silver Lake, but no stocking events have occurred since 1940. In the 2015 survey, however, four walleyes were captured. These fish measured between 17.2-22.8 inches. Natural recruitment is unlikely to be occurring and it is most likely these fish were introduced illegally through unpermitted stocking or illegal transfer from nearby waters (Eric Wegleitner, personal communications).

Panfish

The panfish present on Silver Lake represent different population dynamics depending on the species. The results for the stakeholder survey show anglers prefer to catch bluegill and sunfish on Silver Lake (Figure 3.7-2). Brief summaries of panfish with fishable populations in Silver Lake are provided based off of the survey completed in 2015.

Bluegill were the most common panfish species captured in the 2015 survey. In total, 238 bluegill were sampled. The average size of these fish was 4.6 inches and the largest individual measured 7.6 inches.

Pumpkinseed were the next most encountered panfish species in the 2015 survey. In total, 60 pumpkinseeds were sampled. The average size of these fish was 5.9 inches, with four fish measuring over eight inches. The largest individual measured 8.5 inches.

Yellow perch were captured in the 2015 survey as well. In total, 15 perch were captured. The average size of these fish was only 4.2 inches, and individuals measured over eight inches.

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 3.6-5). 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 lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. While located in the ceded territory, there has been no record of spear harvest for walleye or muskellunge in the last 20 years.

Figure 3.6-5. Location of Silver Lake within the Native American Ceded Territory (GLIFWC, 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Silver Lake Fish Habitat

Substrate Composition

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

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker, 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result.

Walleye are 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 and care for their eggs in muck as well. According to the point-intercept survey conducted by Onterra in 2021, 94% of the substrate sampled in the littoral zone of Silver Lake were soft sediments, 5% was composed of sand, and 1% were composed of rock.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The Fish Sticks program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.7-

3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


Photograph 3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.7-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan, & Haynes, 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (Neuswanger & Bozek, 2004). Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested. If interested, the Silver Lake Association, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Silver Lake.

Fishing Regulations

Regulations for Wisconsin fish species as of February 2021 are displayed in Table 3.6-2. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-2. WDNR fishing regulations for Silver Lake (As of January 2022).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass	5	14"	May 1, 2021 to March 6, 2021
Muskellunge and hybrids	1	45"	May 29, 2021 to December 31, 2021
Northern pike	5	None	May 1, 2021 to March 6, 2021
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 1, 2021 to March 6, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10	None	Open All Year

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer.

These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent, and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time. Silver Lake is listed as an impaired water body for elevated mercury levels. Because of this, women under 50 and children under 15 should not eat walleye over 15 inches. Women over 50 and men aged 15 or older are advised one meal of walleye over 15 inches a month.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-6. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

Fish Consumption Guidelines for Most Wisconsin Inland Waterways		
	Women of childbearing age, nursing mothers and all children under 15	**Women beyond their childbearing years and men**
Unrestricted*	-	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout
1 meal per week	Bluegill, crappies, yellow perch, sunfish, bullhead and inland trout	Walleye, pike, bass, catfish and all other species
1 meal per month	Walleye, pike, bass, catfish and all other species	Muskellunge
Do not eat	Muskellunge	-

**Doctors suggest that eating 1-2 servings per week of low-contaminant fish or shellfish can benefit your health. Little additional benefit is obtained by consuming more than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 3.6-6. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

3.7 SILVER LAKE AREAS OF SPECIAL CONSERVATION INTEREST

Of all the water on earth, only 2.5% is freshwater and only 0.01% is available as freshwater in lakes and rivers (Silk & Ciruna, 2005). Species richness in freshwater ecosystems is greater relative to habitat extent when compared to marine and terrestrial ecosystems, and unfortunately, biodiversity loss in freshwater ecosystems is currently estimated to be five times faster than in any other aquatic or terrestrial ecosystem (Silk & Ciruna, 2005). This loss is driven by a growing human population and its need for water. Freshwater ecosystems are being degraded or lost due to increases in nutrient and pollutant input from land use change, water diversion and extraction, and climate change.

This degradation of freshwater ecosystems results in the loss of freshwater species, communities, and ecosystems, as well as the loss of all other species dependent upon freshwater. Their degradation also inhibits their ability to provide services for humans. Given we are in a period of unprecedented biodiversity loss and in a period of uncertainty associated with the effects of global climate change, it is imperative that conservation efforts be taken to maintain freshwater biodiversity and our natural heritage.

As is discussed in the previous results subsections (Sections 3.1-3.6), Silver Lake is an exceptional freshwater resource with high biodiversity in terms of aquatic plants. Silver Lake supports four native plant species listed as special concern in Wisconsin (Robbins' spikerush, water-thread pondweed, Vasey's pondweed, and northeastern bladderwort). While conservation of the entire Silver Lake ecosystem and surrounding riparian zone is the ideal and ultimate goal, the near-shore areas of Silver Lake contain the highest diversity in terms of aquatic plant species and habitat. These areas are also the most sensitive in terms of their susceptibility to damage watercraft and wave action and habitat loss from shoreland development. These near-shore areas also contain the majority of the populations of special concern species listed earlier.

These Areas of Special Conservation Interest (ASCIs) encompass approximately 16 acres or 27% of Silver Lake's surface area (Map 11 & Photograph 3.7-1). These areas were highlighted with the intent to bring understanding to and highlight the full spectrum of native species and natural community diversity present in Silver Lake. These areas were also created to include critical habitat areas where WDNR Natural Heritage Inventory listed species were documented. These near-shore areas are highly productive and contain most of the lake's biodiversity. These areas support rare aquatic plant communities, spawning, rearing, refuge, and feeding habitat for diverse array of aquatic and terrestrial wildlife (Silk & Ciruna, 2005). These areas in Silver Lake capture the areas of highest aquatic plant species richness and diversity. While surveys aimed at macroinvertebrates (mayflies, stoneflies, caddisflies, etc.) were not completed as part of this study, other studies have shown that macroinvertebrate species richness and diversity are positively correlated with aquatic plant richness and diversity (McCreary Waters & San Giovanni, 2002).

These areas also capture the diversity of benthic (bottom) substrates found in Silver Lake, including rock/cobble, sand, and organic substrates. The benthic zone can be abundant with animals including macro- and microinvertebrates such as crustaceans (e.g., crayfish), insect larvae (e.g., dragonflies, true bugs, etc.), mollusks (e.g., mussels and snails), and burrowing worms (annelids). Rock/cobble substrates tend to support the highest species diversity followed by organic substrates and sand, respectively (Silk & Ciruna, 2005). Different fish species also utilize different benthic substrate types and aquatic plants on which to spawn. While Silver Lake supports aquatic plant growth throughout most of the lake, these areas were also highlighted because of their proximity to shoreland areas. In these areas, the ecotone, or natural transition zone between the aquatic and terrestrial environment is largely intact. These areas also contain the coarse woody habitat in lake mapped by the WDNR in 2017.

Photograph 3.7-1. Intact near-shore habitat in Silver Lake (left) and sensitive aquatic plant (isoetid) plant community in shallow areas (right). Photo credits Onterra 2021.

As discussed, the purpose of bringing attention to these near-shore areas of Silver Lake is these areas encompass the majority of the species, natural communities, and habitats found in the lake and have minimal evidence of direct in-lake or shoreland impacts from human activity (Photo 3.8-1). While these areas are certainly influenced and impacted from human activity outside of these areas, the ERSLA and partners can choose to take proactive action to educate lake users on the importance of these areas and how to minimize human-related disturbance (see Implementation Plan-Section 5.0).

Conserving the integrity of the natural communities within these areas may include reducing watercraft speeds to slow-no-wake while in these areas to avoid impacts to plant and benthic communities through direct contact from props or indirect impacts from wave action. Other conservation actions may include efforts to protect natural shorelands in these areas and prevent or minimize impacts from future development.

Please note that these areas are not legal designations, and were delineated based upon the criteria discussed earlier. The integrity of these areas is also dependent upon the conservation of the larger Silver Lake ecosystem and its watershed and does not devalue the importance of other areas around the lake. However, these areas represent areas of Silver Lake which harbor the majority of the lake's biodiversity and have the least amount of human-related shoreland development.

4.0 SUMMARY AND CONCLUSIONS

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

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

These three objectives were fulfilled during the project and have led to an understanding of the Silver Lake ecosystem, the people that care about the lake, and what needs to be completed to protect and enhance the lake.

A group of Eagle River Silver Lake Association (ERSLA) members and other local partners formed a planning committee for this project and were instrumental in the development of the subsequent Implementation Plan. The planning committee served to provide the local perspective related to recreational use of the lakes and in developing their role in protecting, enhancing, and managing Silver Lake for the years to come. Pairing the understanding of the technical data that has been collected over time as well as the local sociological needs through this planning project has led to the creation of a realistic management plan for the ERSLA to implement in managing Silver Lake.

Historical data, as well as data collected during the management planning project indicate Silver Lake has excellent water quality for a deep headwater drainage lake based on phosphorus and chlorophyll-a levels. The ERSLA has developed actions within the Implementation Plan to monitor water quality parameters in the lake.

The shoreland condition assessment identified areas of the lake's shoreland that are important to protect and maintain in their natural state and also identified areas where restoration actions would have the most benefit. The shorelands around the lakes are mostly in good condition with many areas of intact natural habitat.

The watershed is relatively small and comprised of a variety of land covers including significant percentages of urbanization/residential areas, wetlands, and forests. Modeling overestimates phosphorus levels compared to actual measured levels, likely as a result of wetland areas in the watershed retaining phosphorus.

A long-term aquatic plant dataset is available for Silver Lake in the form of annual point-intercept surveys spanning 2005-2022. Analysis of these data show a high quality aquatic plant population that includes the presence of several rare native species. Trend analysis indicates some species have trended higher or while others have trended lower during the period of study.

Eurasian watermilfoil (EWM) has been present in Silver Lake since at least 2005. Active management through 2,4-D herbicide treatments and hand pulling has occurred in the past. The EWM population was monitored in 2021-2022 as a part of this management planning project. The monitoring showed that the EWM population was at its highest point to-date as of 2022. Some particularly dense areas of the lake were causing limitations to recreational use of the lake, while the point-intercept survey also showed a larger EWM footprint at over 13% littoral occurrence in 2022. Continued monitoring of the EWM population is important in documenting the population dynamics and the distribution within the lake. Monitoring will be instrumental in guiding potential active management strategies in future years. As a part of this management planning project, the ERSLA has outlined how they will monitor EWM and the management approach they will take moving forward.

The ERSLA has developed management actions that will serve to enhance their capacity to manage the lake including outreach and educational initiatives.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of a Planning Committee comprised of members of the Eagle River Silver Lake Association (ERSLA), City of Eagle River, Town of Lincoln, and ecologist/planners from Onterra. It represents the path the ERSLA 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: Increase the ERSLA's Capacity to Manage Silver Lake and Communicate with Members and Riparian Property Owners

Management Action:	Promote lake protection and good lake stewardship through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	ERSLA Board
Description:	Education represents an effective tool to address many lake issues. The ERSLA will continue to make education of lake-related topics a priority for association members and riparian property owners. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan*, allowing it to be better understood by association members. The ERSLA aims to regularly send out updates via email and to conduct in-person annual meetings. These mediums allow for exceptional communication with lake stakeholders. This level of communication is important within a management group because it facilitates the spread of important news, educational topics, and even social happenings. The ERSLA will work with UW-Extension Lakes staff to use stock articles as appropriate to lessen the workload and ensure the messaging is accurate. *www.uwsp.edu/cnr-ap/UWEXLakes* *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic plant species identification • Aquatic invasive species • Blue-green Algae • Basic lake ecology • Water quality

	• Boating safety (promote existing guidelines) • Swimmer's itch • Shoreline habitat restoration and protection • Noise and light pollution • Fishing regulations and overfishing • Recreational use of the lakes
Action Steps:	
	See description above.

Management Action:	Promote more participation and involvement in ERSLA activities
Timeframe:	Continuation of current efforts
Facilitator:	ERSLA Board
Description:	The effectiveness of a lake association is often a reflection of the time and talents of the individuals the association draws from. While it is true that several dedicated people can conduct a vast amount of association-related work, it is helpful to have a large pool of volunteers and talent to draw upon for various lake association and lake management related tasks. The ERSLA will communicate with members through annual meetings and periodic or monthly emails to seek more involvement and participation in ERSLA activities. Currently, the ERSLA communicates with membership primarily through email. The ERSLA will conduct an in-person annual meeting to facilitate more face-to-face interactions from which the ERSLA may be able to secure volunteer involvement for activities. The ERSLA will host the annual meeting at a residence along the shores of the lake. These steps will also serve to keep members informed and connected to what is happening around Silver Lake.
Action Steps:	See Description Above.

Management Action:	Continue ERSLA's involvement with other entities that have responsibilities in managing Silver Lake
Timeframe:	Continuation of current efforts
Facilitator:	ERSLA Board
Description:	The waters of Wisconsin belong to everyone and therefore a goal of protecting and enhancing these shared resources is held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the ERSLA actively engage with all management entities to enhance the understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page.
Action Steps:	
	See table guidelines on the next page.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Lincoln	Lincoln Town Clerk Shelly Sauvola 715-479-7000	Silver Lake falls within the Town.	Keep up to date on Town activities. As needed. (townoflincolnvilas.com)	Aspects that involve the township government such as ordinances, building and zoning, and funding opportunities
City of Eagle River	City Administrator Robin Ginner rcginner@ci.eagle-river.wi.us	Partners with the ERSLA for WDNR grants and other projects	As needed.	Provides a link between the ERSLA and City of Eagle River
Vilas County Lakes & Rivers Association	President Tom Ewing tomewingjr@aol.com	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator Cathy Higley 715.479.3738	Oversees AIS monitoring and prevention activities locally.	As issues arise.	AIS training and ID, AIS monitoring techniques. Assist in connecting/networking ERSLA with other lake associations
Vilas County Land & Water Conservation Department.	Conservation specialist Mariquita Sheehan 715-479-3721-	Oversees conservation efforts for land and water projects.	As opportunities arise.	Can provide assistance with shoreland restorations and habitat improvements. Assist in connecting/networking ERSLA with other lake associations
Wisconsin Lakes	General staff 800-542-5253	Education, networking and assistance.	As needed. (wisconsinlakes.org)	Reps can assist on education
Wisconsin Department of Natural Resources	Fisheries Biologist Eric Wegleitner 715-356-5211 ext. 246	Manages the fishery of the system.	Once a year, or more as issues arise.	Stocking, surveys, volunteer opportunities for improving fishery.
	Lakes Coordinator Kevin Gauthier 715-365-8937	Oversees management plans, grants, all lake activities.	Once a year in late-summer/early fall to inquire about point-intercept survey results, or more as necessary.	Information on updating a lake management plan, submitting grants & permits, and to seek advice on other lake issues.
	Conservation Warden Matt Meade 715-329-0615	Oversees regulations handed down by the state.	As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also.	Suspected violations, including fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network Sandra Wickman 715-365-8951	CLMN training and assistance.	Twice a year or more as needed.	Training, planning of monitoring and reporting of data.
	AIS Regional Coordinator Alan Wirt Alan.Wirt@wisconsin.gov	Oversees local AIS monitoring and prevention.	Twice a year or more as issues arise.	AIS training and ID, AIS monitoring techniques

Management Goal 2: Monitor Water Quality Conditions in Silver Lake

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network
Timeframe:	Beginning 2024
Facilitator:	Steve Haagen or ERSLA Water Quality Sampling Volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The CLMN contains two water quality monitoring programs, 1) one where the volunteer collects Secchi disk transparency and 2) an advanced CLMN program where water chemistry samples would also be collected (chlorophyll-*a*, and total phosphorus). During both of these programs, samples are collected three times during the summer and once during the spring turnover. Volunteer water quality monitoring through the Citizen Lake Monitoring Network (CLMN) has occurred in the past on Silver Lake, particularly between 1993-1998. Efforts to revive this program occurred in 2010, but were not sustained. The ERSLA is currently working with the WDNR to receive the proper training and resume participation in the collection of Secchi disk transparency data on Silver Lake. Following a few years of consistent data collection, the ERSLA would be placed on the waiting list for entrance into the advanced CLMN program that includes the collection of water chemistry data. It also must be noted that the CLMN program may be changing in the near future with sample analysis cost coverage not available annually. Recently there has been a move to have new CLMN volunteers collect samples for three years and then stop so that additional lakes can be funded. If a long-term record is desired by the ERSLA then it will be important to maintain the volunteer data collection without a lapse.
Action Steps:	
1.	Contact CLMN Coordinator (Sandy Wickman) to enroll in the program
2.	Trained volunteer(s) collects data and reports results to WDNR by entering into the SWIMS database as well as sharing with ERSLA members.
3.	Water sampling volunteer and ERSLA facilitate the recruitment of new volunteer(s) as needed.

Management Goal 3: Monitor Aquatic Invasive Species in the Silver Lake Ecosystem and Conduct Management Based on Results

Management Action:	Coordinate periodic vegetation monitoring on Silver Lake
Timeframe:	Point-Intercept Survey every five years, community mapping survey every 10 years
Potential Grant:	WDNR Surface Water Planning Grant ($10,000 max)
Facilitator:	Town of Lincoln, City of Eagle River, ERSLA
Description:	Whole-lake point-intercept surveys have been completed annually on Silver Lake from 2005-2022, with the exception of 2006 as a part of a long-term trends study being conducted by the WDNR. In the event that the annual monitoring by WDNR comes to an end, then the ERSLA would ensure the survey would be completed approximately every 5 years. The survey would be initiated sooner if perceived changes in the aquatic plant community are believed to be occurring. This will allow a continued understanding of the submergent aquatic plant community dynamics within Silver Lake. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Silver Lake, a community mapping survey would be conducted every 10 years. A community mapping survey was completed in 2021 during this management planning project, meaning the next survey would take place in 2031. The ERSLA may contract with a professional firm or local organizations to conduct these monitoring surveys. Additionally, the ERSLA may consider applying for a WDNR surface water planning grant that if awarded, would provide funds towards the completion of aquatic plant monitoring surveys. A grant application of this nature would be a stronger candidate for receiving funding if it also included surveys aimed at monitoring AIS populations in lake such as an EWM mapping survey. These surveys would provide the supporting data necessary to complete a future update to the ERSLA's aquatic plant section of their comprehensive management plan.
Action Steps:	
	See description above.

Management Action:	Conduct annual volunteer-led purple loosestrife monitoring and control efforts
Timeframe:	Continuation of Ongoing effort
Facilitator:	Jon Cook
Description:	Purple loosestrife flowers are produced in mid to late-summer making this an ideal time to search for the species. Hand pulling and/or herbicide treatments should be conducted before flowering occurs, if possible, to reduce the potential spread of seed. Pulled plants must be removed from the site and disposed of properly to prevent seed production. An NR107 permit is required to apply herbicide if the proposed treatment area is wet at the time of treatment. The standard WDNR test for NR 107 permit requirement is often referred to as the *wet sock test* if your socks would get wet if you stood without wearing shoes, then a permit is required. Regardless if the site is wet or dry, a product with an aquatic label must be used. Habitat® herbicide (imazapyr), Aquaneat® (glyphosate) and Rodeo® (glyphosate) have aquatic use labels. Roundup® is a popular glyphosate-based herbicide but it does not have an aquatic label, and therefore cannot be used on shoreline areas. Habitat® herbicide can only be applied by an applicator that is certified by DATCP. An ERSLA volunteer has been searching for purple loosestrife occurrences around the shores of Silver Lake for a number of years. These occurrences have been managed through a combination of cutting and dabbing the cut stem with an herbicide containing glyphosate active ingredient. Younger, small plants are dug out including the roots. The ERSLA will continue this program, ensuring that proper permissions from private riparian property owners is obtained when necessary and that the proper aquatic use herbicide is being used. A permit would be applied for if the treatment is to take place in a wet site as described above, but some of the permit requirements (i.e. permit fees, applicator certification) are waived when targeting purple loosestrife.
Action Steps:	
	See description above.

Management Action:	Coordinate Monitoring of Eurasian Watermilfoil in Silver Lake
Timeframe:	annually
Facilitator:	ERSLA Board
Description:	Eurasian watermilfoil monitoring in Silver Lake has occurred through quantitative methods (point-intercept surveys) and qualitative means (mapping surveys) over time. The primary means of monitoring going

	forward will be through the determination of the littoral frequency of occurrence of EWM based on the whole-lake point-intercept survey. Whole-lake point-intercept surveys have been conducted on nearly an annual basis since 2005, and as long as these data continue to be collected by WDNR as a part of a long-term trends study, there would be no direct costs to the ERSLA for this study. The ERSLA would solicit services to conduct a point-intercept survey as needed if the annual WDNR surveys are no longer occurring. Professional EWM mapping surveys have been completed on Silver Lake in 2010, 2012-2017, 2021, and 2022 by Onterra. This type of survey helps to identify where EWM is likely to be causing impacts to recreational use of the lake for activities including navigation based on the attributed density ratings of colonized EWM. From Onterra's mapping methodologies, colonized areas designated as *highly dominant* or *surface matted* would be most likely to be causing impacts to the recreational use of the lake. The ERSLA would solicit an EWM mapping survey periodically, in particular if they believe active management may be warranted or if the point-intercept survey indicates an EWM occurrence of 15% or greater in the lake. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). The EWM population would be assessed through the completion of a late-summer mapping survey (August or September) when the species is expected to be at its peak growth stage of the year.
Action Steps:	
	See description above.

<u>Management Action:</u>	Conduct management actions towards Eurasian watermilfoil
Timeframe:	As dictated by monitoring survey results
Potential Grant:	WDNR AIS-Established Population Control Grant
Facilitator:	ERSLA Board
Description:	**<u>Hand-Harvesting</u>** Hand-removal of EWM can be an effective way to manage low or emerging populations. This can be conducted either through a volunteer effort or by contracting professionals. Permits are only required if mechanical methods are used in the process, such as Diver Assisted Suction Harvest (DASH) techniques used by some contractors. Hand-harvesting of EWM can occur at any time of the year, as long as the roots are fully extracted. Hand-harvesting typically occurs between mid-June and mid-September, as the plants are brittle and harder to get complete extraction outside that window.

It is important to understand that each riparian owner can legally harvest EWM and native plant species in a 30-foot-wide area of one's frontage directly adjacent to one's pier without a permit. EWM can be hand-removed outside of the 30-foot-wide area without a permit. A permit is required if an area larger than the 30-foot corridor is being harvested or if a mechanical assistance mechanism, like DASH, is being used. Professional services to remove EWM also do not require a permit unless DASH or a mechanical device is being used in the process. Simply wading into the lake and removing EWM by hand with or without the aid of snorkeling accessories can be helpful in managing EWM on a small and individual property-based scale. Some professional firms offer services to remove aquatic vegetation from within the riparian property owner's 30-foot frontage zone, though it is more economical to solicit these efforts from local sources if available. The ERSLA will educate its stakeholders on proper hand-harvesting techniques, so they can properly target EWM in their recreational footprint.

Herbicide Spot Treatment

Professional EWM mapping surveys help to identify where nuisance growth conditions may be contributing to reduced recreational use of the lake. When these data are available, spatially targeted spot-herbicide treatments can be more easily constructed based on mapped EWM extents, whereas the point-intercept survey data alone is more difficult to use for this purpose. The ERSLA wishes to set the following "trigger" for beginning discussions towards conducting an herbicide spot treatment:

> *When impacts to recreational use of the lake are documented, particularly navigational limitations from pier heads, a spot treatment would be considered.*
>
> *Herbicide spot treatment techniques would only be considered if the colonies have a size/shape/location where management is anticipated to be effective. In general, this would be areas confined to bays (not exposed), broad in shape (not narrow bands), and of sufficient size to hold core concentrations and exposure times.*

Spot treatment designs would consider additive impacts within an Area of Potential Impact (AOPI), such that if levels reach whole-lake concentrations, they are accounted for in the treatment and monitoring strategy.

While some herbicide spot treatments show promise, the unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with some WDNR regulators and lake managers. This is particularly true in areas of increased water exchange via flow, exposed and offshore EWM colonies, or when traditional weak-acid herbicides like 2,4-D are used. Future spot herbicide treatments on Silver Lake would consider herbicides thought to be effective under short exposure situations. At the time of this

	writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike™) are examples of herbicides with reported short exposure time requirements that are employed for spot treatments of invasive watermilfoil control in Wisconsin. Many lake groups also attempt to lengthen herbicide exposure times by "containing" the herbicide in place with the use of barrier curtains. Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile. Based on the most recent EWM mapping survey conducted in late-summer 2022, the ERSLA meets its trigger described above in considering a spot-treatment herbicide management strategy. One site on the south end of the lake was found to contain a fairly large contiguous colony comprised mostly of a surface matted density rating. This site is located in a semi-protected bay of the lake which would aid in holding herbicide concentration exposure times. Boating through the surface matted EWM is extremely difficult for riparian property owners that have piers in this area of the lake. The ERSLA will consider their available resources and review the BMP's for this type of management strategy to determine whether or not they would consider a spot-treatment in this site. **<u>Herbicide Whole-Lake Treatment</u>** The ERSLA will use the data from the whole-lake point-intercept survey to select a "trigger" for when they would begin discussions relating to considering a whole-lake herbicide treatment strategy. Whole-lake 2,4-D treatments have taken place in Silver Lake in the past and the ERSLA will reserve this management approach for when the EWM population reaches a level where the EWM population comprises a larger portion of the lakes littoral zone. The ERSLA would set the following "trigger" for initiating conversations leading towards pursuing a whole-lake treatment: *Whole-lake point-intercept survey indicates an EWM littoral frequency of occurrence of 15% or greater* The 15% trigger represents an EWM occurrence that is higher than has been documented to date in Silver Lake. If the 15% EWM occurrence is met, the ERSLA would solicit a professional firm to conduct an EWM mapping survey. The mapping survey would be used to further design a potential whole-lake treatment strategy. It is important to note that this trigger simply initiates discussion related to conducting a whole-lake treatment. Discussions between the ERSLA and partners would include a review of current BMP's as it relates to this management approach. The occurrence of EWM in the most recent point-intercept survey (2022) was 13.2% which is slightly lower than the 15% threshold needed to begin discussions of a potential whole-lake treatment.

	If ERSLA decides to pursue future herbicide management towards EWM, either as a spot treatment or whole-lake treatment, the following set of bullet points would occur: • Early consultation with WDNR would occur. ◦ Create a Control and Monitoring Plan. The Control and Monitoring Plan would likely be created based on the results of a late-summer EWM mapping survey or in combination with the results of a whole-lake point-intercept survey. These data would be used to create a specific EWM control strategy for the following year including information such as the herbicide to be used, dosing strategy, targeted areas, and an accompanying monitoring strategy. The Control and Monitoring Plan would include applicable risk assessment materials for the ERSLA to review, particularly if an herbicide strategy is being considered. This might include a summary of available research, toxicity, selectivity, etc. ◦ Monitoring for EWM efficacy at the scale of likely impact. If the treatment is a true spot treatment, the application area should be monitored. If the Area of Potential Impact (AOPI) is larger, such as a basin or an entire lake, that AOPI should be monitored. ◦ EWM control efficacy would occur by comparing annual late-summer EWM mapping surveys ◦ If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016):* https://dnrx.wisconsin.gov/swims/downloadDocument.do?id=158140137 This generally consists of collecting quantitative point-intercept before the treatment (pre) and the summer following the treatment (post) at the scale of AOPI. ◦ Herbicide concentration monitoring may also occur surrounding the treatment if grant funds are being used or the ERSLA believes important information would be gained from the effort. • An herbicide applicator firm would be selected in late-winter and a permit application would be applied to the WDNR as early in the calendar year as possible, allowing interested parties sufficient time to review the control plan outlined within the annual report as well as review the permit application. • Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June), active growth tissue is confirmed on the target plants. A focused pretreatment survey would take place approximately a week or so prior to treatment. This site visit would

	evaluate the growth stage of the EWM (and native plants) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments and dictate approximate ideal treatment timing. Additional aspects of the treatment may also be investigated, depending on the use pattern being considered, such as the role of stratification.
Action Steps:	
	See description above.

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 in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll - *a*	●		●		●		●		●			
Total Nitrogen	●	●			●	●					●	●
True Color	●				●							
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Hardness	●				●							
Total Suspended Solids	●	●			●	●			●	●		
Calcium	●				●							

In addition, during each sampling event Secchi disk transparency was recorded and a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe.

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) (USGS, 2019) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska & Kreider, 2003).

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Silver Lake during a June 8, 2020 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 August 6, 2020. A point spacing of 37 meters was used resulting in approximately 334 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 Pro6T 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, vouchered, and sent to the University of Wisconsin – Steven's Point Herbarium.

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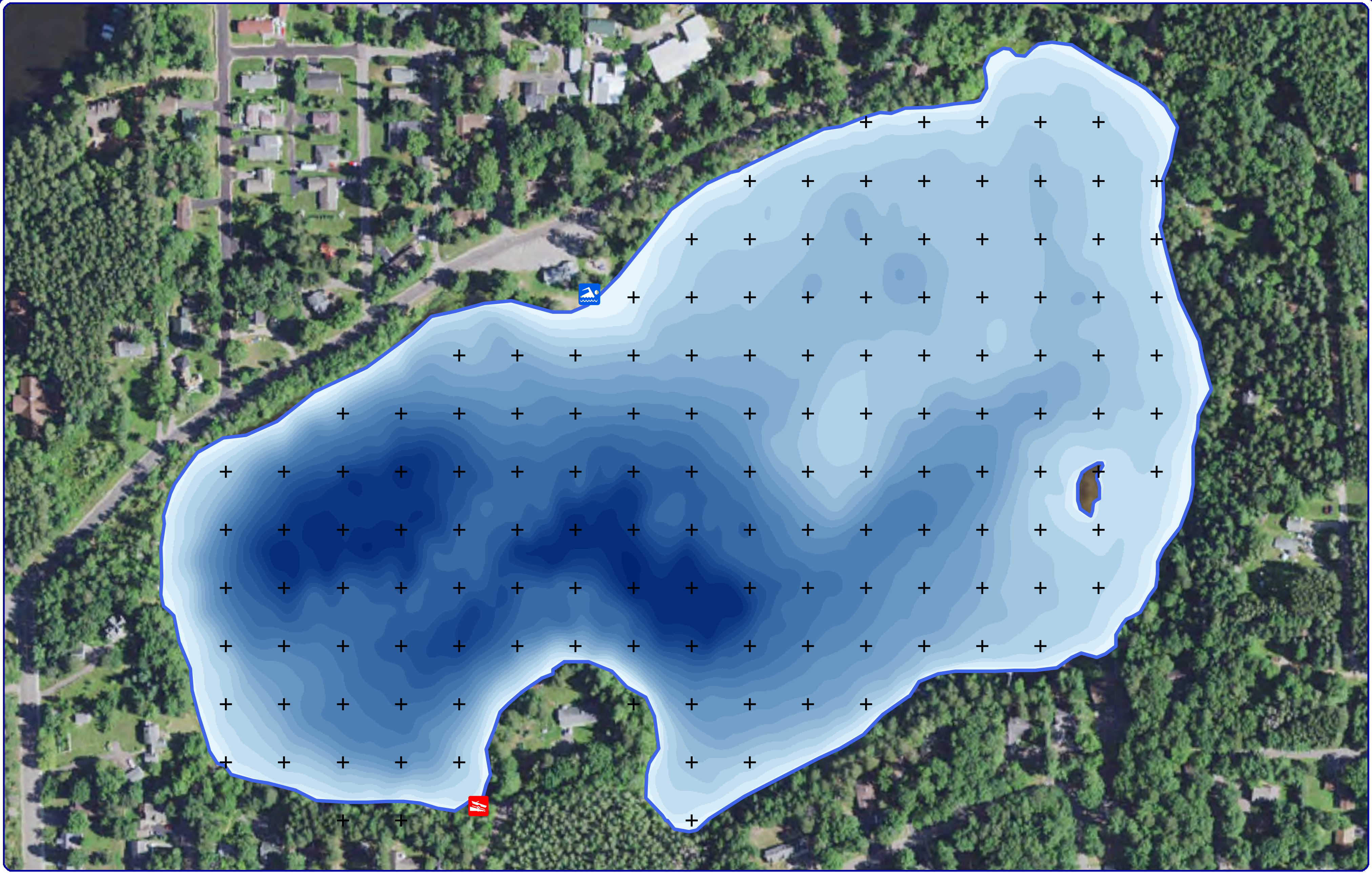

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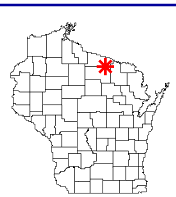
920.338.8860
www.onterra-eco.com

Sources:
Hydro: Onterra
Bathymetry: Onterra, 2015
Aerial Photography: NAIP 2020
Map Date: January 12, 2022 BTB
Filename: Map1_SilverV_Location.mxd



Project Location in Wisconsin

Legend

Silver Lake
(57 Acres; WDNR Definition)

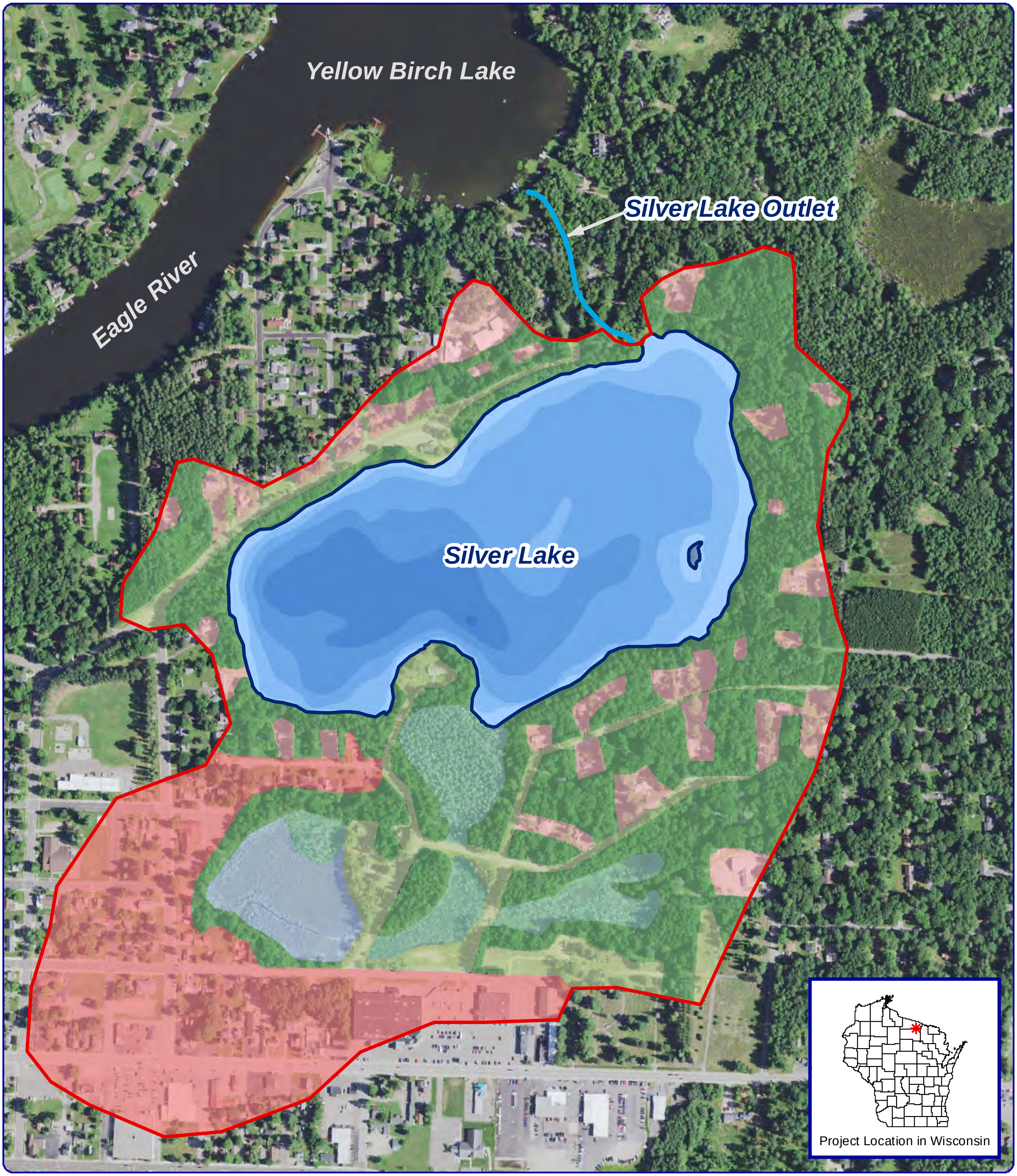
Point-Intercept Survey Sampling Location
(144 total points; 40-meter resolution)

Public Boat Launch

Public Beach

Map 1
Silver Lake
Vilas County, Wisconsin

Project Location & Lake Boundaries



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Legend

- Watershed Boundary
- Forest
- Forested Wetlands
- Rural Open Space
- Urban - Medium Density
- Rural Residential
- Non-Forested Wetlands

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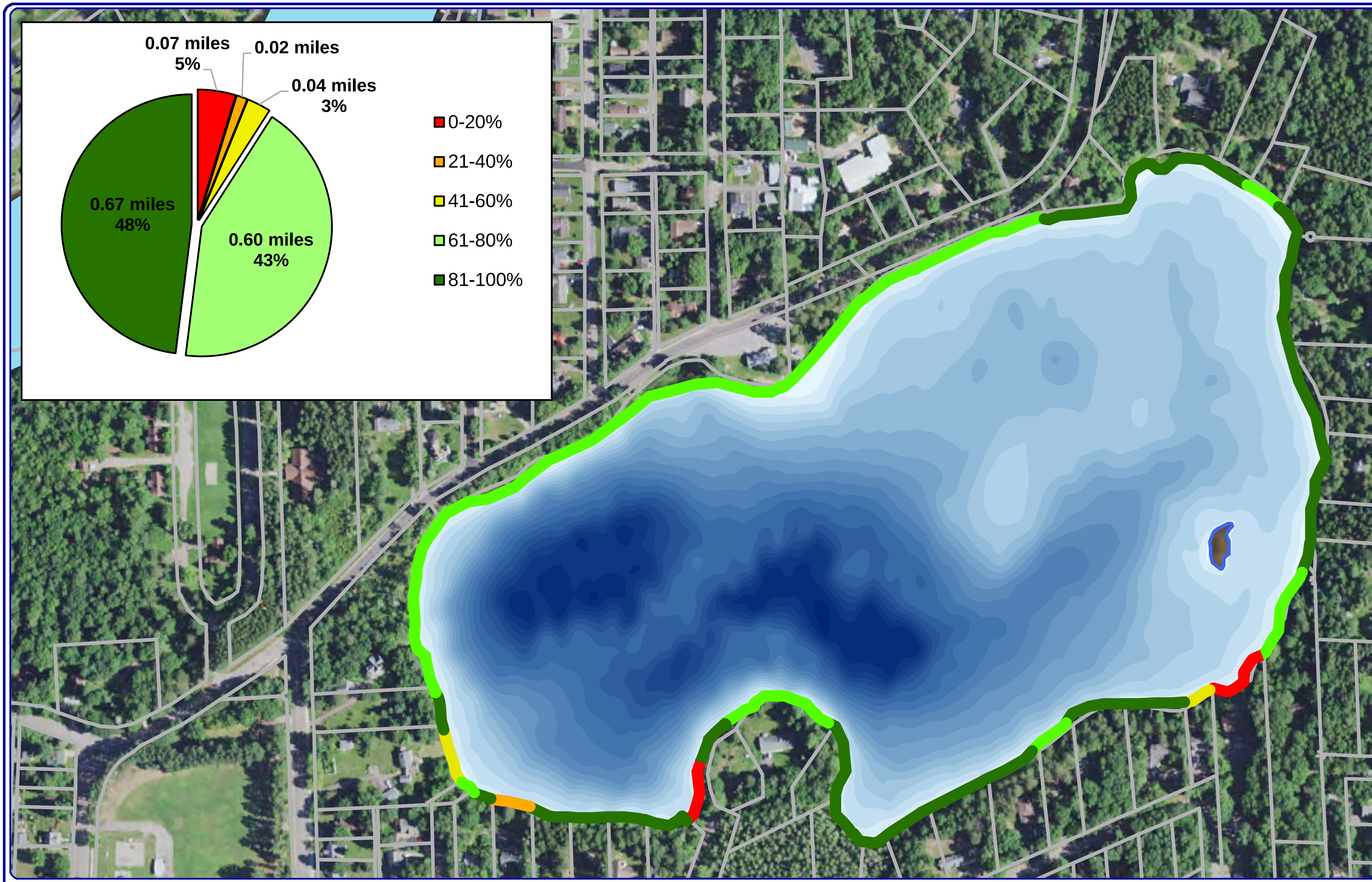
Sources:
Hydro: WDNR
Watershed: Onterra 2021
Orthophotography: 2020 NAIP
Map Date: December 3, 2021 BTB
File Name Map2_SilverV_WS.mxd

Map 2
Silver Lake
Vilas County, Wisconsin
Watershed Boundaries & Land Cover Types



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Sources:
Orthophotography: NAIP 2020
Bathymetry: Onterra 2015
Parcel Info: WDNR 2017
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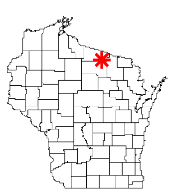
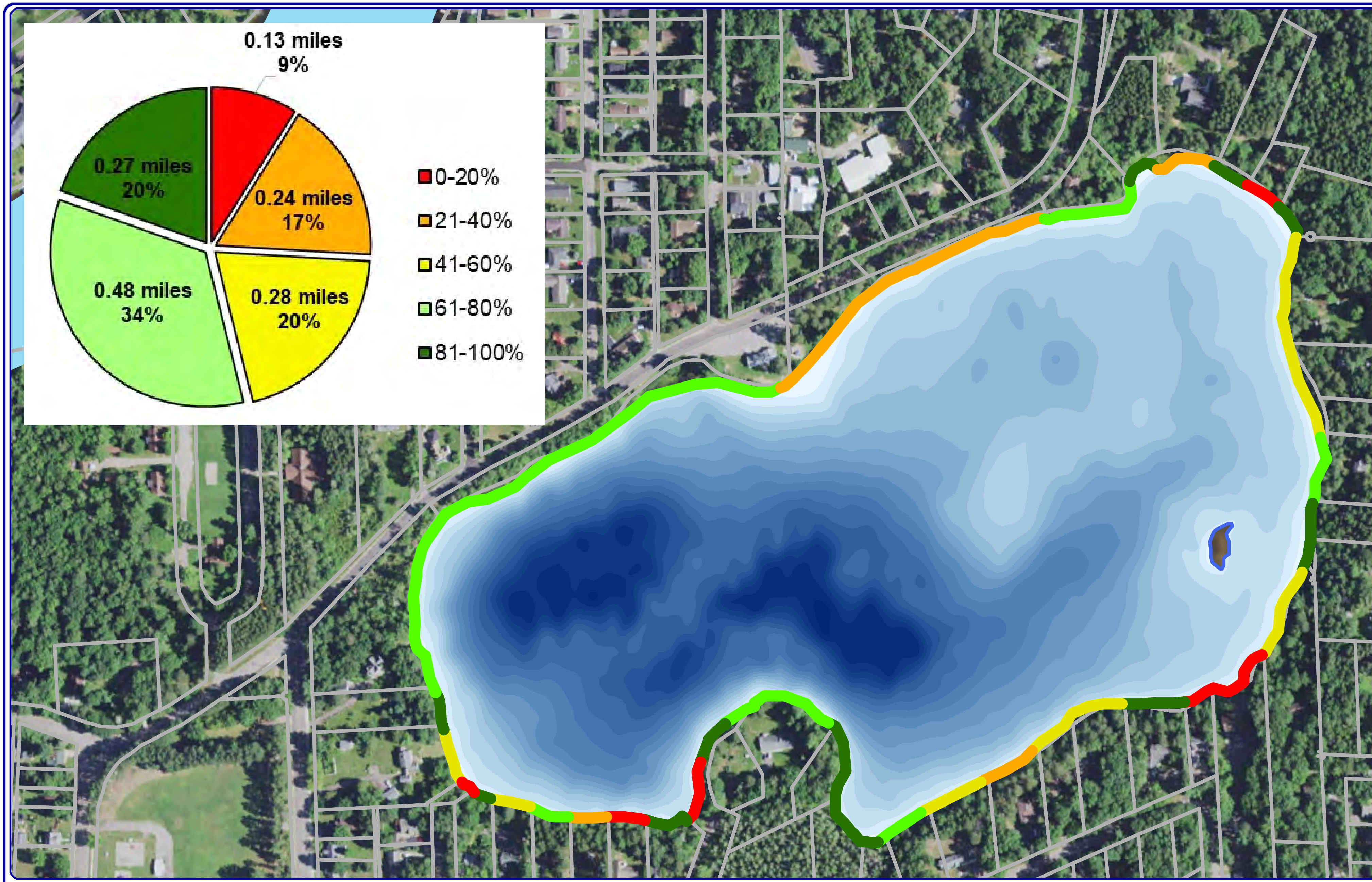


Project Location in Wisconsin

Percent Canopy Cover
- 81 - 100%
- 61 - 80%
- 41 - 60%
- 21 - 40%
- 0 - 20%

Shoreland Parcels

Map 3
Silver Lake
Vilas County, Wisconsin
WDNR: 2017 Parcel Canopy Cover



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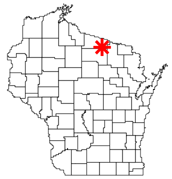
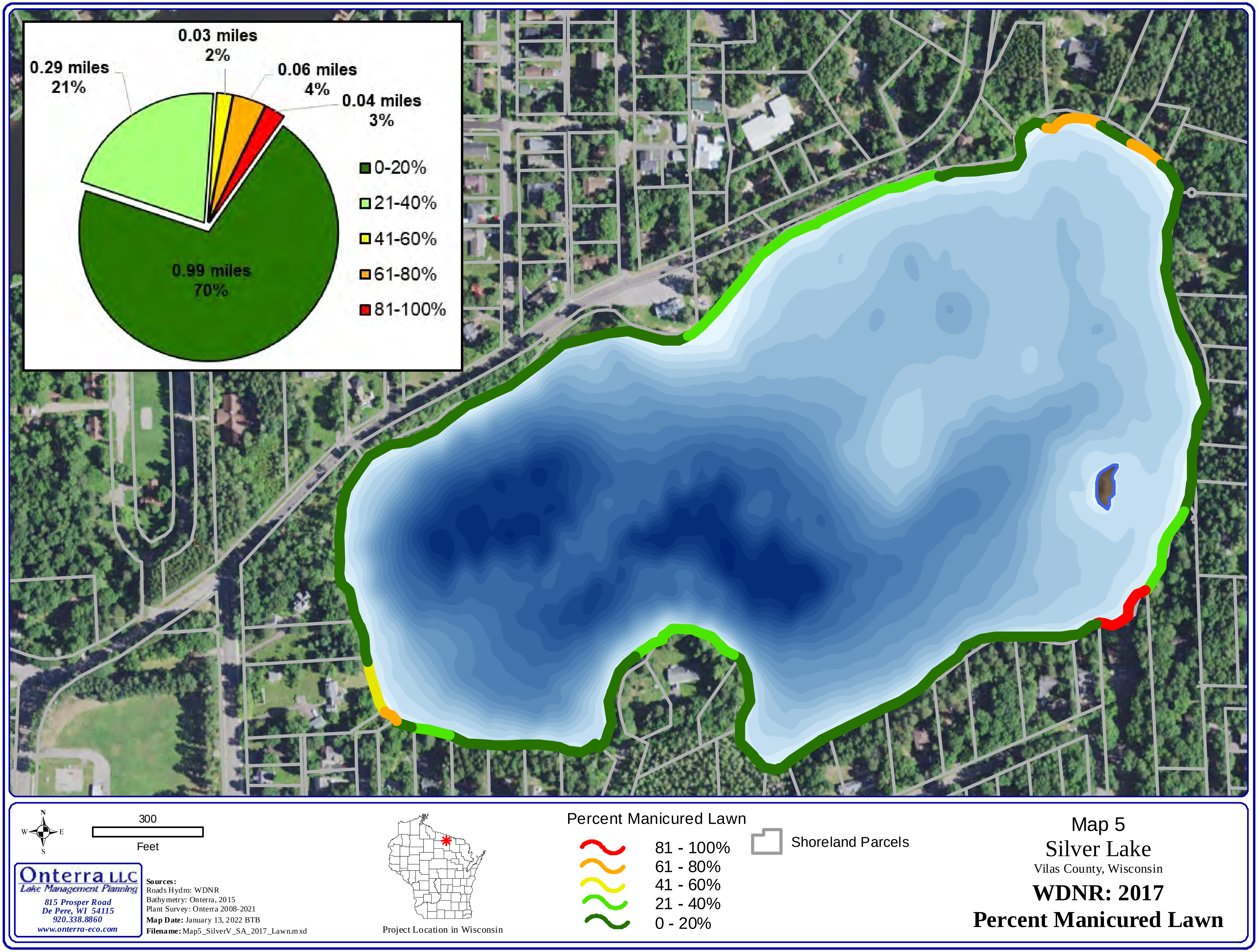
Sources:
Orthophotography: NAIP 2020
Bathymetry: Onterra 2015
Parcel Info: WDNR 2017
Map Date: January 12, 2022 BTB
Filename: Map4_SilverV_DNR_2017_Shrub-Herb.mxd


Project Location in Wisconsin

Percent Shrub-Herbaceous Cover
- 81 - 100%
- 61 - 80%
- 41 - 60%
- 21 - 40%
- 0 - 20%

Shoreland Parcels

Map 4
Silver Lake
Vilas County, Wisconsin
WDNR: 2017 Parcel Shrub-Herbaceous Cover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21-40%
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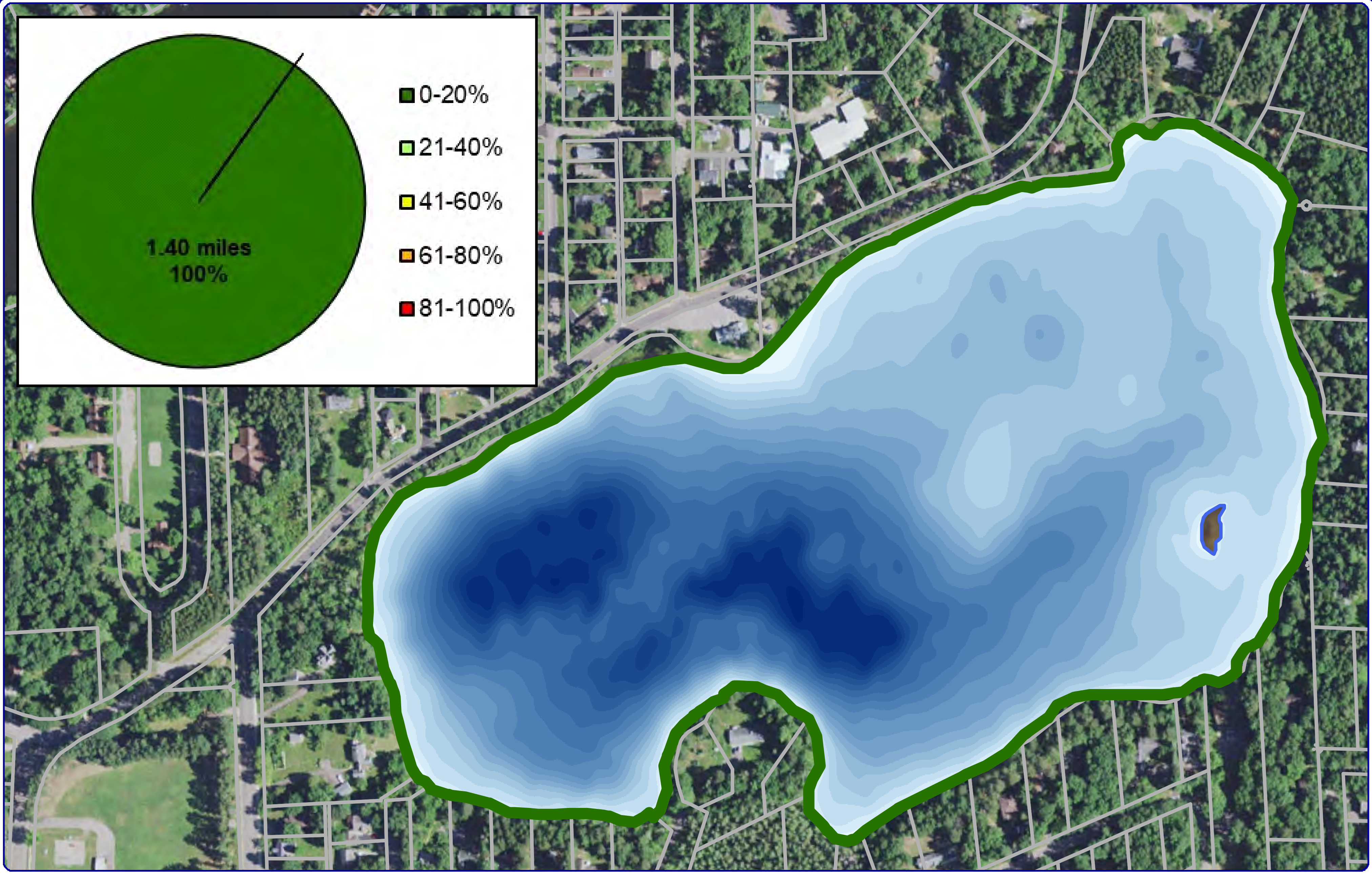
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra 2008-2021
Map Date: January 13, 2022 BTB
Filename: Map5_SilverV_SA_2017_Lawn.mxd
Project Location in Wisconsin
Percent Manicured Lawn
81 - 100%
61 - 80%
41 - 60%
21 - 40%
0 - 20%
Shoreland Parcels
Map 5
Silver Lake
Vilas County, Wisconsin
WDNR: 2017
Percent Manicured Lawn



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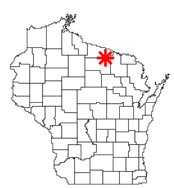
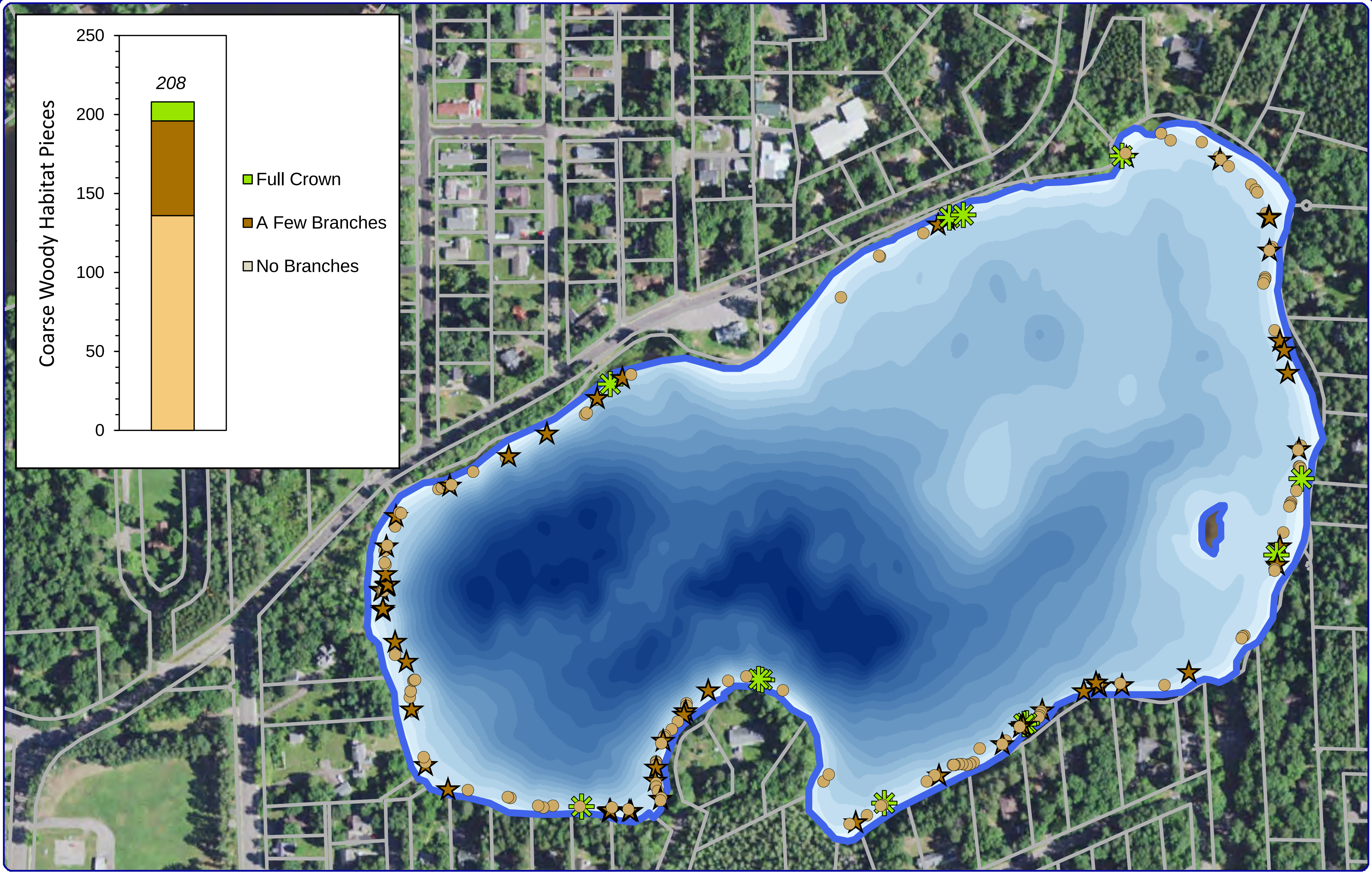
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra 2008-2021
Map Date: January 13, 2022 BTB
Filename: Map5_SilverV_SA_2017_ImpSurface.mxd


Project Location in Wisconsin

Percent Impervious Surface
81 - 100%
61 - 80%
41 - 60%
21 - 40%
0 - 20%

Shoreland Parcels

Map 6
Silver Lake
Vilas County, Wisconsin
WDNR: 2017
Percent Impervious Surface



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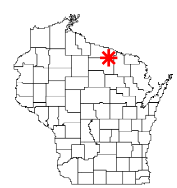
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra 2008-2021
Map Date: January 13, 2022 BTB
Filename: Map5_SilverV_SA_2017_CWH.mxd

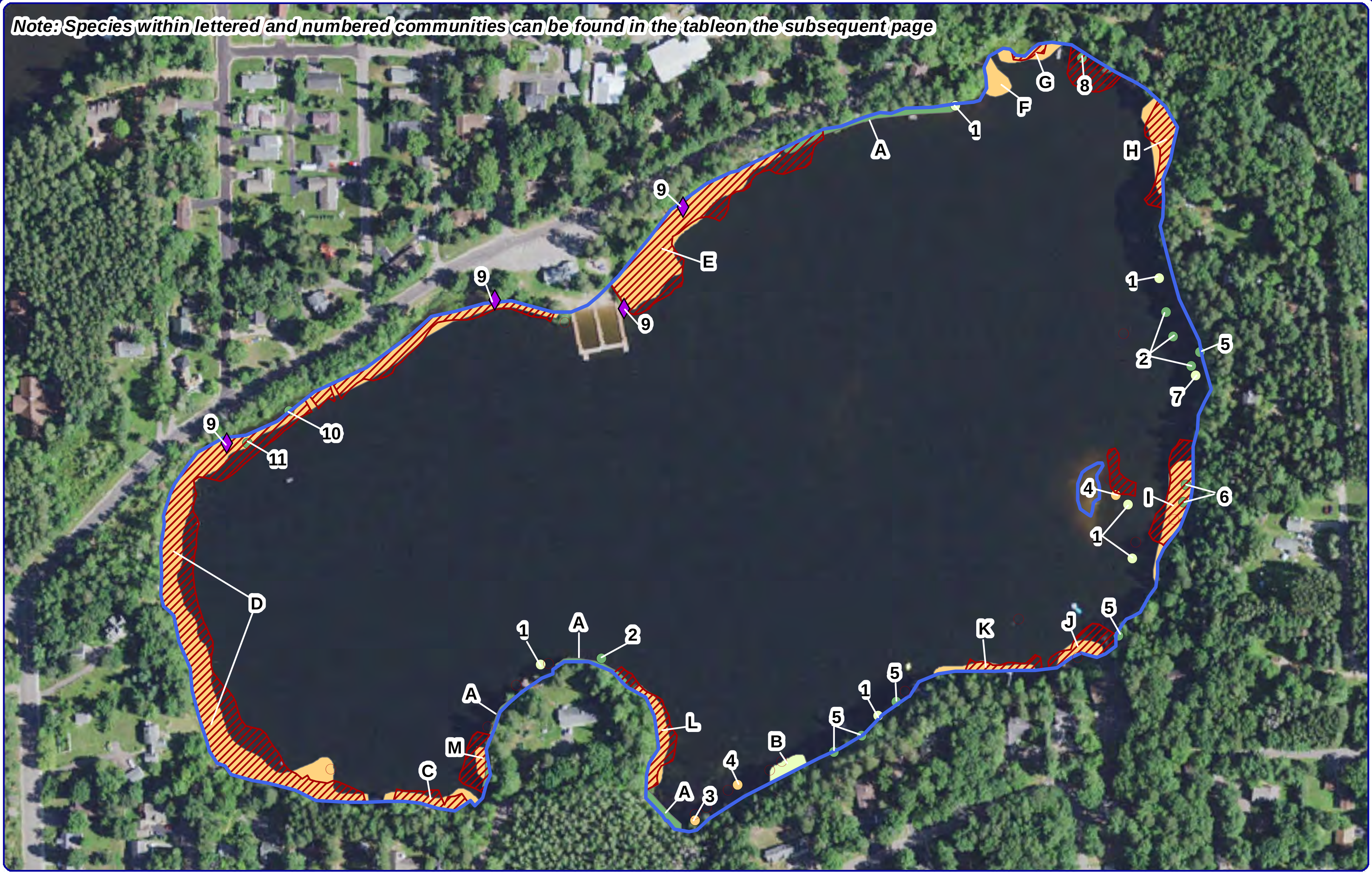


Project Location in Wisconsin

Coarse Woody Habitat

- No Branches
- A Few Branches
- Full Crown

Map 7
Silver Lake
Vilas County, Wisconsin
WDNR: 2017
Coarse Woody Habitat



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Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra 2008-2021
Map Date: January 13, 2022 BTB
Filename: Map5_SilverV_2021_Comm.mxd

Native Large Community
- Emergent
- Floating-leaf
- Mixed Emergent & Floating-leaf
- 2010 Emergent/Floating-leaf

Native Small Community
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- 2010 Emergent/Floating-leaf

Exotic Small Community
- Purple loosestrife

Map 8
Silver Lake
Vilas County, Wisconsin

2021 Floating-leaf & Emergent Plant Communities

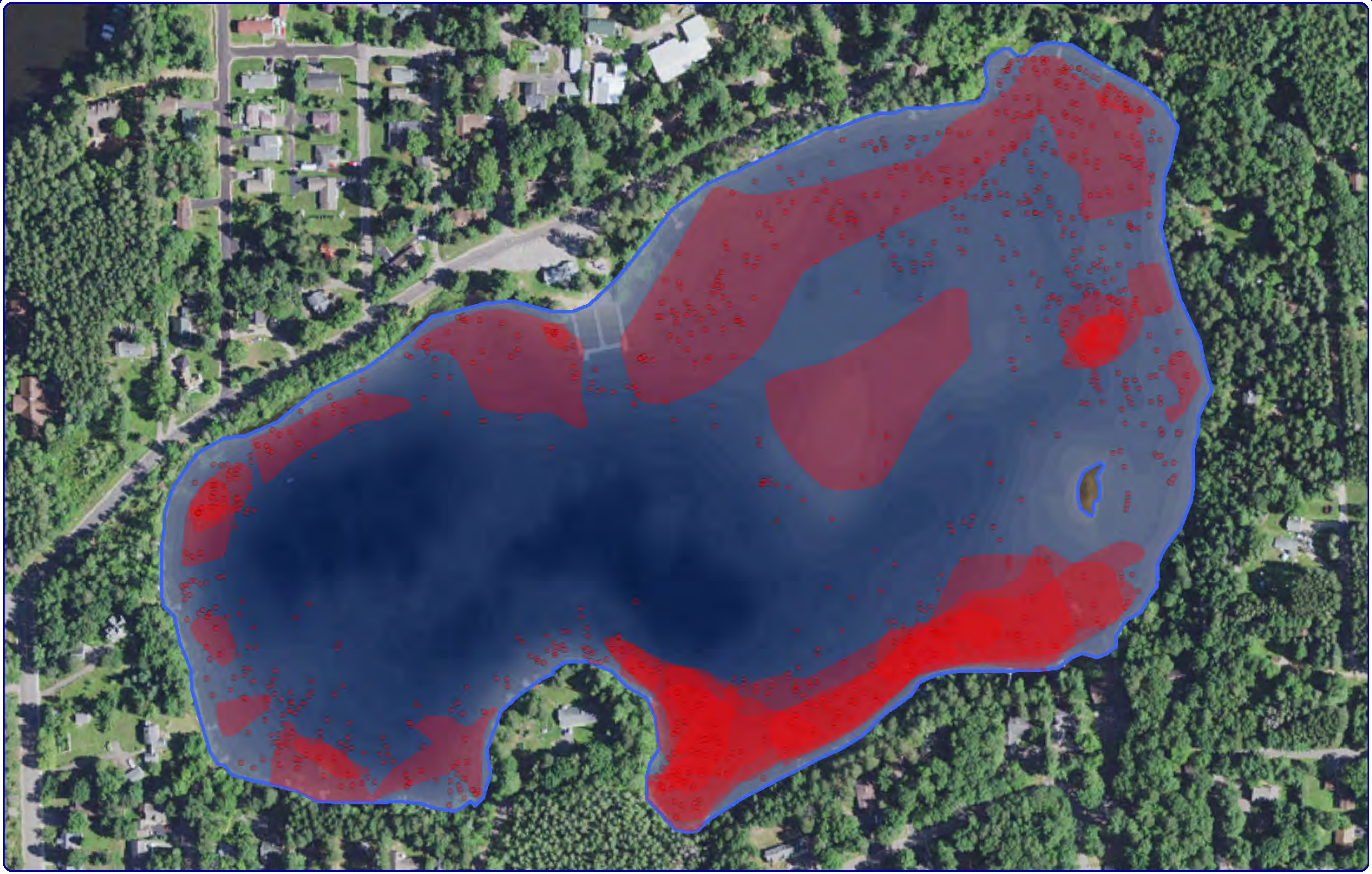
Silver Lake 2021 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Map 8

Large Plant Community (Polygons)						
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**
A	Sweet Gale					
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**
B	Narrow-leaf bur-reed	Spatterdock				
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**
C	Narrow-leaf bur-reed	Spatterdock		Sweet gale	Grass-leaved arrowhead	
D	Narrow-leaf bur-reed	Spatterdock	Grass-leaved arrowhead	Three-way sedge	Sweet gale	Soft rush
E	Narrow-leaf bur-reed	Spatterdock	Three-way sedge	Grass-leaved arrowhead	Water arum	Soft rush
F	Grass-leaved arrowhead	Spatterdock	Narrow-leaf bur-reed			
G	Spatterdock	Grass-leaved arrowhead			Sweet gale	Narrow-leaf bur-reed
H	Narrow-leaf bur-reed	Grass-leaved arrowhead			Three-way sedge	Water arum
I	Narrow-leaf bur-reed	Spatterdock	Sweet gale	Grass-leaved arrowhead	Creeping spikerush	
J	Narrow-leaved cattail	Grass-leaved arrowhead			Spatterdock	Narrow-leaf bur-reed
K	Grass-leaved arrowhead	Narrow-leaf bur-reed			Spatterdock	Sweet gale
L	Spatterdock	Sweet gale	Grass-leaved arrowhead		Narrow-leaf bur-reed	
M	Spatterdock	Grass-leaved arrowhead				

Small Plant Community (Points)		
Emergent	**Species 1**	**Species 2**
2	Grass-leaved arrowhead	
5	Sweet gale	
6	Soft rush	
8	Three-way sedge	Soft rush
9	Purple loosestrife	
10	Sedge sp. (sterile)	
11	Softstem bulrush	
Floating-leaf	**Species 1**	**Species 2**
1	Narrow-leaf bur-reed	
7	Floating-leaf bur-reed	
Floating-leaf & Emergent	**Species 1**	**Species 2**
3	Spatterdock	Grass-leaved arrowhead
4	Grass-leaved arrowhead	Narrow-leaf bur-reed

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 3.4-2



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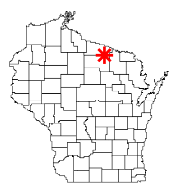
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra 2008-2021
Map Date: January 7, 2022 BTB
Filename: Map9_SilverV_EWM_Footprint.mxd

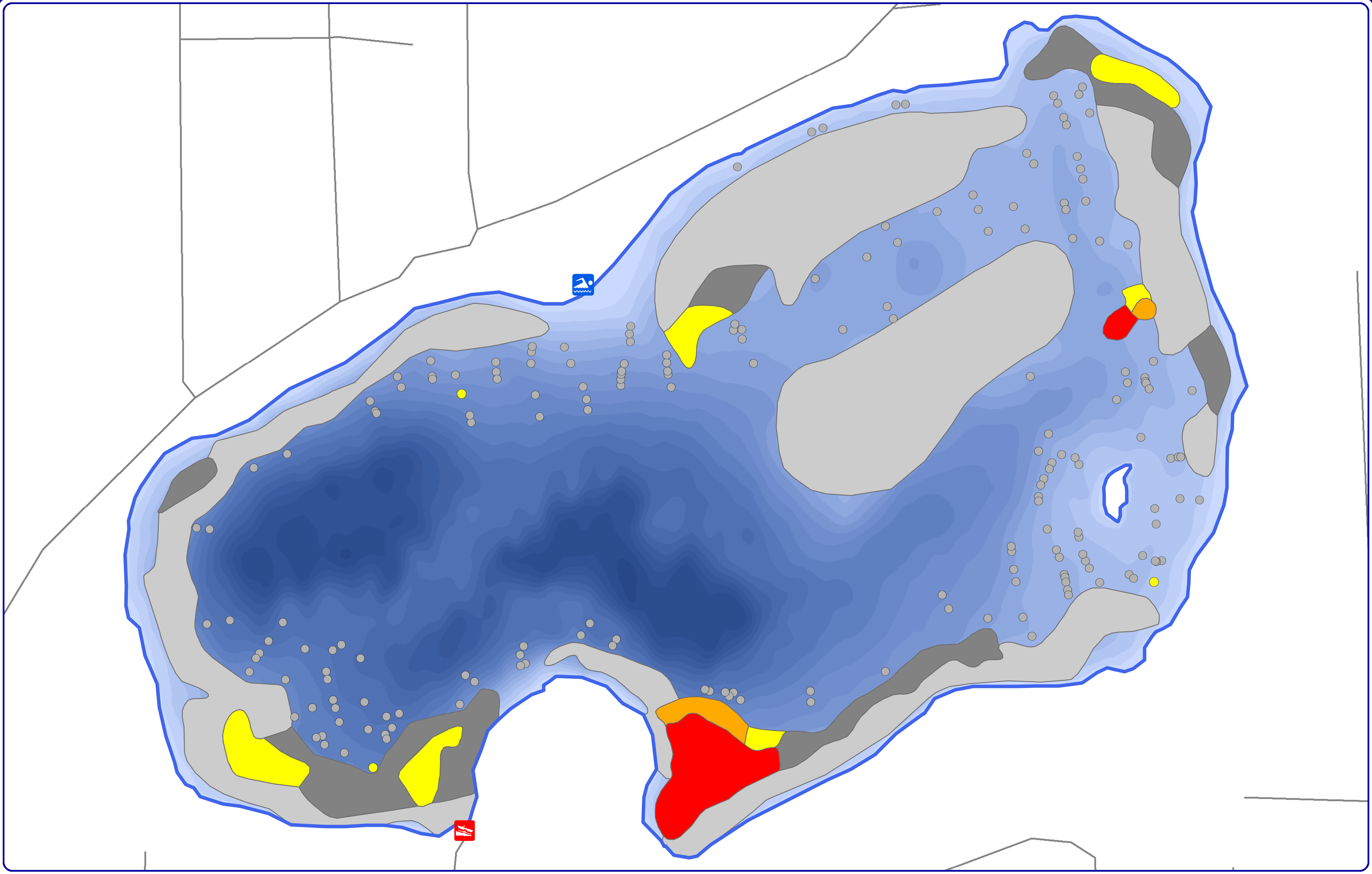


Project Location in Wisconsin

Legend

EWM Occurence From
Any Year Between 2008-2021

Map 9
Silver Lake
Vilas County, Wisconsin
2008-2021
EWM Footprint



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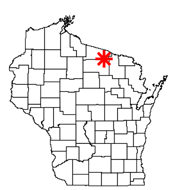
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Plant Survey: Onterra, 2022
Map Date: October 31, 2022 AMS/JMB



Project Location in Wisconsin

Legend

EWM Survey (September 19, 2022)

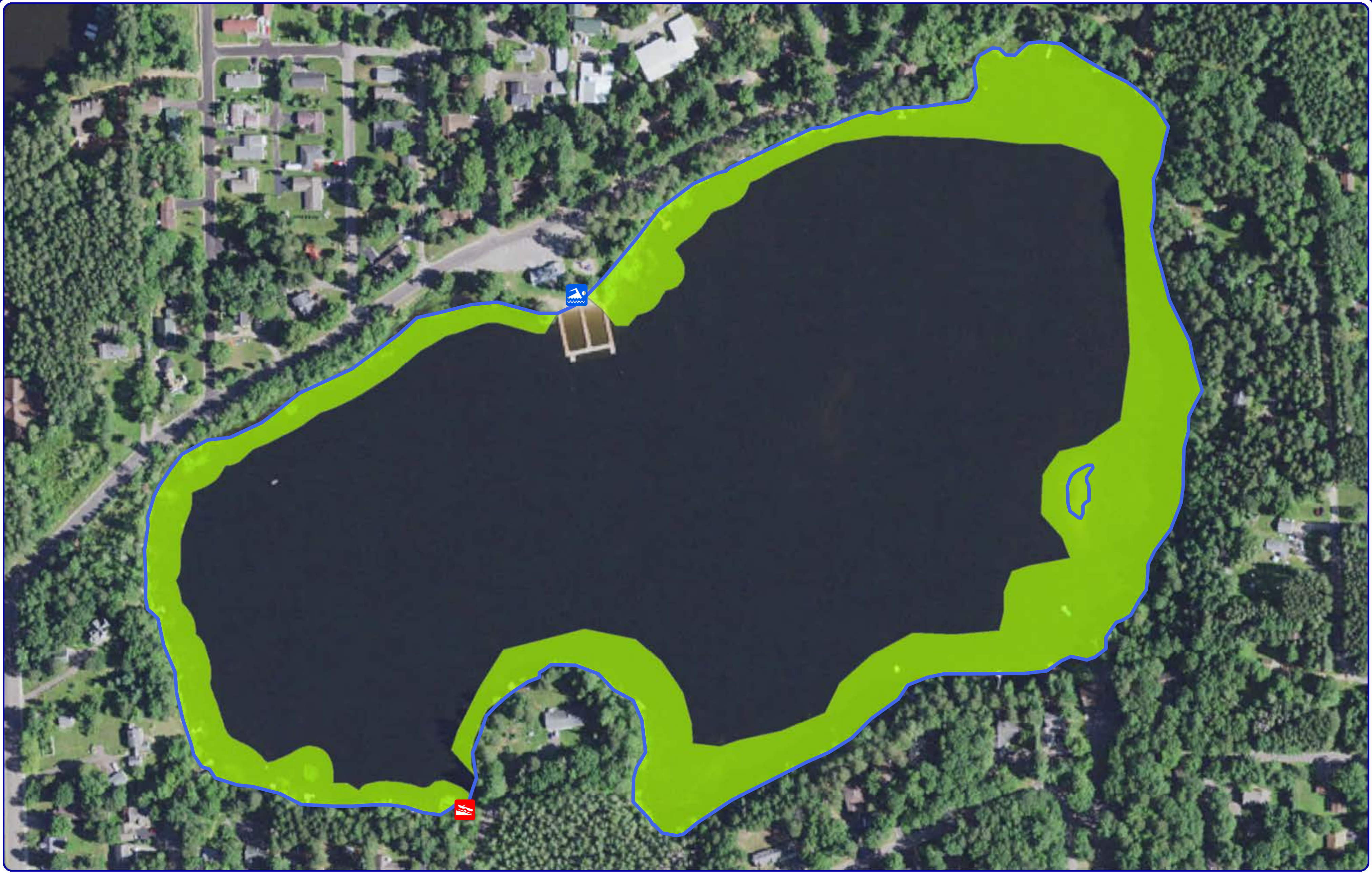
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Boat Landing
- Public Beach

Map 10

Silver Lake

Vilas County, Wisconsin

2022 Late-Season EWM Survey Results



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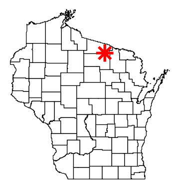
Sources:
Roads Hydro: WDNR
Bathymetry: Onterra, 2015
Aquatic Plants: Onterra, 2021
Map Date: April 11, 2022 TWH
Filename: Map11_SilverV_ASCI.mxd



Project Location in Wisconsin

Legend

Area of Special Conservation Interest (ASCI)

Map 11
Silver Lake
Vilas County, Wisconsin
Areas of Special Conservation Interest (ASCIs)