DRAFT

Shawano Lake

Shawano County, Wisconsin

Comprehensive Management Plan

June 2021

Official First Draft

Created by: Eddie Heath, Tim Hoyman, Todd Hanke, Heather Lutzow, Josephine Barlament
Onterra, LLC
De Pere, WI

Funded by: Shawano Area Waterways Management, Inc.
Wisconsin Dept. of Natural Resources
(AEPP-587-19)

Acknowledgements

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

Shawano Lake Planning Committee

Tim Day - Chair	Todd Dobberstein	Randy Kagerbauer
Bill Monfre	Paul Seidenstricker	Ken VanDenPlas
Dave Zelinger		

DRAFT

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOGRAPHS

MAPS

APPENDICES

1.0 INTRODUCTION

According to the 1974 recording sonar WDNR Lake Survey Map, Shawano Lake is 6,062.7 acres. The WDNR website lists the lake as 6,215 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2018. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 6,258.3 acres. Shawano Lake, Shawano County, is a shallow lowland drainage lake with a maximum depth of 39.5 feet and a mean depth of 9 feet. This eutrophic lake has a relatively small watershed when compared to the size of the lake. Approximately 47 native plant species have been documented within and along the margins of Shawano Lake, of which wild celery is the most common plant. Five exotic plant species are known to exist in Shawano Lake.

Field Survey Notes

The crews always enjoy going to Shawano Lake. The terns around the island, the rafts of scaup, and the occasssional pelican break up the day.

Photograph 1.0-1 Shawano Lake, Shawano County

Lake at a Glance - Shawano Lake

Morphology	
Acreage	6,258.3
Maximum Depth (ft)	39.5
Mean Depth (ft)	9
Shoreline Complexity	3.6
Vegetation	
Number of Native Species	
Threatened/Special Concern Species	American shoreweed, square-stem spikerush
Exotic Plant Species	Hybrid/Eurasian watermilfoil, curly-leaf pondweed, purple loosestrife, reed canary grass, giant reed
Simpson's Diversity	0.92
Average Conservatism	6.5
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.53
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	7:1

There is an abundance of public access to Shawano Lake with 8 public boat landings, 14 walk-in access sites, and combined parking for 250+ vehicle-trailers units; which is why it is listed on the WDNR's super spreader list. Two of the landings offer flush toilets, Huckleberry Harbor offers a fishing pier and picnic area, while the county park supports a public swimming beach (with lifeguards) and two boat power washing stations that traffic that uses the landing are forced past on entry and exit (Map 1). The public also utilizes Shawano Lake through the 19 resorts/rentals properties, 5 campgrounds, and the numerous fishing tournaments that occur on it. In the past year, Shawano Lake hosted 12 permitted fishing tournaments during the ice and open-water seasons.

Shawano Lake is classified as an Area of Special Natural Resource Interest (ASNRI) by the WDNR. Several areas of the lake are listed as sensitive, Public Rights Features and a Sensitive Area Designation has been completed on the lake (Map 8). The Natural Heritage Inventory lists several fish and mussel species, and 2 state-threatened turtles (Wood and Blanding's) from Shawano Lake. Also present is square-stem spike-rush, which is listed as endangered/critically imperiled, and American shoreweed, which is listed as a special concern.

The Shawano Area Waterways Management (SAWM) has been a non-profit organization in existence for approximately 35 years, representing the geographic area outlined on their logo (Figure 1.0-1). Membership consists of concerned property owners and stakeholders of the Shawano Waterways and surrounding area. SAWM's vision is as follows:

Figure 1.0-1. SAWM Logo

Caring for Shawano Waterways Now and for Generations

Assure long term positive ecological improvement in the entire lake and contiguous waterways. Restore / protect / maintain the chemical, biological and physical integrity of Shawano Waterways.

SAWM's areas of focus are; education, native and invasive plant management, water clarity and quality, fisheries, natural vegetation along shoreline, recreation / navigation.

Shawano Lake and its watershed have been studied since 1991 when the Shawano Lake Property Owners Association (SLPOA) was awarded the first of many Wisconsin Department of Natural Resources (WDNR) Grants. This was the first phase in a three-phase management planning project to assess the lake's water quality, watershed, aquatic plant community, and stakeholder perceptions. In 2003, the second of the lake's multi-phase assessment projects began with watershed tributary and in-lake water quality monitoring, aquatic plant assessments, and capacity building and management planning exercises. These studies were completed in 2006.

More intense studies of the lake's nutrient budget were led by the University of Wisconsin-Stevens Point Center for Watershed Science and Education, the results of which were presented in a final report produced in 2008. In 2009, results of the studies described above were used to create the Shawano Lakehed Strategic Management Plan and the Shawano Lake Aquatic Plant Management Plan.

Through 2013, SAWM has been conducting aquatic plant control on Shawano Lake as outlined in the 2009 Aquatic Plant Management Plan, including limited use of an association-owned harvester and nuisance herbicide applications by an association-employed applicator. In 2014, the WDNR requested a more precise plan that gives comprehensive guidance on controlling exotics, in addition to the natives, using both chemical and harvesting techniques. SAWM was also seeking to discover ways to protect the native aquatic plant community by controlling exotics on a lake-wide scale.

In April 2014, SAWM updated its management plan as it relates to aquatic plant management. The Implementation Plan Section (4.0) of the 2014 APM Plan included the following management goals and associated management actions:

Goal #1: Control current Eurasian water milfoil population within Shawano Lake

a. Conduct [and monitor] trial treatment on Shawano Lake (2014)
b. Gain stakeholder input regarding a whole-lake EWM treatment on Shawano Lake (2015)
c. Conduct whole-lake herbicide treatment on Shawano Lake (2016 or later)

Goal #2: Prevent additional AIS from entering Shawano Lake, and prevent AIS from Shawano Lake from infecting other lakes

a. Continue Clean Boats Clean Waters watercraft inspections at Shawano Lake public access locations (continuation of current effort)

Goal # 3: Maintain Navigability on Shawano Lake

a. Support responsible actions to gain reasonable navigational access to open water areas of Shawano Lake (ongoing effort)

In 2016, a whole-lake 2,4-D herbicide treatment was conducted with positive short-term results. Commencing in the spring of 2019, SAWM entered into a project aimed at updating all aspects of their plan into a single Comprehensive Management Plan. The studies included in this project would document the present state of the native and exotic plant populations, compare them to previous occurrences, and use this information to develop a plan for future management of the system. Additionally, SAWM would like to examine their lake in a holistic manner, understanding the ecosystem and better protecting it from future threats by completing assessments of the lake's water quality and watershed as well. Shoreland and fish habitat assessment results educate riparian property owners about healthy shorelines and how they may be able to improve their property through Best Management Practices and/or habitat improvements.

The Summary and Conclusions Section (4.0) provide a succinct overview of the health of Shawano Lake (Click Here).

2.0 STAKEHOLDER PARTICIPATION

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

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

Planning Committee Meeting I

On October 15, 2020, Eddie Heath of Onterra met virtually with the SAWM Planning Committee for nearly 4 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. Study components including AIS survey results, aquatic plant inventories, water quality analysis, watershed modeling, and shoreland assessment results were presented and discussed.

Planning Committee Meeting – focus on Seawalls & Mechanical Harvesting

On November 18, 2020, Eddie Heath of Onterra met virtually with a subset of the SAWM Planning Committee for approximately 2 hours. The majority of the meeting dealt with seawalls and shoreline habitat issues, move on to discussing historic mechanical harvesting activities, and gained momentum discussing overall lake planning activities.

Planning Committee Meeting II

On January 11, 2021, Eddie Heath of Onterra met virtually with the SAWM Planning Committee for over 2 hours. The focus of this meeting was to develop management goals and associated management actions to serve as the Implementation Plan Section (5.0).

Planning Committee Meeting III

Based upon the discussion from previous planning meetings, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee. Written comments were provided back to Onterra. In addition, the Planning Committee met virtually on April 13, 2021 for over 2 hours methodically going through each management action contained within the draft Implementation Plan Section (5.0).

Management Plan Review and Adoption Process

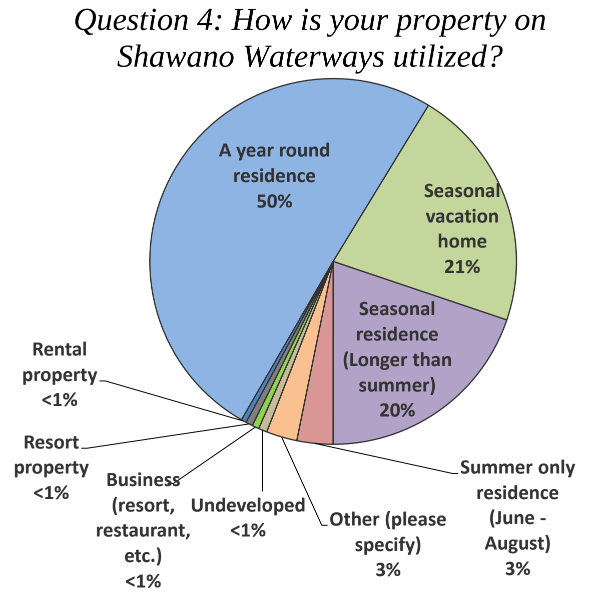
On May 13, 2021, an early draft of the complete Comprehensive Management Plan was provided to the SAWM Planning Committee and SAWM Board of Directors for review. Comments were aggregated by the SAWM Planning Committee Chair and provided to Onterra. These comments were addressed to result in a Pre-Official First Draft for review and acceptance by the Board of Directors. The board accepted the plan on June 22, 2021.

On June 25, 2021, the Official First Draft of the SAWM's Comprehensive Management Plan for Shawano Lake was supplied to WDNR (lakes and fisheries programs), Shawano County, WAMSCO, and NE WI Hydro as well as being made available electronically to all SAWM stakeholders.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners/renters/SAWM members around Shawano Lake. The survey was designed by Onterra staff and the SAWM planning committee and reviewed by a WDNR social scientist. During February 2020, the nine-page, 41-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner 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. Fifty-three percent of the surveys were returned. 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 below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Shawano Lake. About half of stakeholder respondents (50%) live on the lake as a year-round residence, while 21% visit as a seasonal vacation home, 20% are seasonal residents (longer than summer), 3% are summer only residents, and <1% are undeveloped properties. 52% of stakeholder respondents have owned their property for over 15 years, and 30% have owned their property for over 25 years (Figure 2.0-1). Just under 75% of respondents indicate they live on Shawano Lake proper, with the remaining respondents split between living on the channel or on the Wolf River (Question #1, Appendix B).



Question 5: How many days each year is your property used by you or others?

Category (# of days)	Responses
Less than 50 days per year	94
50 to 100 days per year	137
101 to 200 days per year	124
More than 200 days per year	296

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

Relaxing/entertaining was the highest ranked activities when riparians were asked why the own property on Shawano Lake (Figure 2.0-2). Riparian respondents also ranked *motor boating* and *open water fishing* as reasons they choose to be a Shawano Lake riparian.

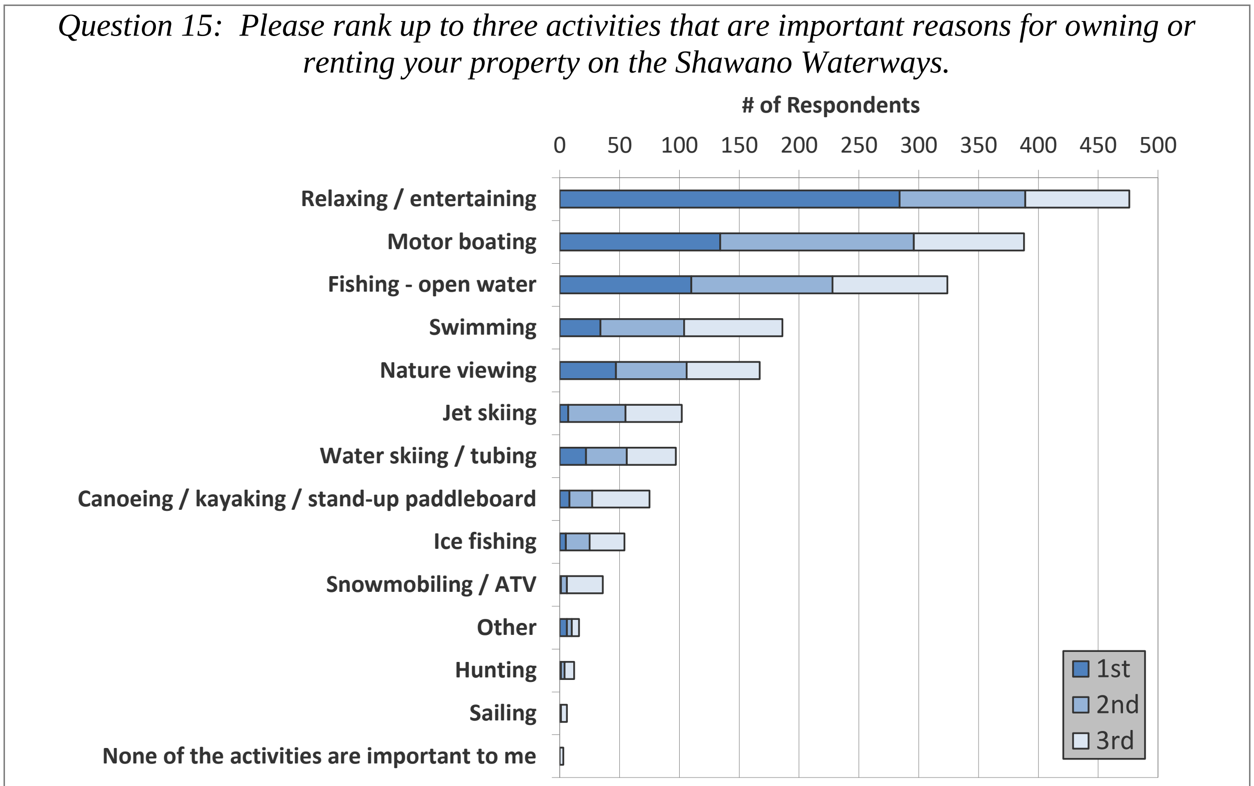


Figure 2.0-2. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Approximately 70% of respondents indicate they use a pontoon boat on the Shawano Waterways and approximately 40% us a motor boat with a greater than 25 horse power motor (Figure 2.0-2). On a large system such as Shawano Lake, some feel that the extra space minimizes the importance for responsible boating. *Excessive watercraft traffic* and *unsafe watercraft practices* ranked 6th and 7th, respectively, in the list of Shawano Lake stakeholder respondents' top concerns (Question #20, Appendix B).

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

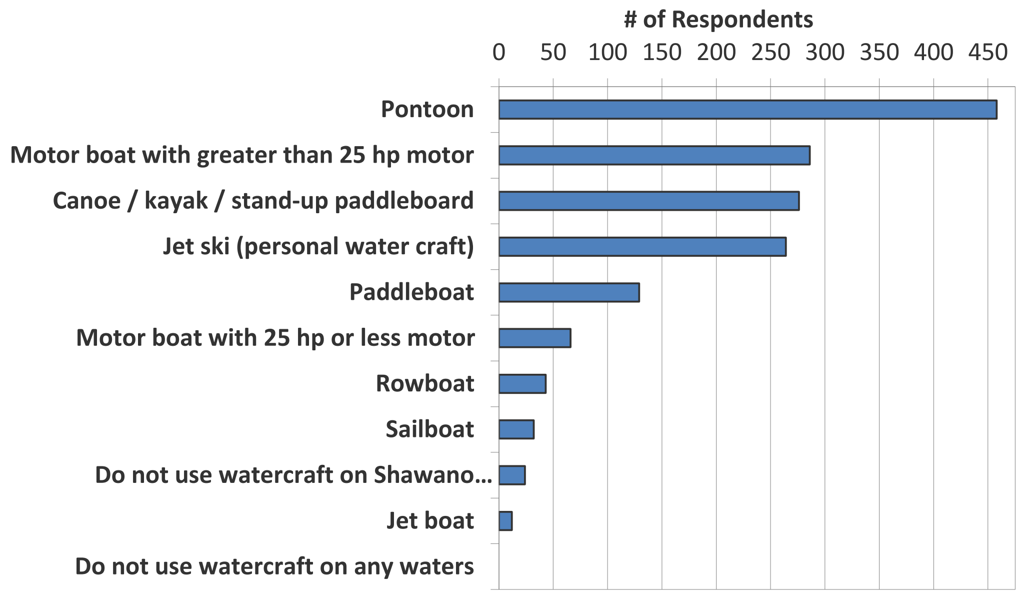


Figure 2.0-3. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

A concern of stakeholder respondents noted throughout the stakeholder survey (Appendix B) were water levels and vegetation management in Shawano Lake. These topics are touched upon in the Aquatic Plants Section (3.5), Summary & Conclusions (4.0) as well as within the Implementation Plan Section (5.0).

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics.

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 Shawano Lake is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the Shawano Lake water quality analysis:

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrants (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a 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 macrophytes within the lake. This is analogous to baking a cake that requires four eggs, and four cups each of water, flour, and sugar. If the baker would like to make four cakes, he needs 16 of each ingredient. If he is short two eggs, he will only be able to make three cakes even if he has sufficient amounts of the other ingredients. In this scenario, the eggs are the limiting nutrient (ingredient).

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading*

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of the phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2019) 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 Shawano Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

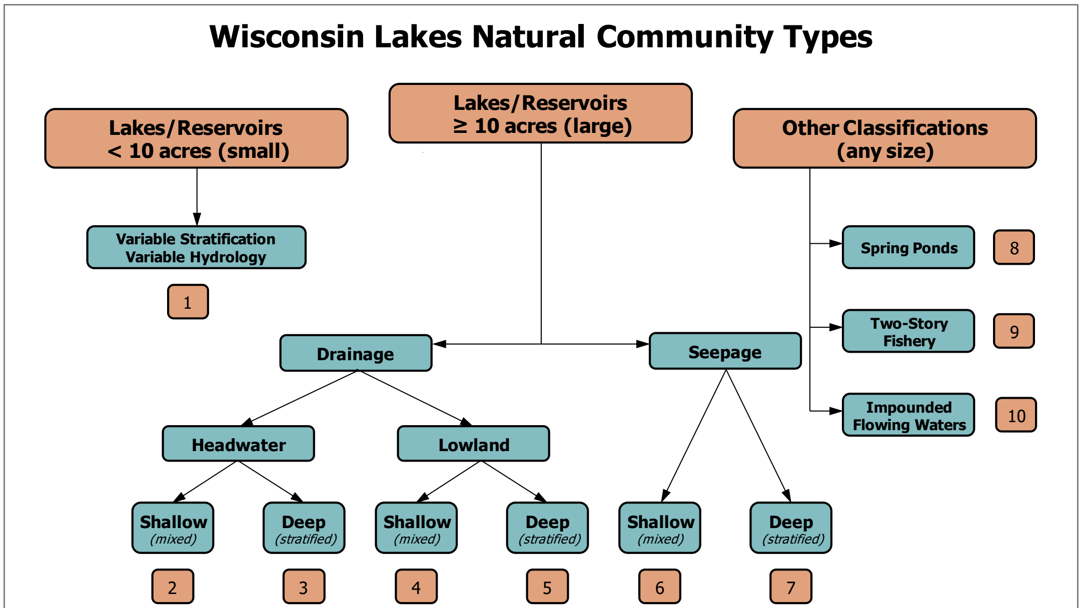


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

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 and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

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

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

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

Because of its depth, relatively small watershed and hydrology, Shawano Lake is classified as a shallow lowland drainage lake (SLDL, category 4 on Figure 3.1-1).

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. Shawano Lake is within the North Central Hardwood Forests (NCHF) ecoregion.

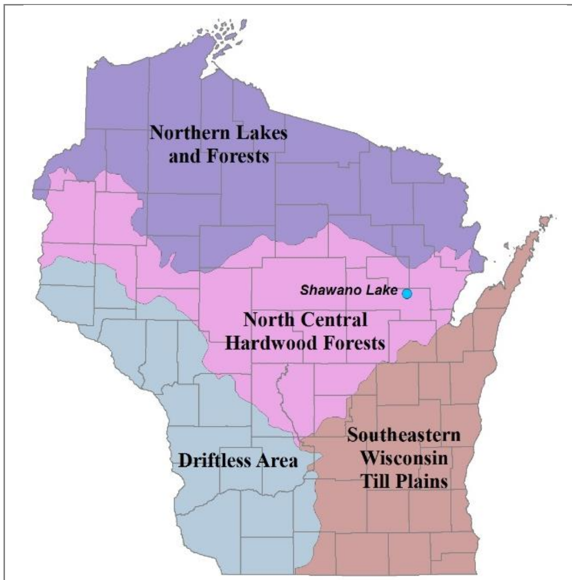


Figure 3.1-2. Location of Shawano Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2020 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, historic, current, and average data from Shawano Lake is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Shawano Lake Water Levels

Eagle Creek Renewable Energy owns and operates a hydroelectric facility on the Wolf River. The Eagle Creek Dam forms Wolf River Pond. The outflow to Shawano Lake connects with this pond and since the topography is so flat, the dam controls the lake level. The water level at the dam is regulated by Federal Energy Regulatory Commission (FERC) which has set the level at 802.5 feet mean sea level (MSL) since 2015. However, SAWM and other entities believe the lake historically operated during ice-free months at 802.9 feet (MSL).

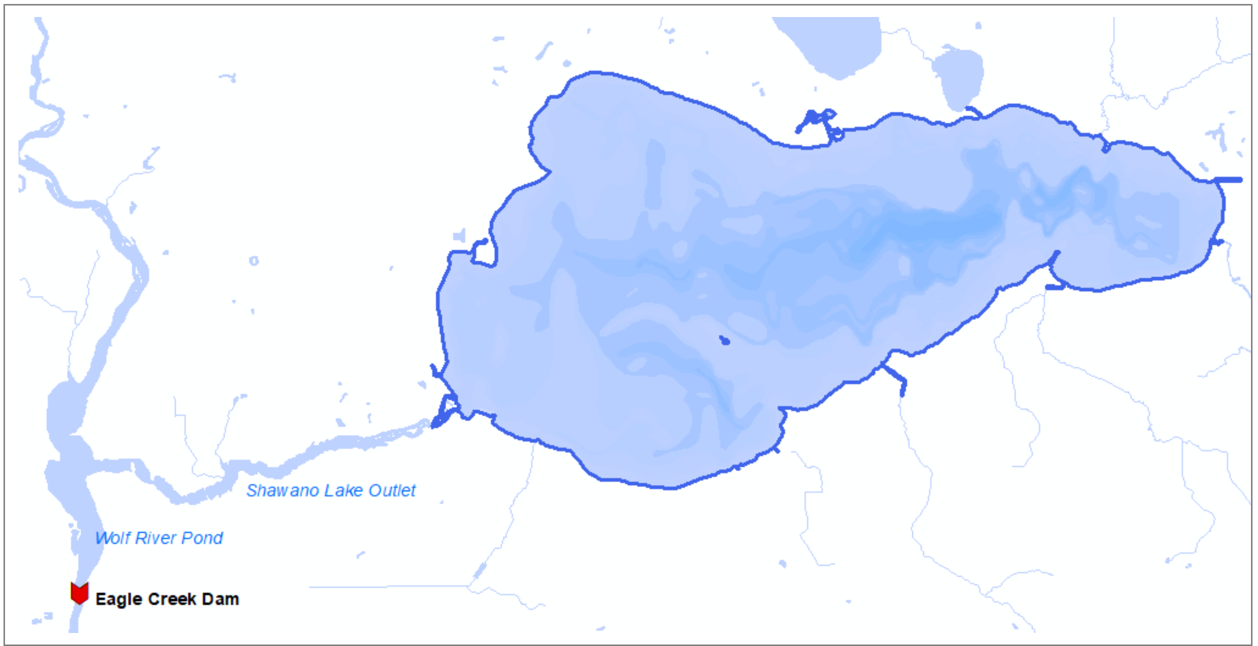


Figure 3.1-3. Eagle Creek Dam. Impounds the Wolf River Pond (1139), Shawano Lake Outlet, and Shawano Lake.

Complaints followed from Shawano Waterway users citing safety and navigational issues as a result of the lower water level on the river, channel and Shawano Lake. FERC has granted temporary variances to allow the dam to target the higher water level during the boating season every year since 2015 but a permanent order allowing the higher historical target level year-round has not yet been finalized. As a part of this management planning project, SAWM solicited riparian preferences on whether they prefer the water to be targeted at the higher, historical level year-round or at the 5-inch lower level year-round. Stakeholder survey respondents overwhelmingly preferred the water to be at the higher level (Figure 3.1-4).

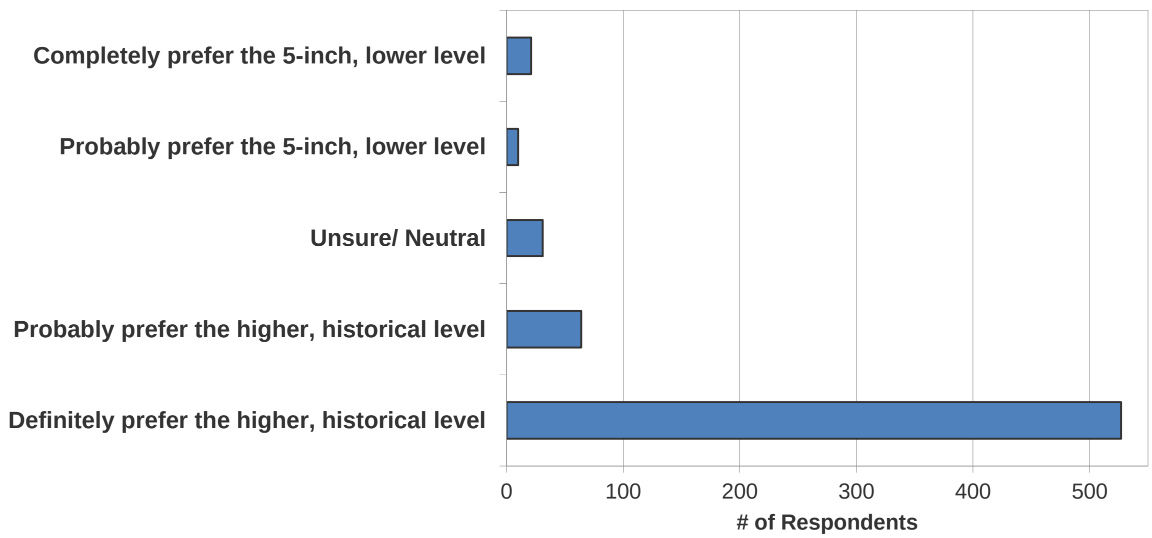


Figure 3.1-4. Stakeholder survey response Question #21. Please tell us if you prefer the water to be targeted at the higher, historical level year-round or at the 5-inch lower level year-round.

Shawano Lake Water Quality Analysis

Shawano Lake Long-term Trends

Total Phosphorus

Near-surface total phosphorus data from Shawano Lake are available annually from 1999 to 2019 (Figure 3.1-5). The weighted summer average total phosphorus concentration is 37.4 µg/L, which falls into the *good* category for Wisconsin's shallow lowland drainage lakes. The lake's weighted summer average total phosphorus concentration is slightly greater than the median value for other shallow lowland drainage lakes in the state and less than the median value for all lake types within the NCHF ecoregion.

The summer mean phosphorus concentration in 2013 was considerably higher than any of the other years with a value of 123 µg/L. This value was so high based upon a reported value of 222 µg/L on July 18, 2013. The May, August, and September phosphorus concentrations were much lower being 25-30 µg/L. It is not clear if this value is correct but the following day the dissolved oxygen in the surface waters of the lake was 3.6 mg/L. While it is unknown if the phosphorus value is correct, the low oxygen concentration suggests that something unusual occurred in the lake. There is not a chlorophyll-*a* sample for that date but the Secchi disc depth was only slightly less than other dates in July.

As discussed in the primer section, internal nutrient loading is a process by which phosphorus (and other nutrients) are released from sediments when bottom waters become devoid of oxygen (anoxic). Internal nutrient loading is more prevalent in deeper lakes which experience summer stratification or in shallow lakes that are highly productive where high rates of decomposition deplete oxygen near the sediment-water interface. Often as lakes become more productive over time, internal nutrient loading increases. In certain instances, this sediment-released phosphorus can be mobilized to surface waters during the summer where it can fuel nuisance algal blooms. Lake managers often try and determine if internal nutrient loading is a significant source of phosphorus in a lake, particularly when an increasing trend in phosphorus is observed. Phosphorus data is only available for one date during the summer. However, the bottom waters were often devoid of oxygen in July and August, suggesting that some phosphorus likely is released from the sediments. In a polymictic lake like Shawano Lake this phosphorus can soon become available for algal growth when the lake subsequently mixes.

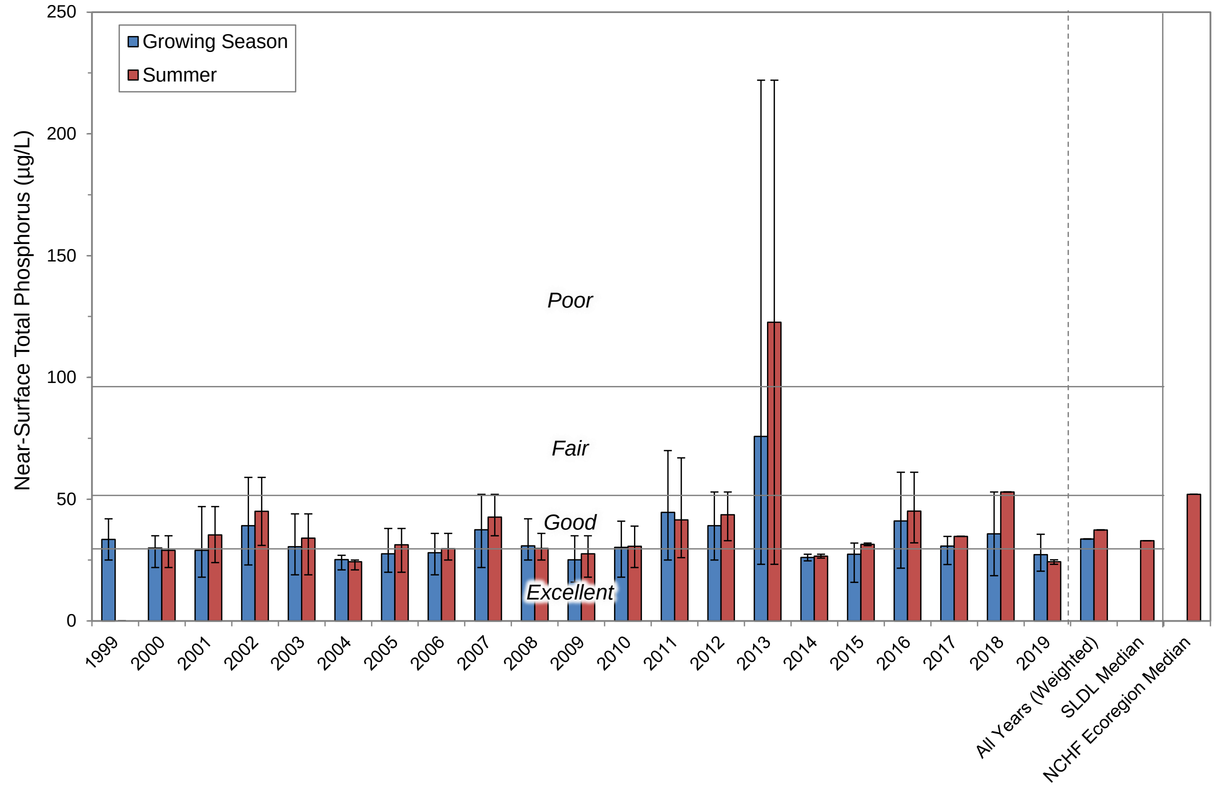


Figure 3.1-5. Shawano Lake, state-wide class 4 (SLDL) lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* samples are available for the same time period as total phosphorus, that is 1999-2019 (Figure 3.1-6). The weighted summer average chlorophyll-*a* concentration is 12.5 µg/L, which falls into the *good* category for Wisconsin's shallow lowland drainage lakes. The lake's weighted summer average chlorophyll-*a* concentration is greater than the median value for other shallow lowland drainage lakes in the state and less than the median value for all lake types within the NCHF ecoregion.

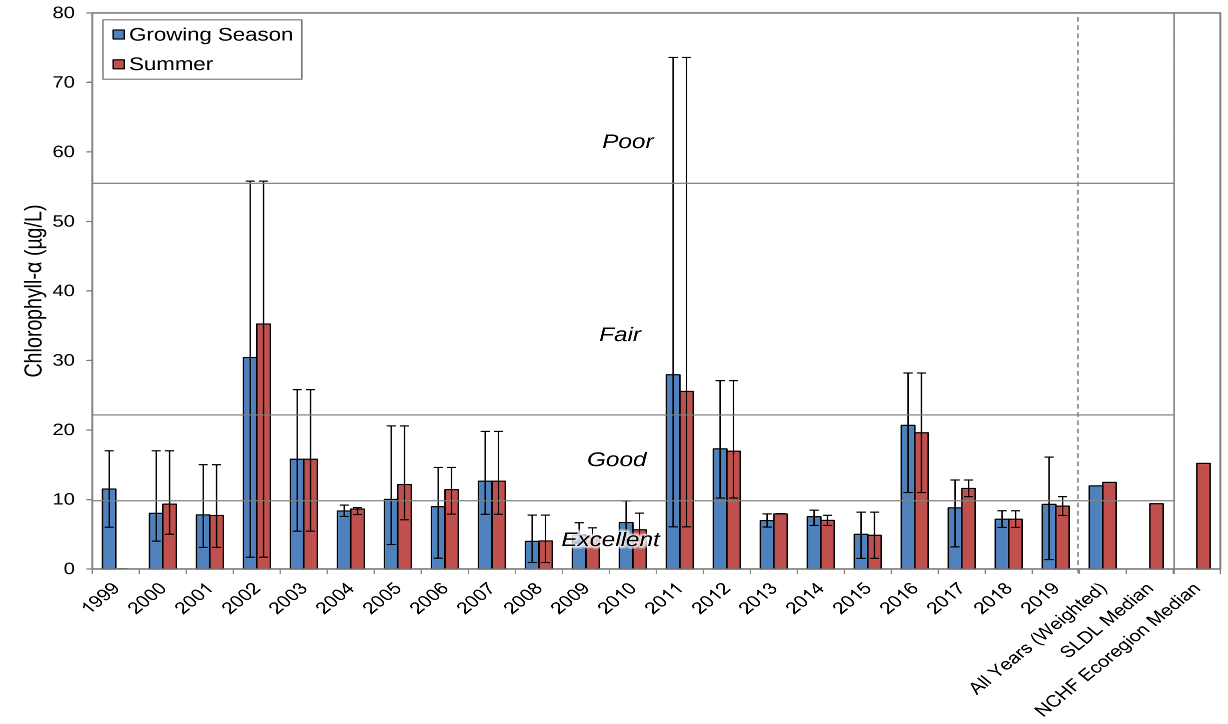


Figure 3.1-6. Shawano Lake, state-wide class 4 (SLDL), and regional chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

There is a longer record of Secchi disc clarity than for either total phosphorus or chlorophyll-*a*. Data is available for 1988 and then continuously for 1993 through 2019 (Figure 3.1-7). The weighted summer average Secchi disc clarity is 7.1 feet, which falls into the *excellent* category for Wisconsin's shallow lowland drainage lakes. The lake's weighted summer average Secchi disc clarity is greater than the median value for other shallow lowland drainage lakes in the state and the median value for all lake types within the NCHF ecoregion.

A few years of higher water clarity were observed in 1997-1999 and again in 2009-2010, and lower water clarity in 1988, 1996, 2002-2003, 2012, and 2016. Trend analysis of the summer Secchi disc ratings indicates that water clarity fluctuates from year to year, but not statically valid increases or decreases have been documented.

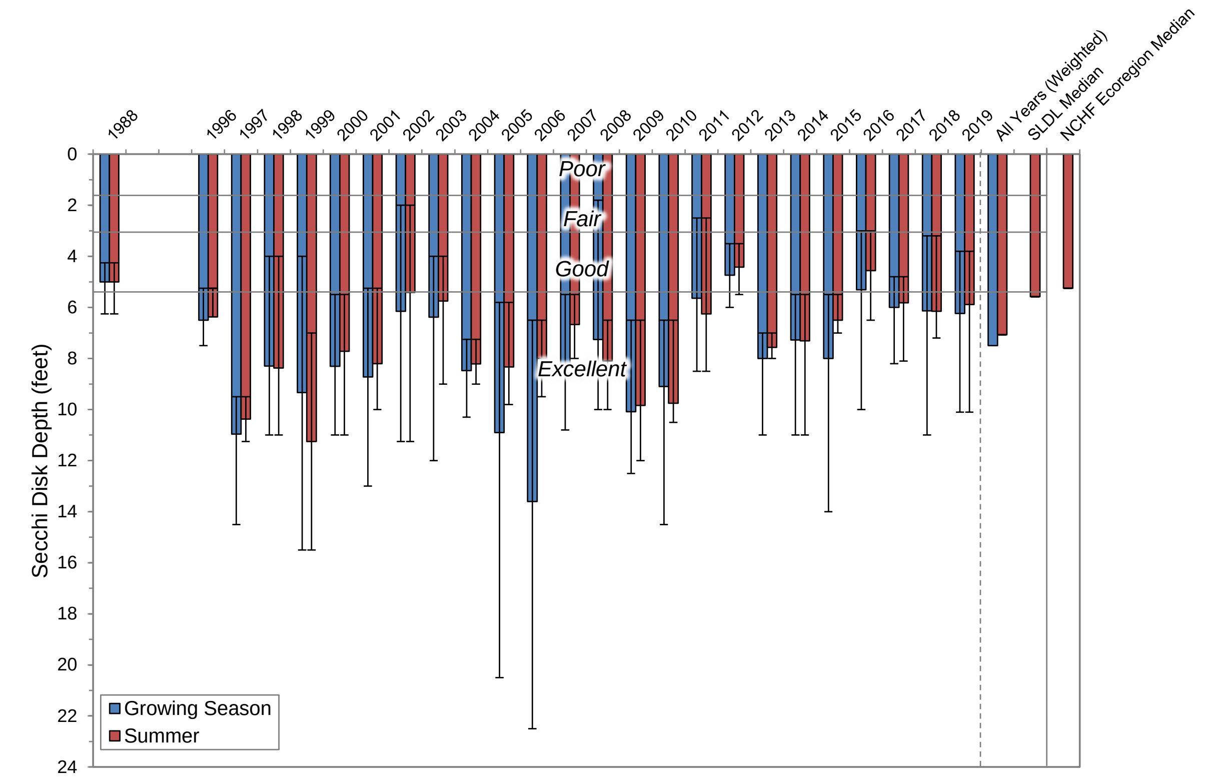


Figure 3.1-7. Shawano Lake, state-wide class 4 (SLDL), and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

The above described trophic parameters change seasonally in Shawano Lake. As will be discussed further in the aquatic vegetation and watershed sections, the lake contains a large population of curly leaf pondweed. This plant dies in late June to July. When this occurs a significant amount of phosphorus is released from the plants. This phosphorus remains in the upper waters of the lake and fuels algal growth. Figure 3.1-8 shows the average monthly concentrations of the three trophic variables. Phosphorus and water clarity improve in May after the spring algal bloom but phosphorus and chlorophyll-*a* increase in July and August in response, in part, to the die off of curly leaf pondweed. As discussed above, there may also be some additional internal loading during anoxic conditions in the bottom waters.

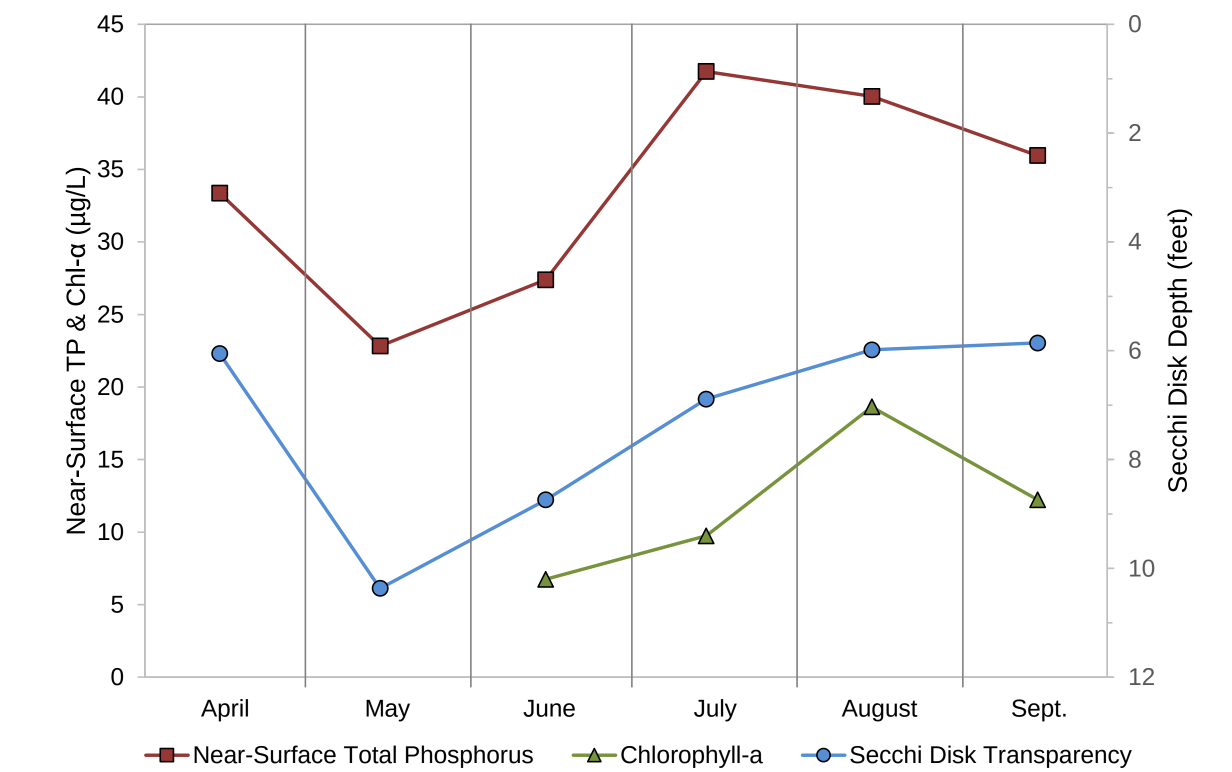


Figure 3.1-8. Seasonal trends of the three trophic variables in Shawano Lake. Phosphorus and chlorophyll-*a* are highest and Secchi disc depth the lowest in July and August in response to phosphorus being released when curly leaf pondweed dies.

Limiting Plant Nutrient of Shawano Lake

Using midsummer nitrogen and phosphorus concentrations from Shawano Lake, a nitrogen:phosphorus ratio of 28:1 was calculated. This finding indicates that Shawano Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Shawano Lake Trophic State

Figure 3.1-9 contain the TSI values for Shawano Lake. The TSI values calculated with Secchi disk clarity, chlorophyll-*a*, and total phosphorus values range in values spanning from mesotrophic to eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Shawano Lake is in a eutrophic state.

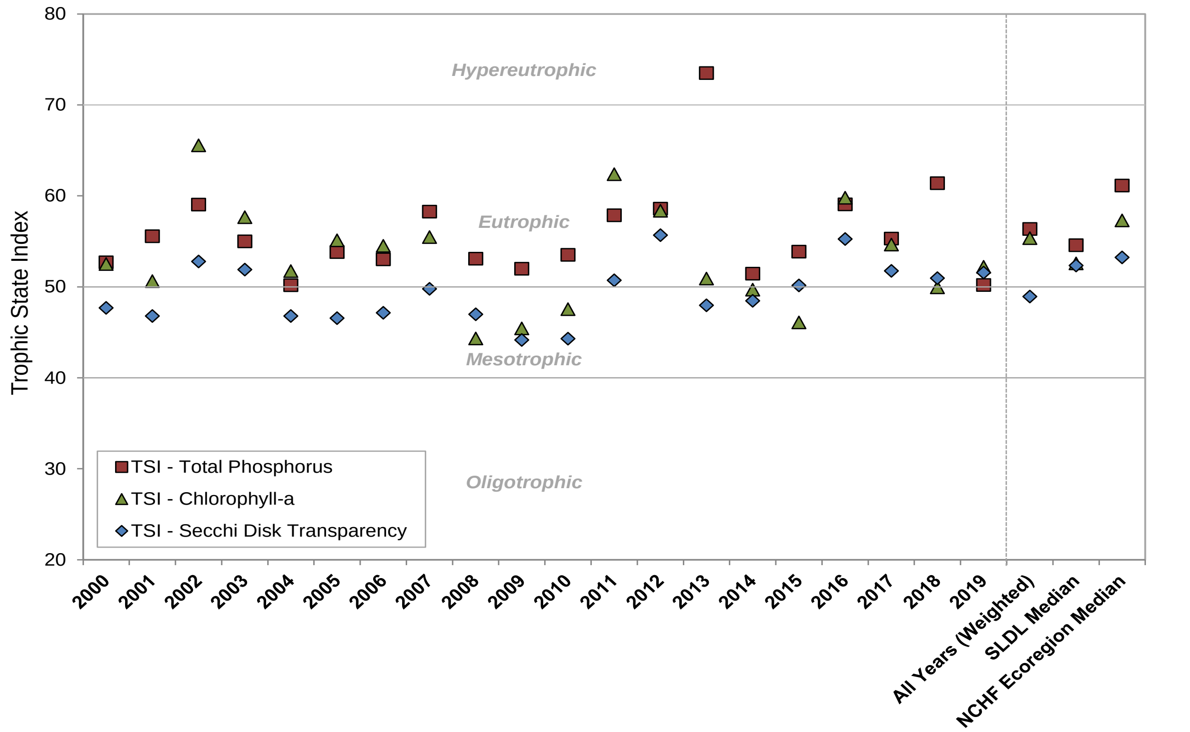


Figure 3.1-9. Shawano Lake, state-wide class 4 (SLDL), and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Shawano Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Shawano Lake by Onterra staff in 2019 but also by WDNR staff and Citizen Lake Volunteers in earlier years. Profiles depicting these data for the summer of 2017 and the growing season of 2019 are displayed in Figure 3.1-10.

Shawano Lake is *polymictic*, meaning the lake periodically mixes during the ice free period. Although in 2017 the lake appears to be stratified throughout the summer, a close examination of the temperature profiles show that temperatures in the bottom waters increased throughout the summer which indicates the lake mixed between the sampling dates. This is common in larger, moderately shallow lakes like Shawano Lake. Also in August 2017, only the bottom 2 feet were anoxic while in July the bottom 10 feet was devoid of dissolved oxygen. This is why the lake is classified as a shallow lake even though the maximum depth is nearly 40 feet. In 2019 the lake was completely mixed in April and October but weakly stratified in mid-July.

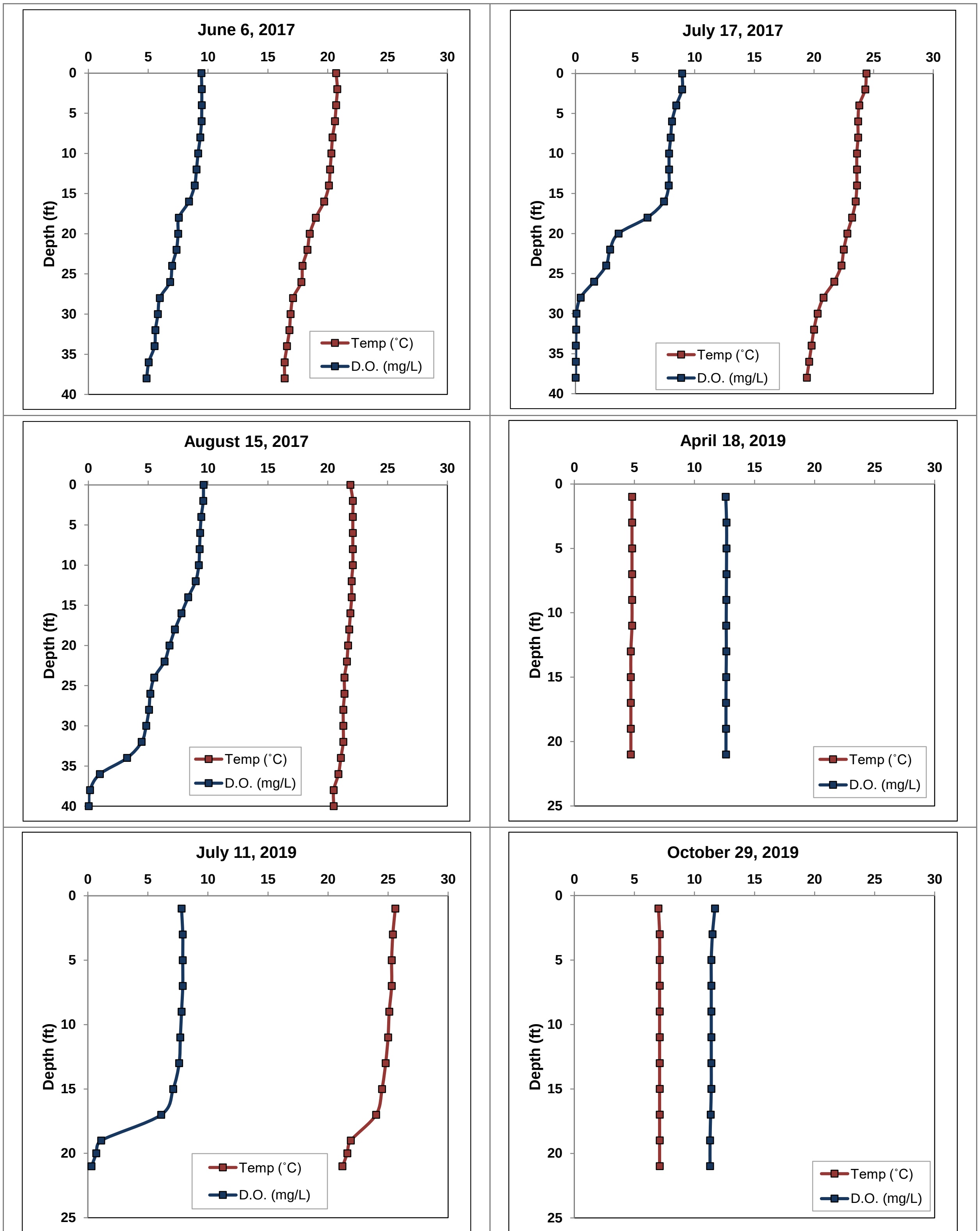


Figure 3.1-10. Shawano Lake dissolved oxygen and temperature profiles from the summer of 2017 and the growing season in 2019.

Additional Water Quality Data Collected at Shawano Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The mid-summer pH of the water in Shawano Lake was found to be alkaline with a value of 8.5 which is at the upper range for Wisconsin Lakes (Figure 3.1-11). This value is not abnormally high, especially with the summer algal blooms that occur in the lake.

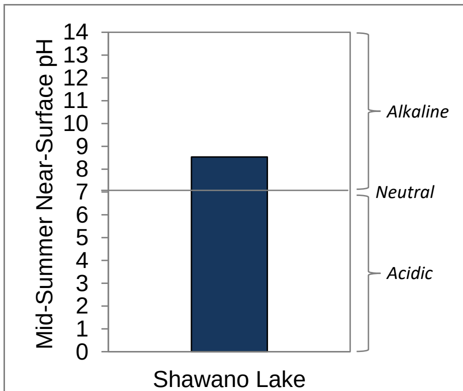


Figure 3.1-11. Shawano Lake mid-summer near-surface pH value.

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 ($CaMgCO_3$). 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 alkalinity in Shawano Lake was 110 mg/L (mg/L as $CaCO_3$), indicating that the lake has no sensitivity to lower pH values from acid rain (Figure 3.1-12).

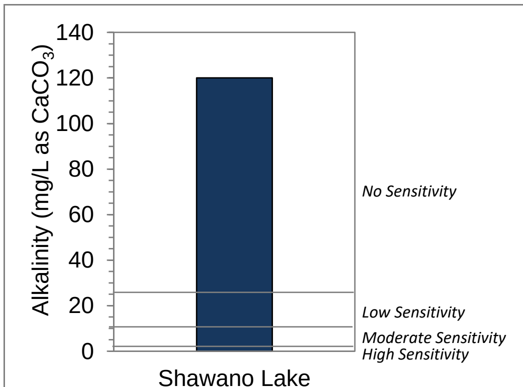


Figure 3.1-12. Shawano Lake mid-summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 Shawano Lake's pH of 8.6 within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Shawano Lake was found to be 29 mg/L, which in part explains why the lake has a population of zebra mussels (Figure 3.1-13).

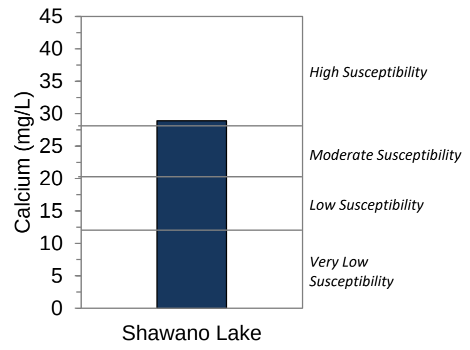


Figure 3.1-13. Shawano Lake mid-summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Zebra mussels (*Dreissena polymorpha*) are small bottom dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring. Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days.

A measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured at 15 SU (standard units) in April and 10 SU in July of 2019 (Figure 3.1-14), indicating the lake's water was on the border between *slightly tea-colored* and *clear* in 2019. For comparison, upstream Loon Lake's true color was 60 SU (standard units) during the summer of 2016 indicating the lake's water is *tea colored* and that the lake's water clarity is primarily influenced by dissolved components in the water.

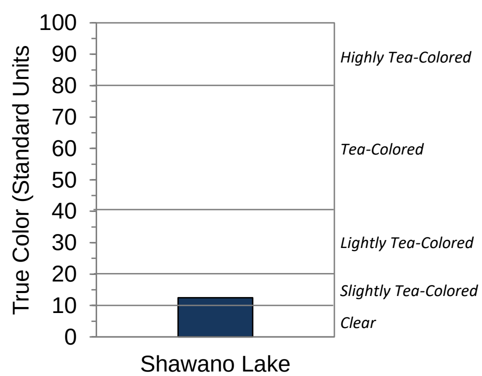


Figure 3.1-14. Shawano Lake 2019 average near-surface true color values during mid-summer.

Stakeholder Survey Responses to Shawano 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. Figures 3.1-15 and 3.1-16 display the responses of members of Shawano Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Shawano Lake. Respondents generally indicate the water quality is *fair* and has become *somewhat degraded* since they first visited the lake

Question 16: How would you describe the current water quality of Shawano Waterways?

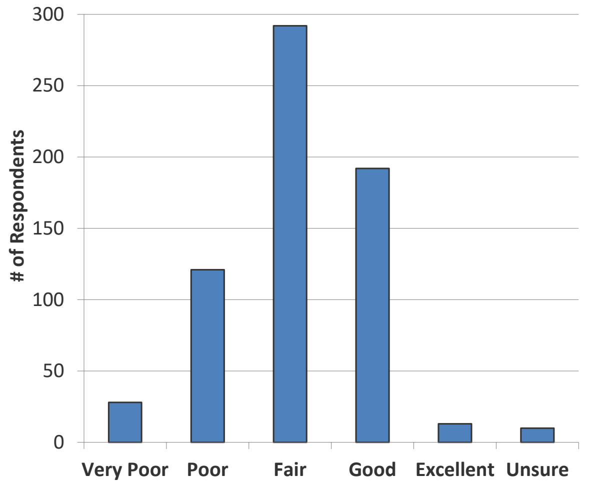


Figure 3.1-15. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: How as the water quality changed in Shawano Lake since you first visited the lake?

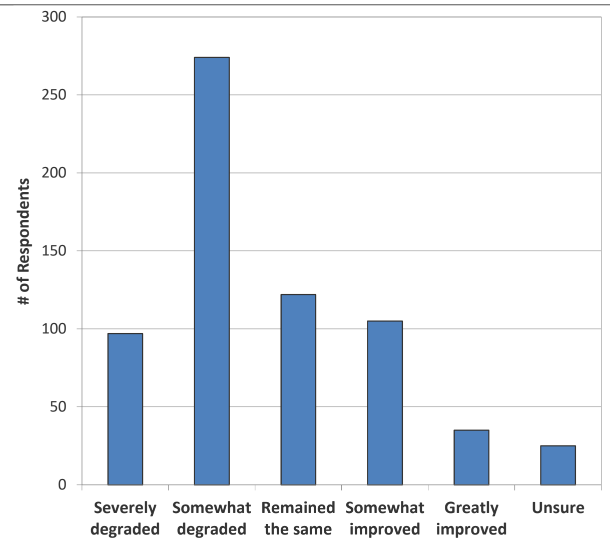


Figure 3.1-16. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The majority of respondents indicated aquatic plant growth was what they thought of when describing water quality. Aquatic plant growth can affect and be affected by water quality, but is not a water quality metric. Water clarity was the second most common attribute respondents indicated factored into their description of water quality. On Shawano Lake, water clarity is *excellent* and although fluctuations are noted, no increasing or decreasing trends have been detected.

Question 18: Considering how you answered the questions above, what do you think of when describing water quality?

Answer Options	Response Percent	Response Count
Water clarity (clearness of water)	67.5%	445
Aquatic plant growth (not including algae blooms)	82.9%	546
Water color	27.3%	180
Algae blooms	56.3%	371
Smell	18.5%	122
Water level	52.4%	345
Fish kills	16.7%	110
Other (please specify)	7.0%	46
	answered question	**659**
	skipped question	**4**

Figure 3.1-17. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.2 Paleoecology

Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology, the examination of fossilized animals and plants and geochemical parameters to determine ecological conditions in the past, offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed.

The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

Nearly all natural lakes in Wisconsin were created as a result of the last glaciation period. Most Wisconsin lakes are 12,000 to 14,000 years old as this is when the glacial ice sheets melted and receded from the state. The exception to this are lakes along Lake Michigan like those found in Door County. These lakes are much younger, having been formed when the lake level of Lake Michigan dramatically dropped about 2,800 years ago. Although the newly formed lakes underwent significant ecological changes immediately after the recession of the glaciers, as the climate became warmer and drier, the last 150 years have generally seen the most dramatic changes to the lake's ecology due to the impacts from human settlement within their watersheds and along their shorelines.

Generally, Europeans began settling in Wisconsin after the 1830s in the southern part of the state and later in the northern part of the state. Early settlement largely consisted of subsistence farming in the lakes' watersheds which had minor but noticeable impacts on lake ecology. The greatest impact that settlement has caused to lakes occurred during the twentieth and twenty-first centuries. Often lakes with agriculture in their watersheds experienced significant degradation beginning in the 1940s and 1950s. Following World War II, mechanization improved allowing more land to be tilled. There was also an increased use of synthetic fertilizers to enhance production. Many of the factories that were used to produce ammunition for the war effort were converted to producing this fertilizer. The increased mechanization and use of fertilizers resulted in increased soil erosion from the land to the lakes as well as a large input of nutrients, e.g., phosphorus, that are attached to soil particles as well as associated with the fertilizer. Also, cow herd sizes increased, resulting in additional nutrients from manure. Since the 1970s, many parts of the state have experienced increased urbanization which has resulted in increased runoff from homes and streets into the lakes as well.

Shawano Lake Paleoecological Results

A sediment core was extracted from the deep area of Shawano Lake on October 1, 1991 by Tim Rasman of the Wisconsin Department of Natural Resources using SCUBA. The water depth was 40 feet and the core was 64 cm long. The core was sectioned on shore and returned to the DNR lab in Madison and analyzed by Paul Garrison of the Wisconsin DNR (Garrison 2020). The sediment core was analyzed for changes in the sedimentation rate during the last 150 years as well as changes in geochemical variables e.g., aluminum, phosphorus, organic matter. The core was also analyzed for remnants of algae in the form of chlorophyll and zooplankton fossils. Fossils of diatoms, which are a type of algae that contain shells made of silica, are usually very useful in reconstructing changes in the phosphorus concentration of the lake. Unfortunately, in Shawano Lake these fossils were not preserved in the sediments below the surface layer. Below is a summary of that report from the core collected in 1991.

It is important to note that this sediment core was collected nearly 30 years ago so the results do not reflect changes that have occurred in Shawano Lake since 1991. The average sedimentation rate (sediment infilling) in the deep area of the lake for the period 1831-1991 was 0.0255 g/cm2/yr which places the lake near the median of 59 lakes in Wisconsin where sediment cores have been dated. The lake's sedimentation rate began to increase around 1890 and peaked in the early twentieth century (Figure 3.2-1). This increase was likely the result of land clearing with the early settlement of the lake's watershed. Following this early development, the sedimentation rate declined to 0.020 g/cm2/yr which was near the background rate but again increased in the 1980s. The increase in the 1980s, likely was a result of increased development around the lake. Many lakes with substantial agriculture in their watershed experienced increased sedimentation following World War II with the development of larger and more powerful tractors. This increased sedimentation did not occur in Shawano Lake.

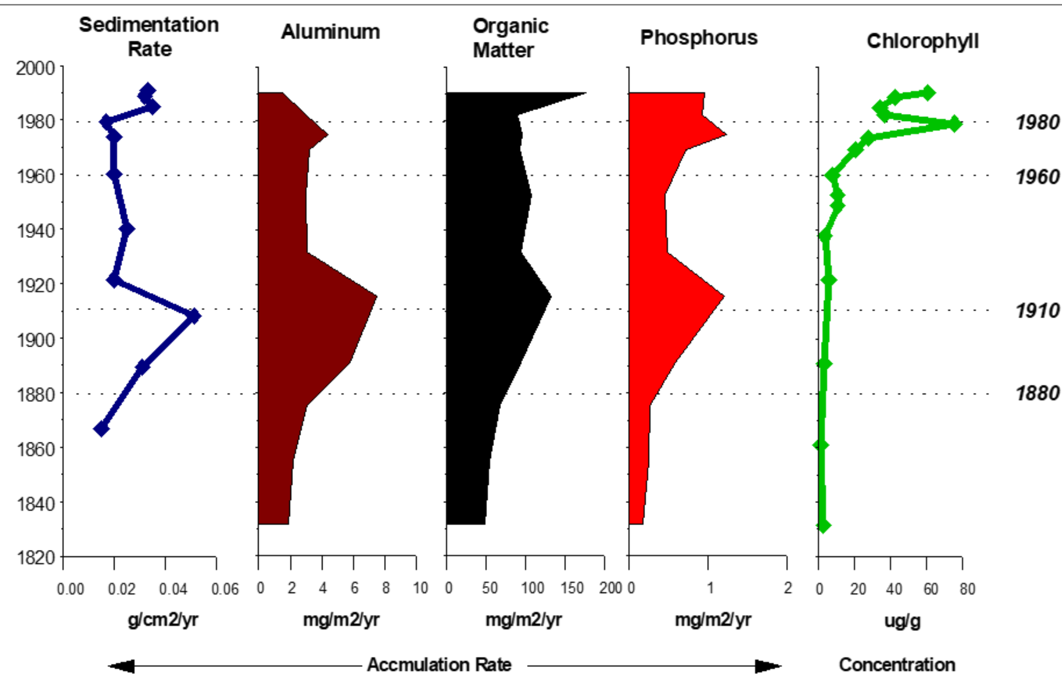


Figure 3.2-1. Accumulation rate for sediment and other geochemical variables. Aluminum represents soil erosion while organic matter is an indication of lake productivity. Chlorophyll is an indication of the trend in the algal community.

In order to estimate how changes in watershed land use has affected the lake; the core was analyzed for a number of elements including aluminum, potassium organic matter, calcium, iron, manganese, nitrogen, and phosphorus. Aluminum, a proxy for detrital aluminosilicate minerals that are common in soil erosion, increased during the same time period as the sedimentation rate in the later part of the nineteenth and early twentieth centuries (Figure 3.2-1). This increase in soil erosion likely was the result of increased agricultural activity. The amount of soil erosion declined to near background levels by 1930 and then experienced a brief increase in the 1970s. Unlike the sedimentation rate which increased in the 1980's, the amount of soil erosion declined during this period. This suggests that the increased sedimentation was not the result of sediment being delivered from the watershed.

The profile of organic matter reflects the change in the lake's overall productivity, especially from algae and submerged aquatic plants. With the increased delivery of sediment in the early part of the twentieth century, there was an increase in the lake's productivity (Figure 3.2-1). Although the lake's productivity declined by 1930, it remained higher than it was in the mid-1800s. In the 1980s the lake's productivity again increased. The phosphorus profile is similar to that of the organic matter, reflecting an increase in the first two decades of the twentieth century. The phosphorus accumulation rate began to increase in the 1970s even though the rate of soil erosion remained low or declined. This suggests that the increased phosphorus is not from soil particles. It likely this increased phosphorus is the result of the use of commercial fertilizer on agricultural fields as well as shoreland homes and other developments within the watershed. As is detailed in the attached report, it appears that internal loading of phosphorus has been increasing throughout the twentieth century.

Although diatoms were not preserved in the sediments, chlorophyll was preserved in the sediments. Changes in the concentration of chlorophyll is an indication of the algal levels in the lake. During the increased productivity in the early part of the twentieth century, there was little increase in chlorophyll (Figure 3.2-1). This indicates that most of the increased productivity was in the form of macrophytes. Chlorophyll levels began to increase in the 1970s in response to increased phosphorus levels and remained high in the 1980s. This suggests that algal levels in 1990, and likely at the present time, are much higher than they were historically.

Zooplankton remains are used to reconstruct changes in submerged aquatic plant coverage and sometimes fish predation. Only the group Cladocera are preserved in the sediments but these zooplankters are very informative. In the Shawano Lake core, the dominant zooplankter was *Bosmina longirostris* (Figure 3.2-2). This species inhabits the pelagic zone and is frequently the dominant fossil in lakes. In this core, species that inhabit the littoral zone (*Alona* spp. and *Chydorus* spp.) are also well represented. Starting around 1880 there is a decline in B. *longirostris* and an increase in *Alona* spp. This likely indicates that the macrophyte community expanded at this time. This expansion continued and it appears to have stabilized around the mid-1950s. *Chydorus sphaericus* can be found in the littoral zone but also is common in the pelagic zone when filamentous algal species occur in the open water. Typically these filaments are blue-green algae. Therefore, it appears that blue-green algal blooms have become more common since 1975. Since the frequency of C. *sphaericus* is highest in the surface sediments, it is likely that algal blooms were more common in the 1980s than at any other time in the last 150 years.

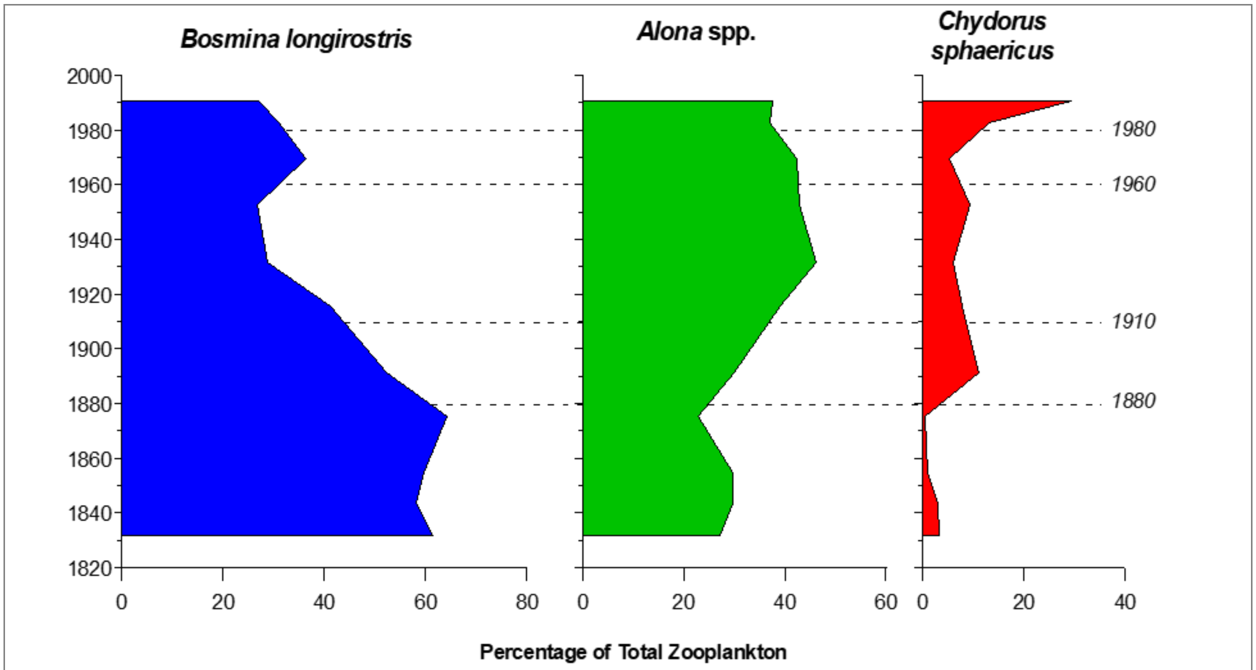


Figure 3.2-2. Profiles of Cladoceran zooplankton. *B. longirostris* is found in the open water while *Alona* is found in the littoral zone and is an indication of changes in the macrophyte community. *C. sphaericus* is found in the littoral zone but increases in the presence of algal blooms in the open waters of the lake.

It should be kept in mind that this sediment core was collected in 1991 and does not reflect changes that have happened in the lake since then. In summary, the highest delivery of sediment from the watershed occurred from the 1890s through 1910s although a secondary peak occurred in the 1980s. Although soil erosion declined in the 1980s, the lake's productivity and phosphorus levels increased suggesting elevated usage of synthetic fertilizers and more internal loading from the sediments. The biological fossils chlorophyll and zooplankton suggest that the amount of macrophytes in the lake has increased since 1950 and that algal concentrations, especially blue-green algae became more common in the 1980s.

3.3 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Shawano Lakehed Assessment – WiLMS Model

Shawano Lake's surficial watershed encompasses an area of approximately 47,351 acres, yielding a small watershed to lake area ratio of about 8:1 (Figure 3.3-1, Map 2). In other words, the model predicts that approximately eight acres of land drain to every one acre of Shawano Lake. However, there is a potential that even less of the land area in this watershed actually contributes nutrients to Shawano Lake. This is because low-lying areas may function as *phosphorus sinks*, where precipitation and nutrients enter directly into the groundwater and do not travel over land to Shawano Lake. Figure 3.3-1 and Map 2 show a potential *effective watershed* where water is most likely to enter Shawano Lake from overland flow. This effective watershed may more accurately portrait the watershed of Shawano Lake when the water table is low, whereas the *surficial watershed* may be more representative during periods of high water.

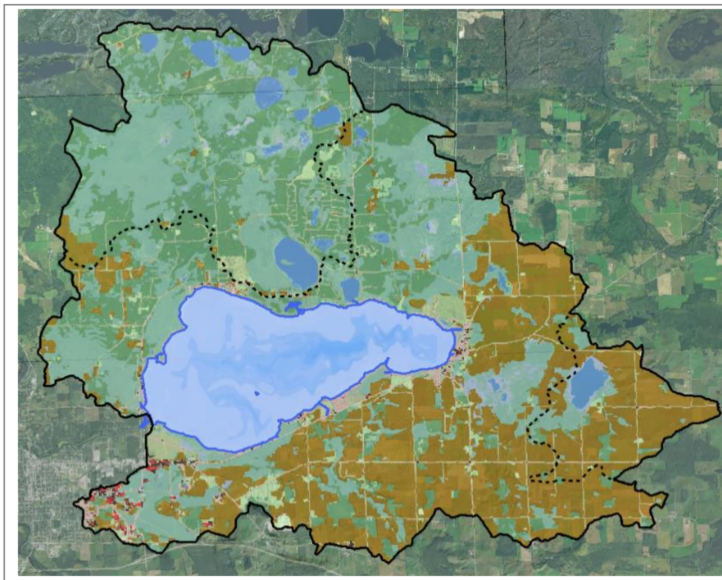


Figure 3.3-1. Shawano Lakehed delineation. Solid black line is entire watershed, dashed black lines are Loon and White Clay subwatersheds.

Onterra LLC Lake Management Planning

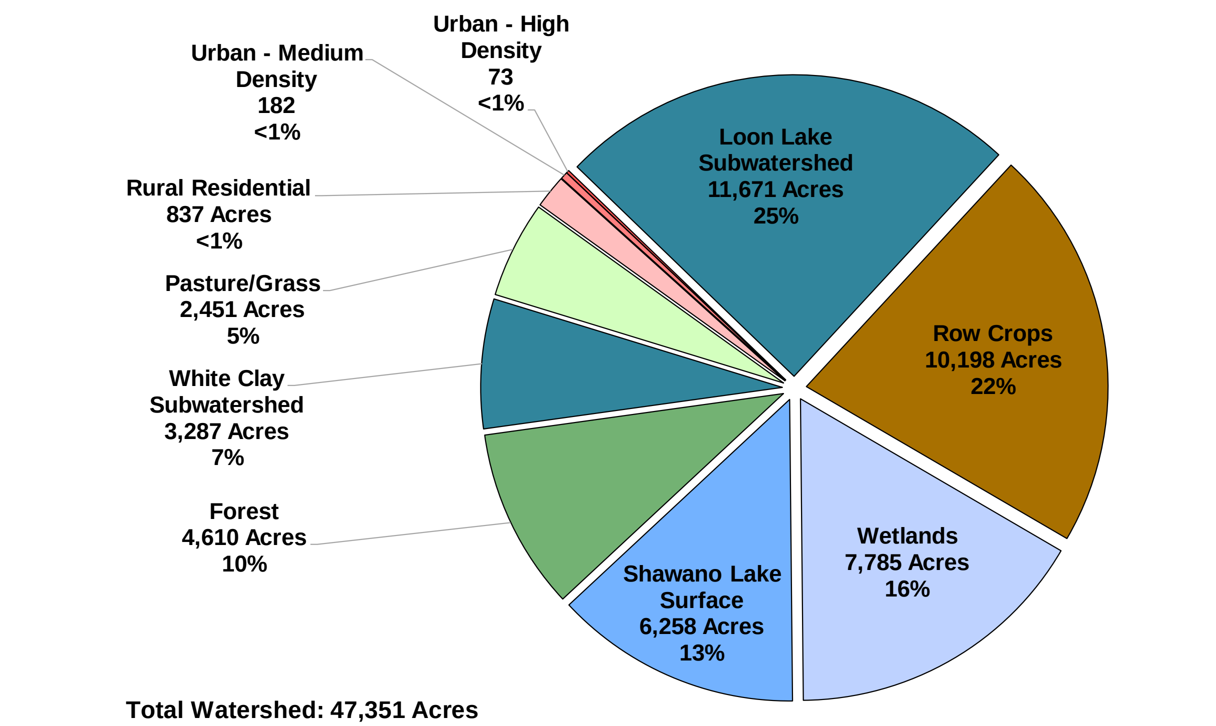


Figure 3.3-2. Shawano Lakehed land cover types in acres. Based upon 2016 National Land Cover Database (USGS 2019).

The watershed of Shawano Lake contains numerous lakes of which Loon and White Clay are the largest (Map 2). There are also seven streams that enter the lake and the outlet of the lake flows through Shawano Lake Outlet to the Wolf River. The three streams that drain the largest part of the watershed are Loon, Duchess, and Pickerel creeks. In general, the landuse in the portion of the watershed north of the lake and drained by Loon and Duchess creeks have a high percentage of forests and wetlands (Figure 3.3-1). Much of the landuse on the eastern and southern part of lake's watershed are in crops and pasture/hay. Specifically, the lake's watershed is composed of forests (10%), row crops (22%), pasture/hay (5%), wetlands (16%), the lake surface itself (13%), rural residential which includes shoreland homes (<1%), and medium and high density urban (<1%) (Figure 3.3-2).

A study conducted by the Wisconsin DNR in 2013-2015 (WDNR 2016) found that the phosphorus concentrations consistently exceeded the standard of 0.075 ug/L in a number of streams. These streams drained areas where agriculture was a significant landuse. These streams also ranked as poor based upon the macroinvertebrate IBI and fish IBI. The streams with the best water quality were Loon, Duchess, and Murray creeks. The landuse in these streams tends to be largely composed of forests and wetlands.

In 2005-2007 a study was conducted by the University of Wisconsin – Stevens Point, Center for Watershed Science and Education (Turyk et al. 2008) which included estimating nutrients delivered to the lake from the streams as well as groundwater and shoreland runoff around the lake. A companion study was conducted by William James of the U.S. Army Corps of Engineers to estimate the amount of internal loading from the bottom sediments (Owens et al. 2007). Flows and phosphorus concentrations were measured in six streams during the growing season, April –

October. Using stream flow and phosphorus concentrations, phosphorus loads could be estimated. For the present management plan, data from this previous study was used to estimate the annual input of phosphorus to Shawano Lake from the watershed. Since the UWSP measurements were only made during the growing season, loads for the rest of the year were estimated based upon measured loading during baseflow conditions and an estimate of increased loading during spring runoff, largely during March. The UWSP study extensively examined phosphorus loading from shoreland homes and also documented phosphorus input from groundwater. The Army Corps of Engineers study estimated the amount of phosphorus released from the lake sediments by collecting sediment cores and measuring phosphorus release rates under presence and absence of oxygen.

Curly-leaf pondweed (CLP) releases phosphorus during die off which occurs during mid-summer. A study in 2013 mapped the extent of CLP in the lake. This study found that CLP covered 496 acres. A study in Lake Chetac, Sawyer County, WI found that about 50% of the phosphorus contained in the CLP remains in the water column following the die off (SEH 2010). This means that about 1409 pounds of phosphorus is released into Shawano Lake during mid-summer.
WiLMS modeling was used to estimate the amount of phosphorus that falls onto the lake from precipitation. While this was estimated in the UWSP study, it was felt the phosphorus concentration was too low and significantly underestimated the amount of phosphorus that enters the lake from the atmosphere.

It is estimated than in a normal year about 16,237 pounds of phosphorus enters the lake (Figure 3.3-3). The largest source of phosphorus to Shawano Lake is direct deposition onto the lake surface (25%). The next two most important single sources are phosphorus released during CLP die off (21%) and lake sediments (15%). Pickerel Creek is the tributary that contributes the greatest phosphorus load from the watershed (12%), followed by Loon Creek (7%). Groundwater contributes 5% of the annual load while Duchess Creek and homes around the lake each contribute about 4% of the annual load. Taken together, runoff from the watershed contributes about 32% of the total annual load. Internal loading from CLP and sediments contributes 37% of the annual load. This source of phosphorus is especially detrimental to the lake since it enters the lake during the summer recreational period and contributes to increased algal growth.

Using predictive equations from Carlson (1977) it is estimated Shawano Lake should have a growing season mean total phosphorus concentration of approximately 26 µg/L. This is less than the long-term average of 34 µg/L that was measured in the lake. It is possible that the contribution of the watershed streams is underestimated. The UWSP report found that some of their modelling suggested that loading during their study was lower than the long-term average. In fact, the WiLMS model found that the annual load was considerably higher than the UWSP study but Onterra staff felt the WiLMS model significantly overestimated the phosphorus load and the UWSP study was more reasonable. The annual phosphorus load from the watershed would need to be a little more than double than was estimated in this study to meet the long-term average phosphorus concentration of 34 µg/L. If more phosphorus is entering the lake from the watershed, this would reduce the importance of the internal load although the internal load does result in a significant increase in phosphorus concentration in the lake during the summer as discussed in the water quality section above.

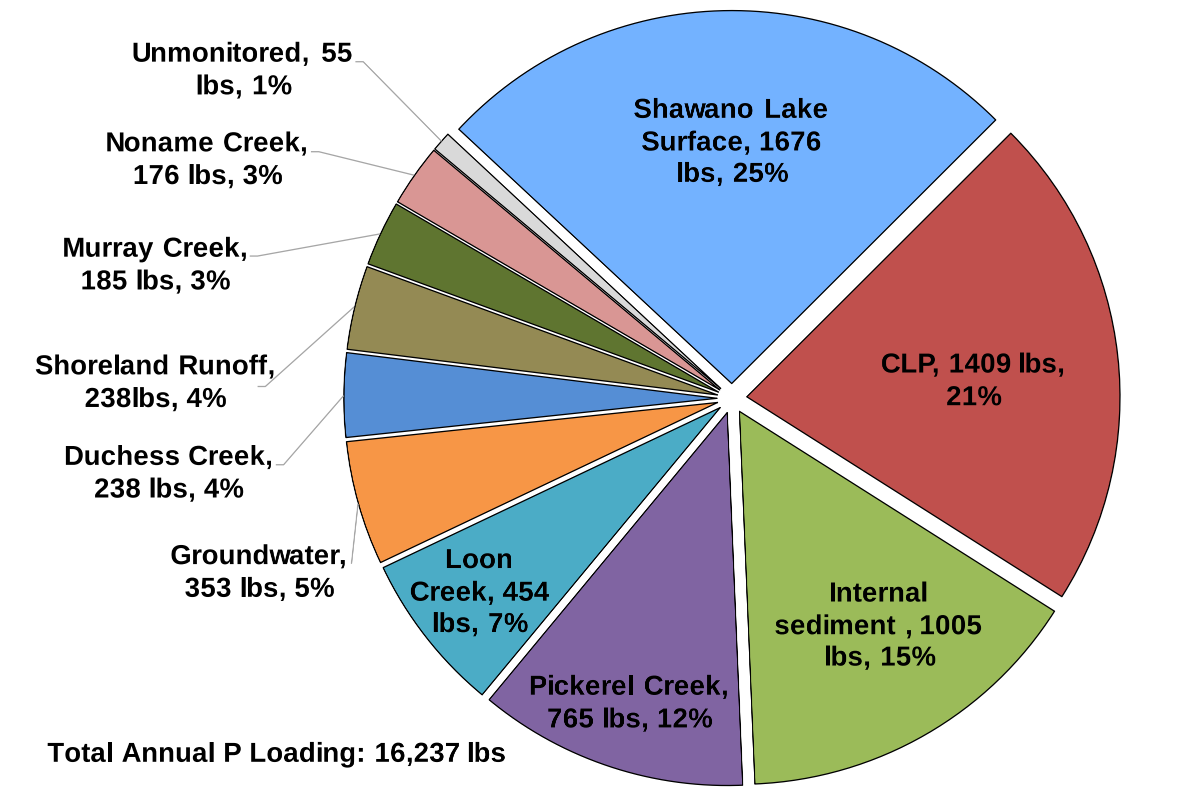


Figure 3.3-3. Shawano Lakehed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Shawano Lakehed Assessment – TMDL Model

Section 303(d) of the Clean Water Act (CWA) requires states to determine which waterbodies are impaired and orchestrate a plan to reach the goal of restoring all identified impaired waters to meet applicable water quality standards (WDNR 2020). One of the tools WDNR biologists use to achieve this goal is to develop a total maximum daily load (TMDL) for an impaired waterbody. The primary objective of an approved TMDL is to establish pollutant load allocations to point and nonpoint sources in order to achieve pollutant load reductions needed to meet water quality goals (WDNR 2020). Meeting these water quality goals in turn should theoretically improve water quality and eventually lead to the delisting of the impaired waterbody from the impaired waters and restoration waters list.

The Wolf River TMDL watershed is approximately 2,388,00 acres (3,730 square miles), includes portions of eleven counties, and covers approximately 10% of the state of Wisconsin. The watershed originates in Pine Lake and discharges into Lake Poygan of the Lake Winnebago System. The Wolf River watershed is subdivided into twenty sub-watersheds (Figure 3.3-4). The U.S. EPA approved the Wisconsin River TMDL on February 27, 2020. This report can be accessed here: https://dnr.wisconsin.gov/topic/TMDLs/FoxWolf/index.html

Code	Name	Acres
WR20	Upper Wolf River and Post Lake	131,503
WR19	Lily River	132,673
WR18	Wolf River - Langlade and Evergreen River	115,035
WR17	West Branch Wolf River	161,114
WR16	Red River	132,556
WR15	Shawano Lake	45,544
WR14	Middle Wolf River	85,619
WR13	Shioc River	121,447
WR12	Wolf River - New London and Bear Creek	91,191
WR11	Middle and South Branches Embarrass River	160,004
WR10	Pigeon River	74,444
WR09	North Branch and Mainstem Embarrass River	200,074
WR08	South Branch Little Wolf River	102,586
WR07	Upper Little Wolf River	116,512
WR06	Lower Little Wolf River	98,307
WR05	Waupaca River	186,096
WR04	Lower Wolf River	76,768
WR03	Walla Walla and Alder Creeks	71,739
WR02	Pine and Willow Rivers	193,329
WR01	Arrowhead River and Daggets Creek	91,463

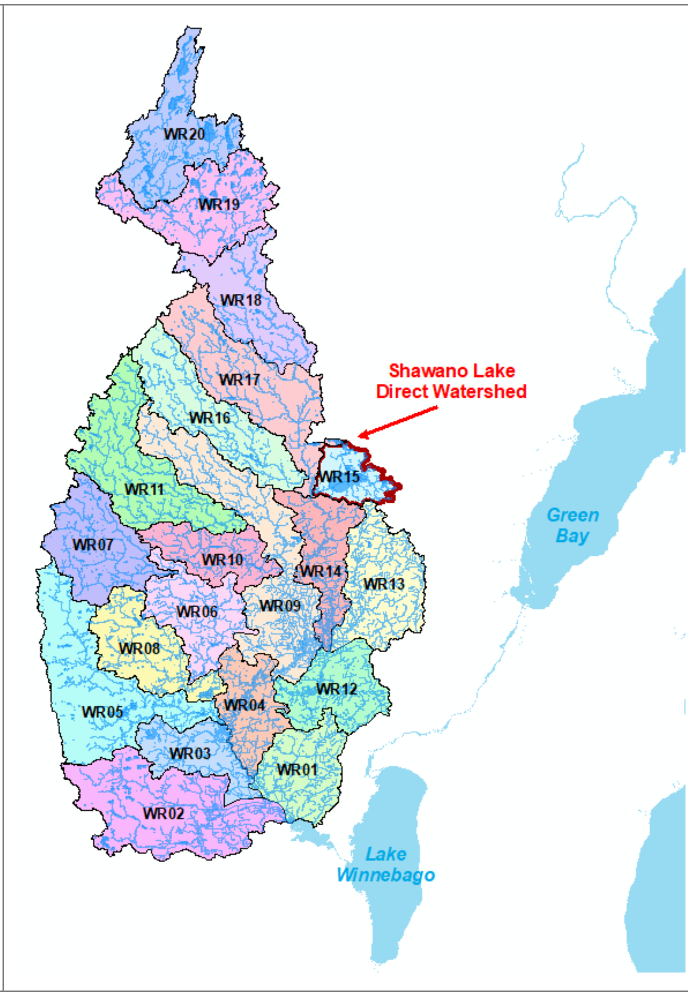


Figure 3.3-4. Wolf River Watershed. WDNR 2020.

3.4 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 et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. 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 and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay, Gillum and 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.

Photograph 3.4-1. Example of coarse woody habitat in a lake.

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 is important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

With development of a lake's shoreland zone, much of the coarse woody habitat that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions due to logging practices. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities 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 et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.4-2. Example of a biolog restoration site.

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

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

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).

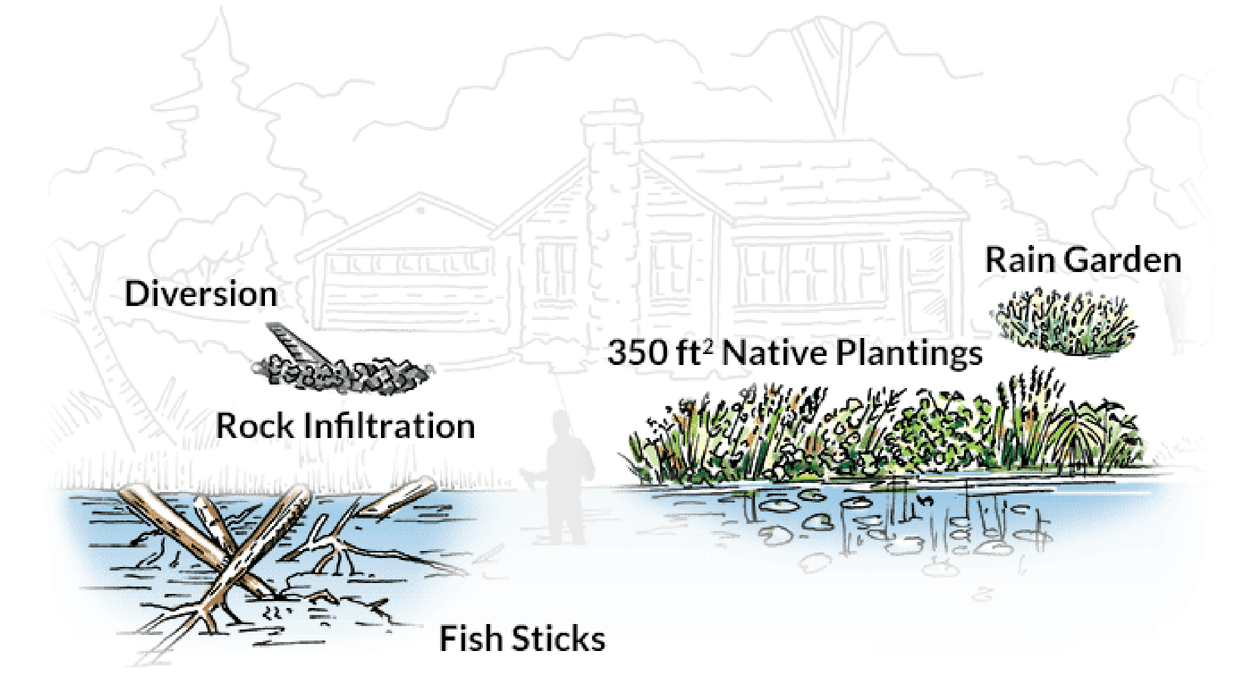


Figure 3.4-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- 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.

Shawano Lake Shoreland Zone Condition

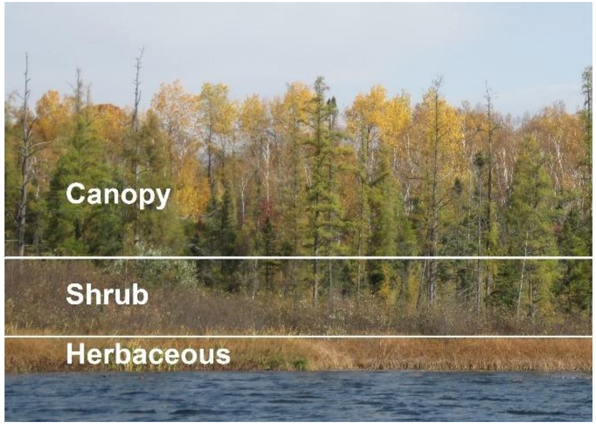
Shoreland Development

Shawano Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state (Photograph 3.4-3).

Photograph 3.4-3. Developed shoreline (left) and a shoreline in its natural state (right) on Shawano Lake.

During the summer of 2019, the Fox-Wolf Watershed Alliance (FWWA) and Waterways Association of Menominee and Shawano Counties (WAMSCO) completed a shoreline survey of Shawano Lake utilizing the WDNR's "Lake Shoreland & Shallows Habitat Monitoring Field Protocol." Under this protocol, the riparian buffer zone assessed for each parcel includes from high water level to 35' inland. Within this zone, natural vegetation within the canopy and shrub/herbaceous layers (Photograph 3.4-4) was given an estimated percentage of the plot that is dominated by each category. The full report of the assessment, including maps and complete survey methodology, can be found in Appendix D. The main takeaway from the study is that Shawano Lake, like many other lakes, is in need of shoreline restoration. The area with the most room for improvement is within the shrub/herbaceous layers around Shawano Lake. Adding more native plants within the riparian zone would reduce runoff impacts to the lake. More information about possible funding assistance to complete restoration projects can be found on page 17 of the report.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Fifty-seven percent of the lawns around Shawano Lake were categorized as "poor," meaning they are too manicured and unnatural. Manicured lawns also attract geese which can be a nuisance. Placing lawns on flat, un-sloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site. Allowing tree falls and other natural habitat features along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.



Photograph 3.4-4. Example of canopy, shrub and herbaceous layers.

Coarse Woody Habitat

As part of the shoreland condition assessment, Shawano Lake was also surveyed to determine the extent of its coarse woody habitat (CWH). The WDNR protocol for surveying coarse woody habitat was not used during this survey. If coarse woody habitat was found while assessing a parcel, a note was made for documentation. Coarse woody habitat located between high water level and the 2-foot depth contour that was greater than 4" in diameter and at least 5' long was recorded during the survey. Lumber and fish cribs were not recorded. Only eight locations around the lake contained coarse woody habitat (Appendix D). This finding suggests that the addition of tree drops, would be very beneficial fish habitat for Shawano Lake. 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 et al. 2005).

Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Shawano Lake and those cited in this literature comparison are not the same, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Seawalls

The importance of the shoreland zone of a lake is well discussed above. It is important to also acknowledge that natural shorelines are dynamic and are altered over time from shoreland erosion and impacts from ice shoves. While the impacted shorelines continue to provide valuable wildlife habitat, the changes are undesired by the property owners. Seawalls are commonly constructed to reduce shoreline erosion and protect adjacent upland properties from wave action and winter ice shoves. However, these structures reduce the natural complexity of the nearshore habitat and reduce biodiversity. Therefore, these artificial structures are generally discouraged. Seawall installation/repair requires a WDNR permit, which SAWM has taken an active role in assisting members create their application and navigating this process.

On large lakes like Shawano Lake, erosion and ice shoves can be extremely damaging to valuable shoreline properties. Ramped concrete seawalls have been favored by Shawano Lake riparians. These structures mimic the contours of the existing shoreline, allowing the ice shoves to slide up and over the shoreline interface. Unlike vertical seawalls that deflect wave energy back into the lake, ramped seawalls are hypothesized to help dissipate it. Concrete sea walls, regardless of being vertical or sloping, provide no habitat value to the important organisms that rely on the terrestrial-aquatic interface for their survival. When a circumstance justifies the need for shoreland modifications to protect property, the WDNR favors properly implemented rip-rap/rock. These structures mimic a type of native shoreline, providing a level of environmental benefit in addition to shoreland stabilization.

Of the stakeholder survey respondents that live on the lake, 38% indicated having ramped concreate seawalls (Figure 3.4-2). 21% of riparian stakeholder survey respondents indicated they have rip-rap shorelines, with another 5% of “other” responses indicating some variation of stone or rip-rap. Within the “other” responses, numerous respondents indicating failing seawalls due to wave action, ice-shoves, and water levels.

Question 22: What type of seawall do you have on the shoreline of your property?

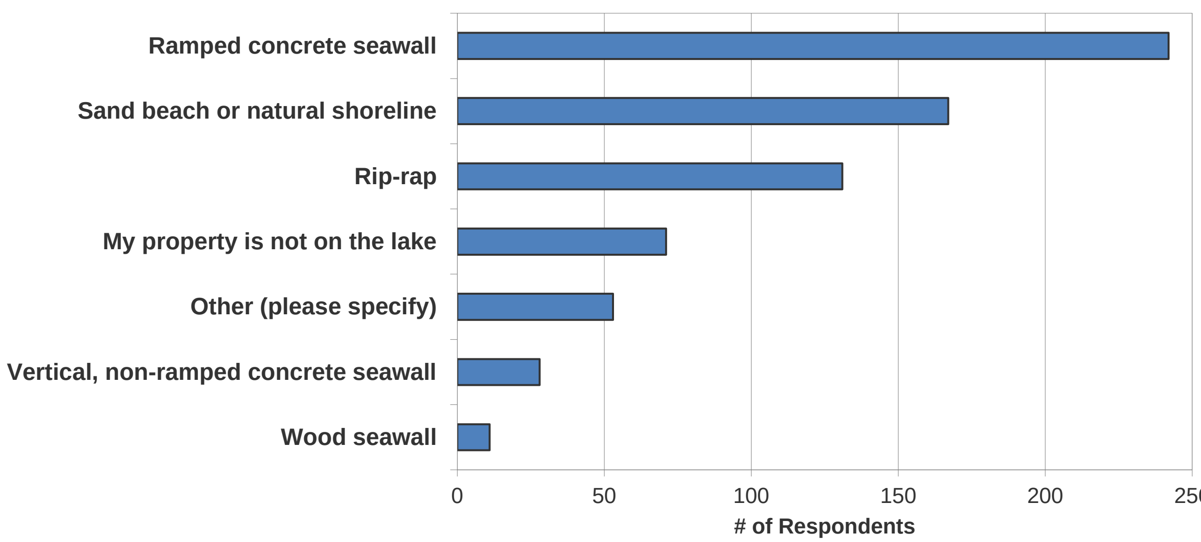


Figure 3.4-2. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.5 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 3.5-1. Example of emergent and floating-leaf communities.

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

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

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

Permits

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

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

Manual Removal (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 3.5-2. 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 $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 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.

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting


Photograph 3.5-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

Photograph 3.5-4. Liquid herbicide application.

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 65°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

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

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

Aquatic herbicides can be classified in many ways. Organization of this section follows (Netherland 2009) in which mode of action (i.e., how the herbicide works) and application techniques (i.e., foliar or submersed treatment) group the aquatic herbicides. Table 3.6-1 provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from (Netherland 2009).

Table 3.5-1. 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 submergen 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

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

1. Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g., mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause 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 emergent 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 Shawano 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 Shawano Lake in 2016. 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 Shawano 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 Shawano 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 where 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 Shawano Lake is compared to data collected by Onterra and the WDNR Science Services on 85 lakes within the North Central Hardwood 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 Shawano 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 exotics, 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 3.5-1). 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, 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.

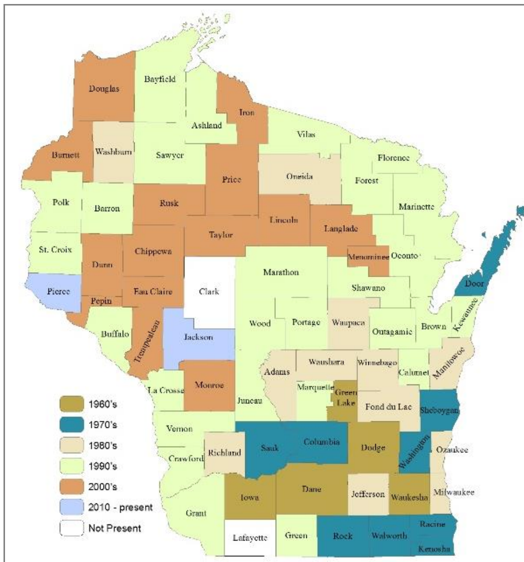


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

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.

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

Shawano Lake Aquatic Plant Survey Results

Numerous aquatic plant surveys have been conducted on Shawano Lake. This includes systematic point-intercept surveys in 2005, 2013, and 2015-2019, a floating-leaf and emergent community mapping survey in 2013, a focused curly-leaf pondweed mapping survey in 2013, and focused Eurasian watermilfoil mapping surveys in 2013, 2015-2019. In total, approximately 57 aquatic plant species have been identified from in and along the margins of Shawano Lake (Table 3.5-2).

During the point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). Data from the most recent point-intercept survey indicate that 73% of the point-intercept locations in 15 feet of water or less contained soft organic sediments (i.e., muck), 27% contained sand, and less than 1% contained rock (Figure 3.5-2). Sampling locations with sand and/or rock were primarily located in shallower, near-shore areas, while the majority of sampling locations with soft organic sediments were located in deeper areas. The combination of both soft and hard substrates in Shawano Lake creates habitat types which support different aquatic plant community assemblages.

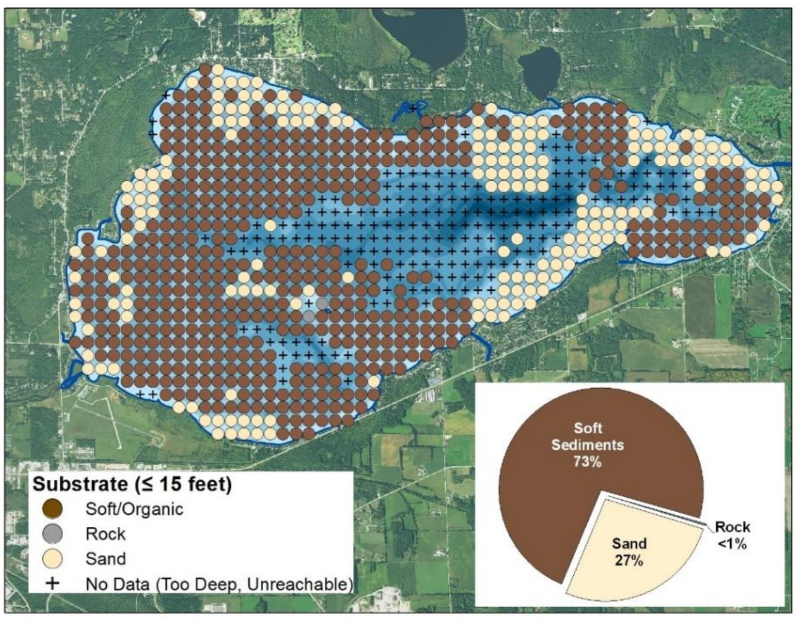


Figure 3.5-2. Shawano Lake substrate types. Determined from the 2019 point-intercept survey. Please note that substrate types can only be determined at sampling locations in 15 feet of water or less.

Table 3.5-2. Aquatic plant species located in Shawano Lake.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2005	2013	2015	2016	2017	2018	2019
Emergent	*Decodon verticillatus*	Water-willow	Native	7		I					
	Eleocharis palustris	Creeping spikerush	Native	6		X	X	X		X	X
	Eleocharis quadrangulata	Square-stem spikerush	Native - Endangered	10		X					
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	X	I					
	Phragmites australis subsp. americanus	Common reed	Native	5		I					
	Phragmites australis subsp. australis	Giant reed	Non-Native Invasive	N/A		X				X	
	Pontederia cordata	Pickerelweed	Native	9		X				X	
	Sagittaria latifolia	Common arrowhead	Native	3		I					
	Sagittaria rigida	Stiff arrowhead	Native	8		I					
	Schoenoplectus acutus	Hardstem bulrush	Native	5		X	X	X		X	X
	Schoenoplectus pungens	Three-square rush	Native	5		X		X		X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4		I			X		
	Sparganium eurycarpum	Common bur-reed	Native	5		I					
	Typha spp.	Cattail spp.	N/A	N/A		I					
	Zizania spp.	Wild rice sp.	Native	8		X	X		X		
FL	*Brasenia schreberi*	Watershield	Native	7		X	X				
	Nuphar variegata	Spatterdock	Native	6	X	X	X	X		X	X
	Nymphaea odorata	White water lily	Native	6	X	X	X	X	X	X	X
	Persicaria amphibia	Water smartweed	Native	5		I					
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9							X
FL/E	*Sparganium sp.*	Bur-reed sp.	Native	N/A					X		
Submergent	*Bidens beckii*	Water marigold	Native	8		X	X	X	X	X	X
	Ceratophyllum demersum	Coontail	Native	3	X	X	X	X	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	Native	10						X	X
	Chara & Nitella	Charophytes	Native	7	X	X	X	X	X	X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X	X	X	X	X	X
	Heteranthera dubia	Water stargrass	Native	6		X	X	X	X	X	X
	Littorella uniflora	American shoreweed	Native - Special Concern	10						X	
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X	X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10		X	X	X			X
	Najas flexilis	Slender naiad	Native	6	X	X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7		X	X	X	X	X	X
	Najas spp.	Slender and Southern Naiad	Native	N/A	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	Native	7		X		X		X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X	X	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7							X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X	X	X	X	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8		X	X				
	Potamogeton foliosus	Leafy pondweed	Native	6	X			X	X		X
	Potamogeton friesii	Fries' pondweed	Native	8		X	X	X	X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X	X	X	X	X	X
	Potamogeton hybrid 1	Pondweed Hybrid 1	0	N/A		X	X	X			X
	Potamogeton hybrid 2	Pondweed Hybrid 2	0	N/A		X					
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	X	X	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	Native	8		X	X	X	X	X	X
	Potamogeton pusillus	Small pondweed	Native	7		X	X	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5		X	X	X	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8	X	X	X		X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X	X	X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8		X	X				X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	X	X	X		X	X	X
	Stuckenia pectinata	Sago pondweed	Native	3		X	X	X	X	X	X
	Utricularia vulgaris	Common bladderwort	Native	7	X	X		X			X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X
	Zannichellia palustris	Horned pondweed	Native	7	X						
SE	*Eleocharis acicularis*	Needle spikerush	Native	5		X		X	X	X	
FF	*Lemna trisulca*	Forked duckweed	Native	6		X	X	X	X	X	X
	Spirodela polyrhiza	Greater duckweed	Native	5		X					X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL=Floating-leaf; FL/S=Floating-leaf and emergent; SE=Submergent and 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. Shawano Lake's mean summer Secchi disk depth in 2019 was 5.9 feet, and aquatic plants were recorded growing to a maximum depth of 18 feet. The total number of littoral sites in 2019 was 813, or 89% of total sites sampled.

Figure 3.5-3 shows that the majority of the aquatic vegetation in Shawano Lake is located within the shallow bays and near-shore areas. As discussed in the water quality section, the water clarity in Shawano Lake is relatively low which limits sunlight penetration and restricts aquatic plants from inhabiting deeper areas of the lake. The majority of the aquatic vegetation in Shawano Lake was found to be growing between 1 and 12 feet which has remained consistent across surveys.

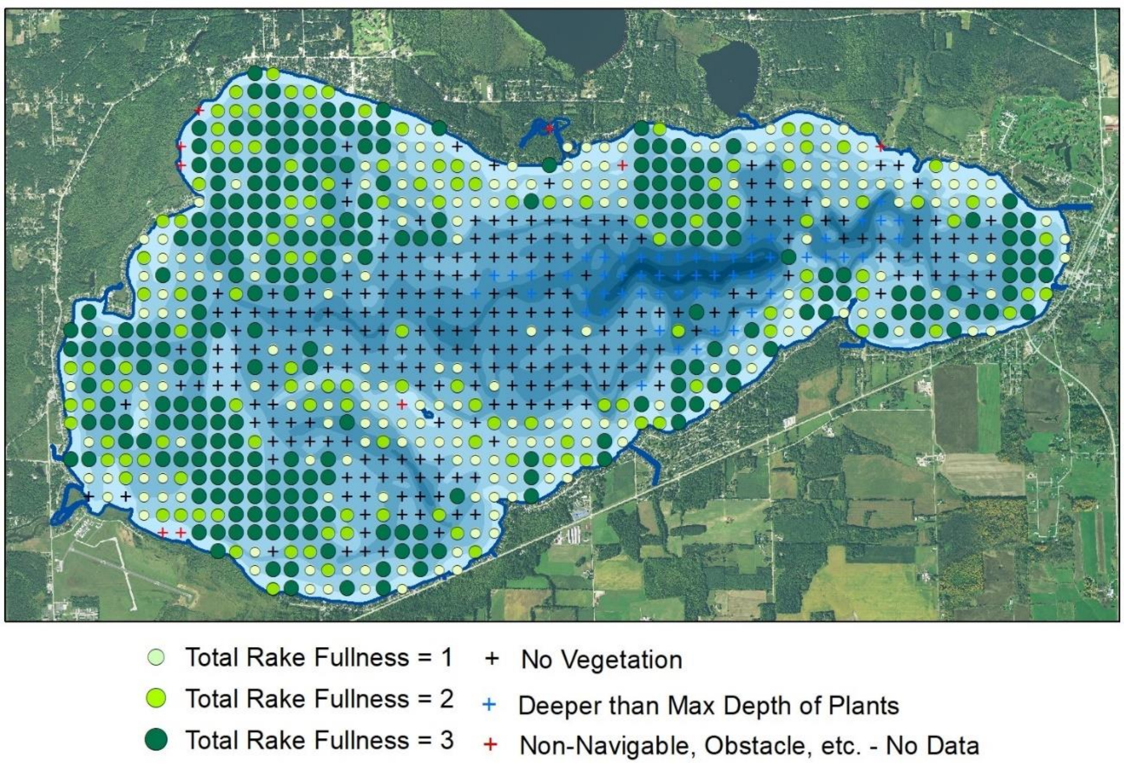


Figure 3.5-3. Distribution of vegetation in Shawano Lake. Created using data from the 2019 survey by Onterra. Littoral frequency of occurrence of vegetation in 2019 was 74% (n=813)

Approximately 74% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth, or the littoral zone, contained aquatic vegetation in 2019 (Figure 3.5-3). The littoral frequency of occurrence of vegetation is similar to recent years, in 2018 and 2017 it was 71%, and in 2016 it was 67%. The lowest value occurred during the year of the whole-lake 2,4-D treatment.

Total Rake Fullness (TRF) values are recorded at each sampling location as a part of the point-intercept survey methodology. Figure 3.5-3 shows the TRF ratings for the sampled locations on Shawano Lake in 2019. During the 2019 survey 32% of sampling locations had a TRF of 3, the highest amount of vegetation, 16% had a rating of 2, and 25% a rating of 1. These data indicate that the overall biomass of aquatic vegetation in Shawano Lake is high. The consistent littoral frequency of occurrence of vegetation, similar max depth and average depth of plants indicates that the plant community in Shawano Lake has remained similar through the years and the distribution of vegetation is previous surveys is likely similar to the distribution seen in 2019. This is indicative of a dynamic and resilient community that is able to withstand disturbance and stress.

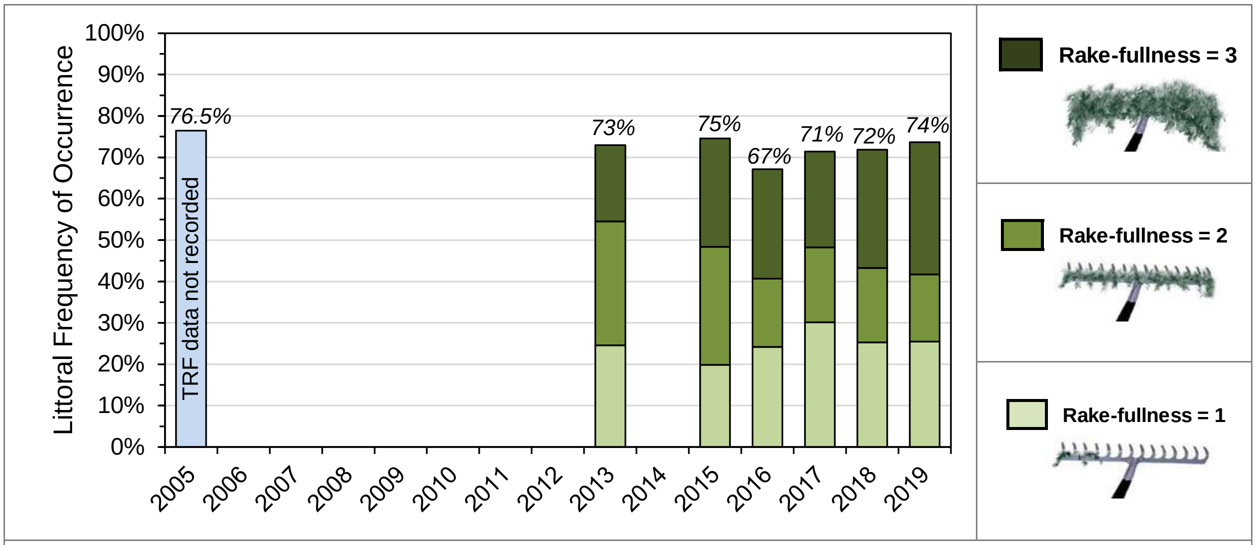


Figure 3.5-4. Shawano Lake littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) data. Note that TRF was not recorded in 2005.

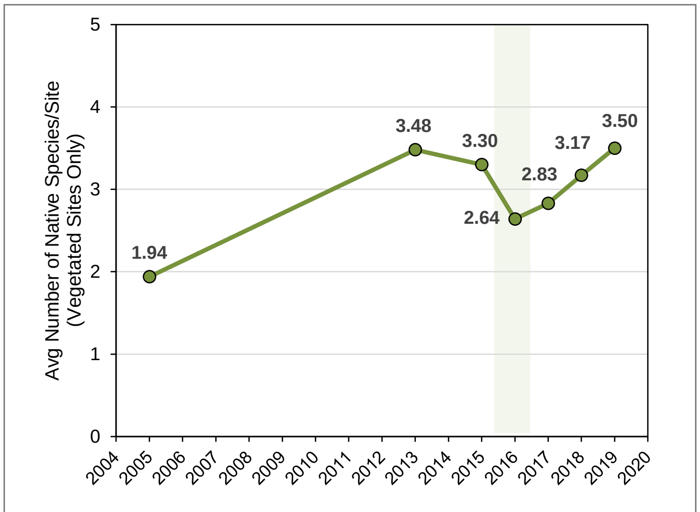


Figure 3.5-5. Average number of native species per sampling site in Shawano Lake. Shaded stripe indicates whole-lake 2,4-D treatment.

Figure 3.5-5 shows the average number of native species present on the sampling rake for vegetated site only on Shawano lake. This metric helps to indicate the species abundance and distribution across sampling locations. Shawano Lake's native species distribution has remained mostly consistent across survey years with the exception of a reduction in 2016 and 2017 following a whole-lake 2,4-D treatment conducted for EWM management. Collateral native impacts are expected from this form of management. The resilience of Shawano Lake's aquatic plant community is noted by how quickly it was able to rebound. Map 5 shows the species richness from the 2019 point-intercept survey.

Photograph 3.5-5. Lake quillwort (Isoetes lacustris) of the isoetid growth form (left) and Large-leaf pondweed (Potamogeton amplifolius) of the Elodeid growth form (right). Photo credit: Onterra

Aquatic plants can be placed in one of two general groups, based upon their form of growth and habitat preferences. These groups are the isoetid growth form and the elodeid growth form. Shawano Lake has both isoetid and elodeid species within its waters. Plants of the isoetid growth form are small, slow growing, and inconspicuous submerged plants. (Photograph 3.5-5, left frame) They often have evergreen leaves located in a rosette and are usually found growing in sandy soils within the near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). Some common isoetid species in Shawano Lake include dwarf watermilfoil and needle spikerush. Submersed species of the elodeid growth form have leaves on tall, erect stems which grow upwards into the water column (Photograph 3.5-5, right frame). Examples of Shawano Lake elodeid species include slender naiad, muskgrasses, wild celery, and small pondweed.

Alkalinity is the primary water chemistry factor determining whether a lake is dominated by plant species of the isoetid or elodeid growth form (Vestergaard and Sand-Jensen 2000). Most elodeids are restricted to lakes of relatively higher alkalinity, as their carbon demand for photosynthesis cannot be met solely by the dissolved carbon dioxide (CO_2) present in the water, and they must acquire additional carbon through bicarbonate (HCO_3^-). While isoetids are able to grow in lakes of higher alkalinity, their short stature makes them poor competitors for light, and they are usually outcompeted and displaced by the taller elodeids. Thus, isoetids are most prevalent in lakes of low alkalinity where they can avoid competition from elodeids. However, in lakes with intermediate alkalinity levels, like Shawano Lake, we see a mixed community of both, with isoetids inhabiting the shallow, sandy/rocky areas and elodeids thriving in the deeper areas of softer sediment.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006).

The data collected during the point intercept surveys can be used to compare the frequency of individual species in Shawano Lake and observe how their abundance may have changed across surveys. The littoral frequencies of aquatic plant species which had a littoral occurrence of at least 5% in one or more of the point-intercept surveys are displayed in Figure 3.5-6. Due to their morphologic similarity and often difficulty in identification to species, the occurrences of Slender, Southern, and Northern Naiad have been combined for analysis.

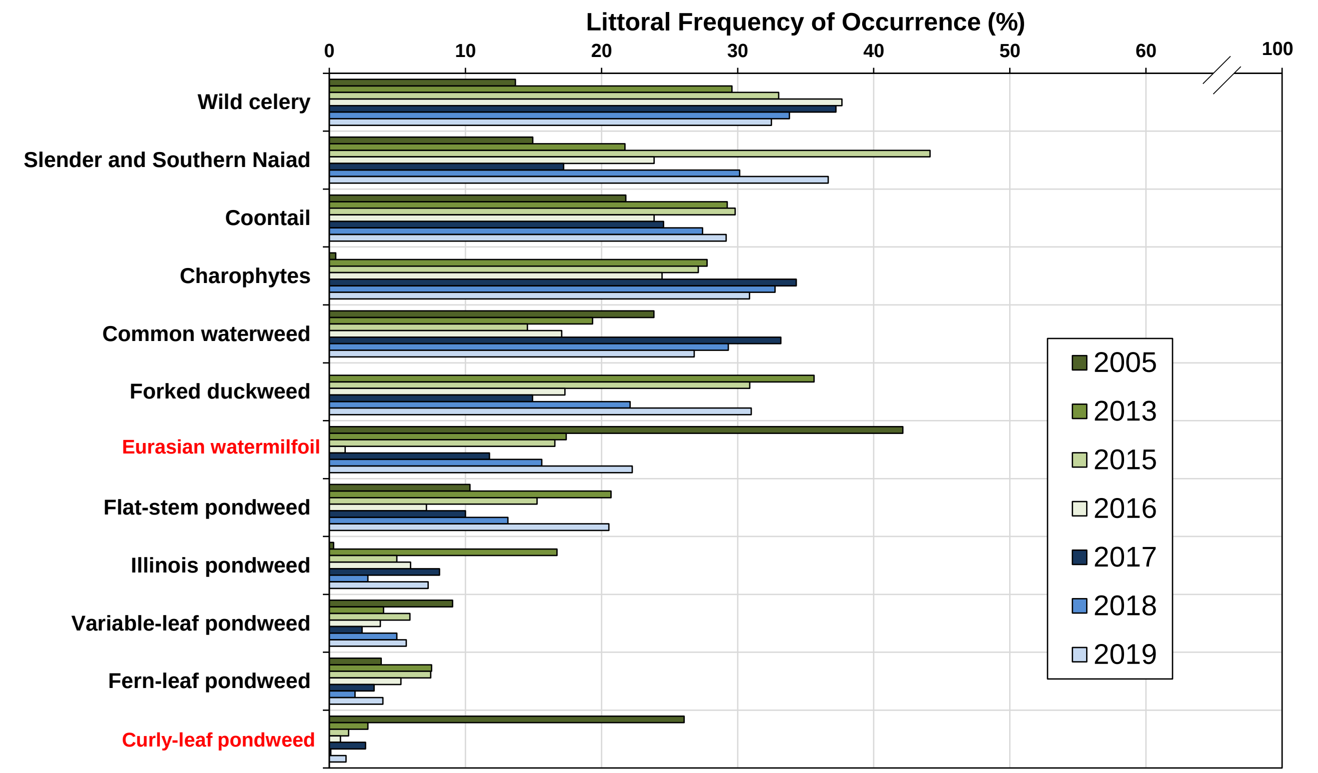


Figure 3.5-6. Shawano Lake aquatic plant littoral frequency of occurrence of select species. Species with a frequency of at least 5% in one or more surveys are displayed. Created using data from 2005, 2013, and 2015 through 2019 surveys.

Figures 3.5-7 -3.5-11 will investigate the population dynamics of a few select species from Shawano Lake. The grey shaded stripe indicates the year in which a whole-lake 2,4-D treatment occurred on Shawano Lake. While herbicide application strategies are implemented to maximize target plant (EWM) impacts and minimize impacts to native species, certain native aquatic plants are susceptible to the type of herbicide application strategy that was implemented on Shawano Lake. More discussion of this management strategy will be included within a subsequent subsection on Non-Native Aquatic Plants.

The most commonly encountered species in Shawano Lake when considering all surveys is wild celery (*Vallisneria americana*). Wild celery emerges a little later than many native plant species and perhaps is dormant during the herbicide treatment and thus less susceptible to impacts from this herbicide. Wild celery populations were highest during the year of the whole-lake 2,4-D treatment but exhibited relatively stable populations between 2015 and 2019 (Figure 3.5-12).

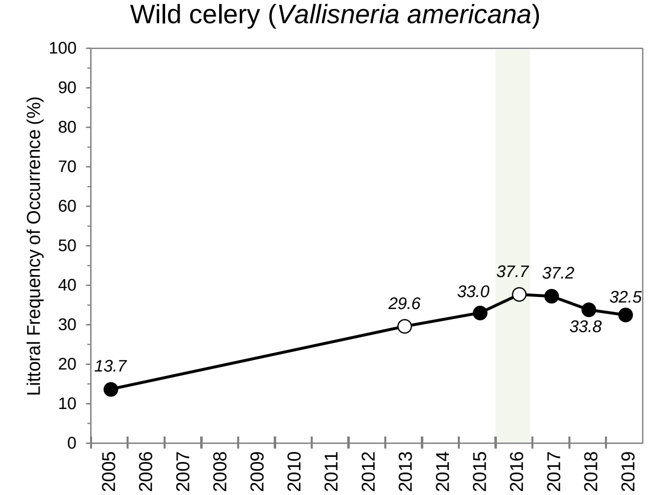


Figure 3.5-7. Littoral frequency of occurrence of wild celery. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Shaded stripe indicates whole-lake 2,4-D treatment.

Photograph 3.5-6. Wild celery (*Vallisneria americana*). Photo credit Onterra.

Wild celery contains a basil rosette, which means that the long, grass-like leaves extend in a circular fashion from the base of the plant located at the sediment-water interface (Photograph 3.5-6). To keep the leaves standing in the water column, lacunar cells in the leaves trap air and gasses making them more buoyant. Towards the late-summer when water celery is at its peak growth stage, it is easily uprooted by wind and wave activity. The wild celery can then pile up on shorelines depending on the predominant wind direction. This was observed on Shawano Lake at the end of the 2012 and 2016 growing season (Photograph 3.5-7). SAWM utilized their mechanical harvester to mitigate the recreation and navigation impacts. This condition is common on many lakes and has occurred on Shawano Lake in the past. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Shawano Lake ecosystem.

Photograph 3.5-7. Floating wild celery mats in and 2012 (left) and 2016 (right) on Shawano Lake. 2016 photo courtesy of SAWM. 2012 photo courtesy of Brenda Nordin WDNR

Slender naiad and southern naiad are morphologically similar species (Photograph 3.5-8), with field crews distinguishing between these species in more recent years (Figure 3.5-8). Slender naiad is an annual, reproducing from seed each year, while southern naiad is a perennial, growing out of the previous year's stems. Onterra's experience is that slender naiad is particularly susceptible to whole-lake 2,4-D treatments whereas southern naiad is more tolerant. Although southern naiad is native to North America, in some lakes it has been observed exhibiting aggressive growth in recent years. While southern naiad provides shelter for smaller fish and invertebrates and is a food source for some duck species, it can dislodge from sediments and form surface mats that interfere with navigation, recreation, and aesthetics

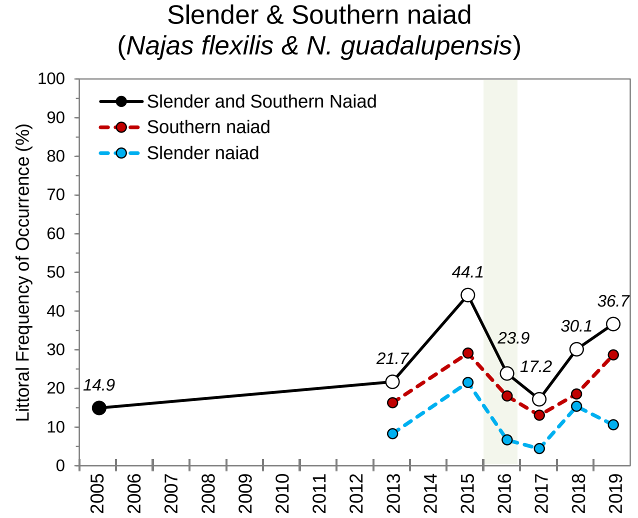


Figure 3.5-8. Littoral frequency of occurrence of slender naiad. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05).

Photograph 3.5-8. Slender naiad (Najas flexilis; left) and southern naiad (N. guadalupensis; right). Photo credit Onterra.

Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface (Photograph 3.5-9). Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps to improve water clarity. However, in some lakes such as Shawano Lake, coontail can form dense surface mats that interfere with recreation and navigation. Coontail populations in Shawano Lake have been relatively stable at 20-30% of the littoral sampling locations (Figure 3.5-9).

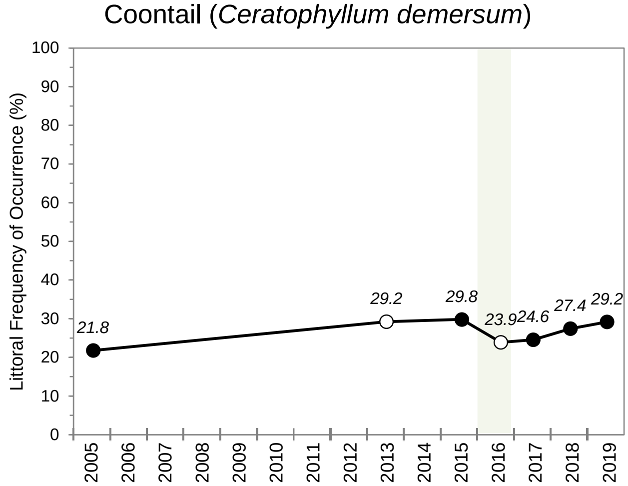


Figure 3.5-9. Littoral frequency of occurrence of coontail. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 3.6-9. Coontail (*Ceratophyllum demersum*). Photo credit Onterra.

Like coontail, common waterweed obtains the majority of its nutrients directly from the water. While common waterweed can be found growing in many of Wisconsin's waterbodies, excessive growth of common waterweed is often observed in waterbodies with higher nutrients. It can tolerate the low light conditions found in eutrophic systems better than many other aquatic plant species. For these reasons, common waterweed has competitive advantages over other aquatic plant species that favor its growth in productive systems. On Shawano Lake, particularly the western part of the lake and Cecil Bay, common waterweed forms large and dense mats. In recent years with lower density EWM, common waterweed populations have increased (Figure 3.5-10)

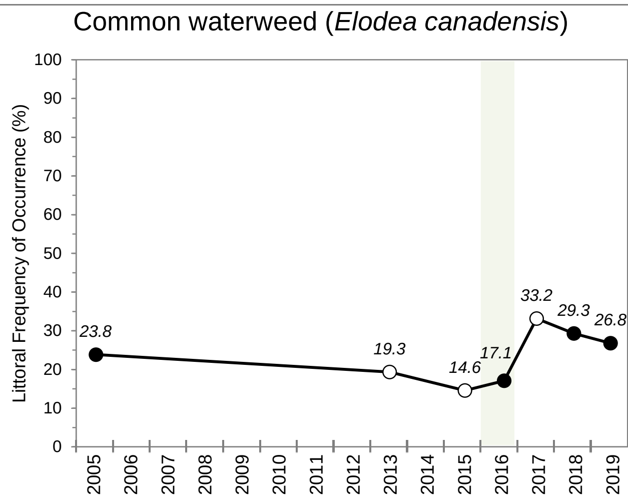


Figure 3.5-10. Littoral frequency of occurrence of common waterweed. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 3.5-10. Common waterweed (*Elodea canadensis*)
Photo credit: O**nterra**.

Charophytes are a group of macro-algae comprised mainly of muskgrasses (*Chara* spp.) and stoneworts (*Nittella* spp.). On Shawano Lake, birds-nest stonewort (*Tolypella* spp.) was also confirmed form the lake (Photograph 3.5-11). Charophytes are almost universally resilient to most herbicide treatments, particularly with systemic herbicides like 2,4-D. As an alga, herbicides are not moved through (translocated) the tissue as the "plant" is made up of colonies of individual cells. Muskgrasses and stoneworts are important for sediment stabilization and their populations statistically increased in 2017 (Figure 3.5-11), potentially filling niches where there were losses of other native aquatic plants.

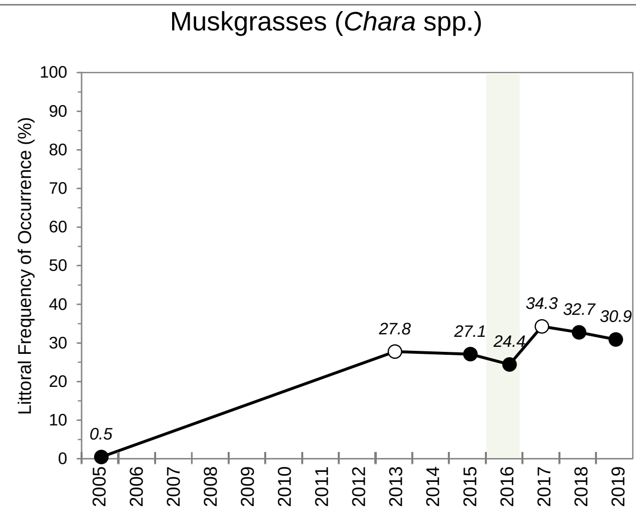


Figure 3.5-11. Littoral frequency of occurrence of muskgrasses. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 3.5-11. Birds-nest stonewort (*Tollypella* spp.) from Shawano Lake. Photo credit Onterra.

Lakes with diverse aquatic plant communities are believed to have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. One may assume that because a lake has a high number of aquatic plant species that it also has high species diversity. However, species diversity is influenced by both the number of species and how evenly they are distributed within the community.

Onterra LLC
Lake Management Planning

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 Shawano Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NCHF Ecoregion. The Simpson's Diversity Index values were calculated for Shawano Lake using the point-intercept survey data. Shawano Lake's species diversity has remained well above the median value for the ecoregion and even above the upper quartile for all survey years. In 2019 the diversity value was calculated to be 0.92, a tie for the second highest values across the survey years (Figure 3.5-12).

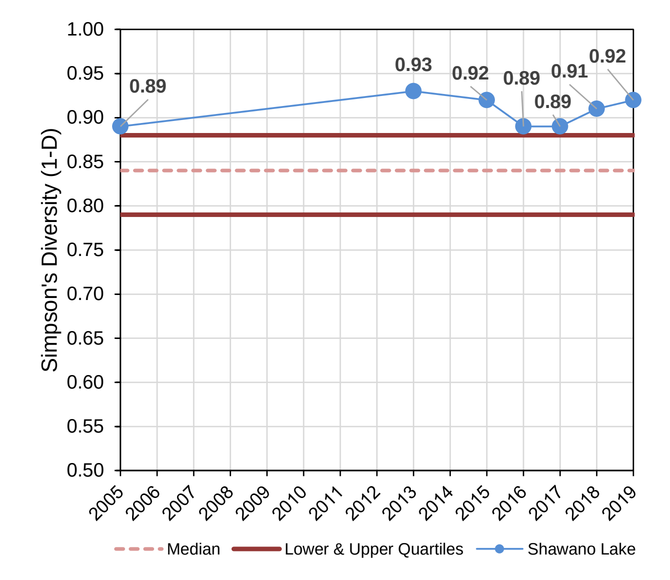


Figure 3.5-12. Shawano Lake Simpson's diversity index. Lower and upper quartiles and median value represent are based on data from lakes in the North Central Hardwood forest (NCHF) ecoregion. Regional and State data calculated with Onterra and WDNR data.

In other words, if two plants were randomly sampled from Shawano Lake in 2019 there would be a 92% chance that those two plants would be different species. This value has remained consistently high across all the surveys indicating that Shawano lake has a higher diversity of plant species than similar lakes in the ecoregion.

One way to visualize the diversity of Shawano Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species. Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while wild celery was found at 33% of the littoral sampling locations in 2019 (littoral occurrence), it's relative frequency of occurrence was 10% (Figure 3.5-13). Explained another way, if 100 plants were randomly sampled from Shawano Lake in 2019, 10 of them would have been wild celery, 12 slender, southern, or northern naiad, 9 coontail, etc. In most of the survey years 50% of Shawano Lake's plant community was comprised of just five to six species: wild celery, naiad species, coontail, common waterweed, forked duckweed, and in some years, Eurasian watermilfoil. As seen in Figure 3.5-13 this species distribution has remained largely the same through the survey years. This dominance of the plant community by a low number of species can result in lower species diversity however, as discussed above, Shawano lake has an excellent species diversity value that has also remined high across survey years. In 2016 and 2017 only four species comprised over 50% of the plant community in Shawano Lake. This displays a small decrease in evenness of species distribution in those years which is also reflected above in figure 3.5-3 in which the average number of native species per vegetated sampling location also experienced a small decrease in those years.

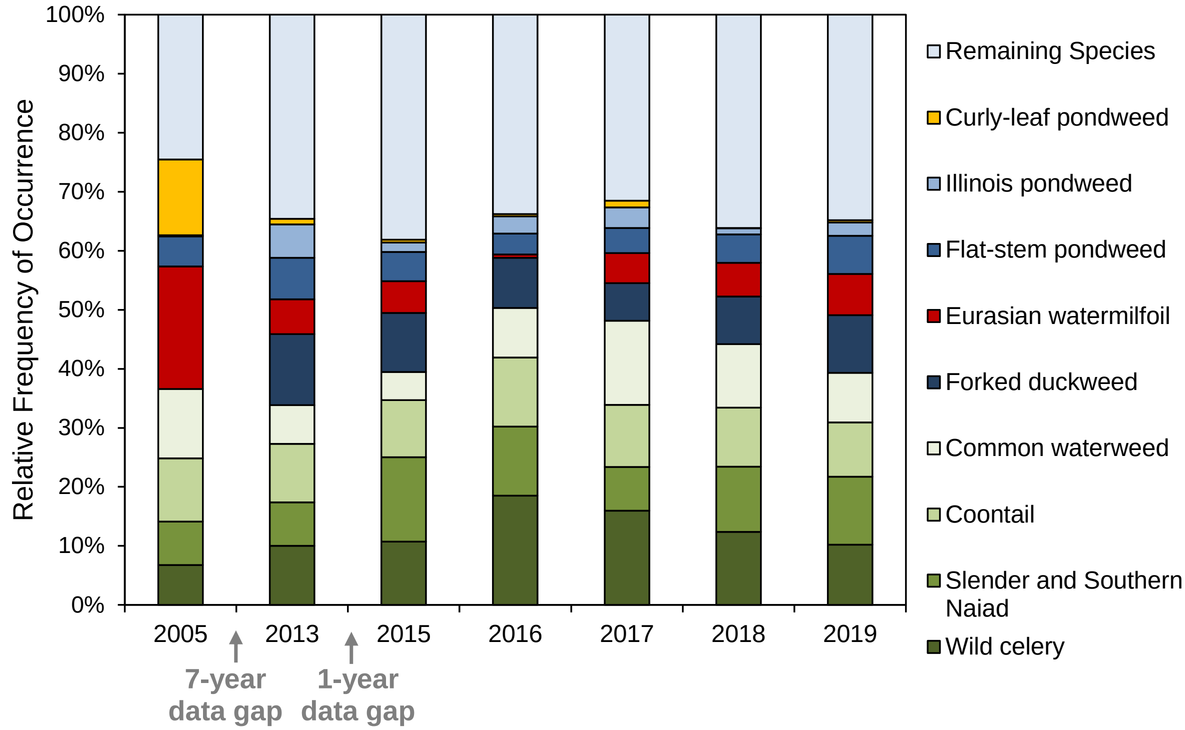


Figure 3.5-13. Shawano Lake relative aquatic plant relative frequency of occurrence.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. Because there were no other plant surveys completed on Shawano lake in 2019 all of the 37 plants sampled during the point-intercept survey were included in the calculations for this analysis. Figure 3.5-14 (top left frame) shows that the native species richness for Shawano Lake is well above the Northern Central Hardwood Forests Ecoregion and Wisconsin State medians.

The species that are present in Shawano Lake are indicative of high-quality conditions. Data collected from the aquatic plant surveys show that the average conservatism value (6.5) is above the North Central Hardwood Forest Lakes Ecoregion and Wisconsin State medians (Figure 3.5-14, top right frame), indicating that several of the plant species found in Shawano Lake are considered sensitive to environmental disturbance and their presence signifies above average environmental conditions. Combining Shawano Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in very high value of 39.5; well above the median values for the ecoregion and state (Figure 3.5-14, bottom frame), and further illustrating the high quality of Shawano Lake's plant community.

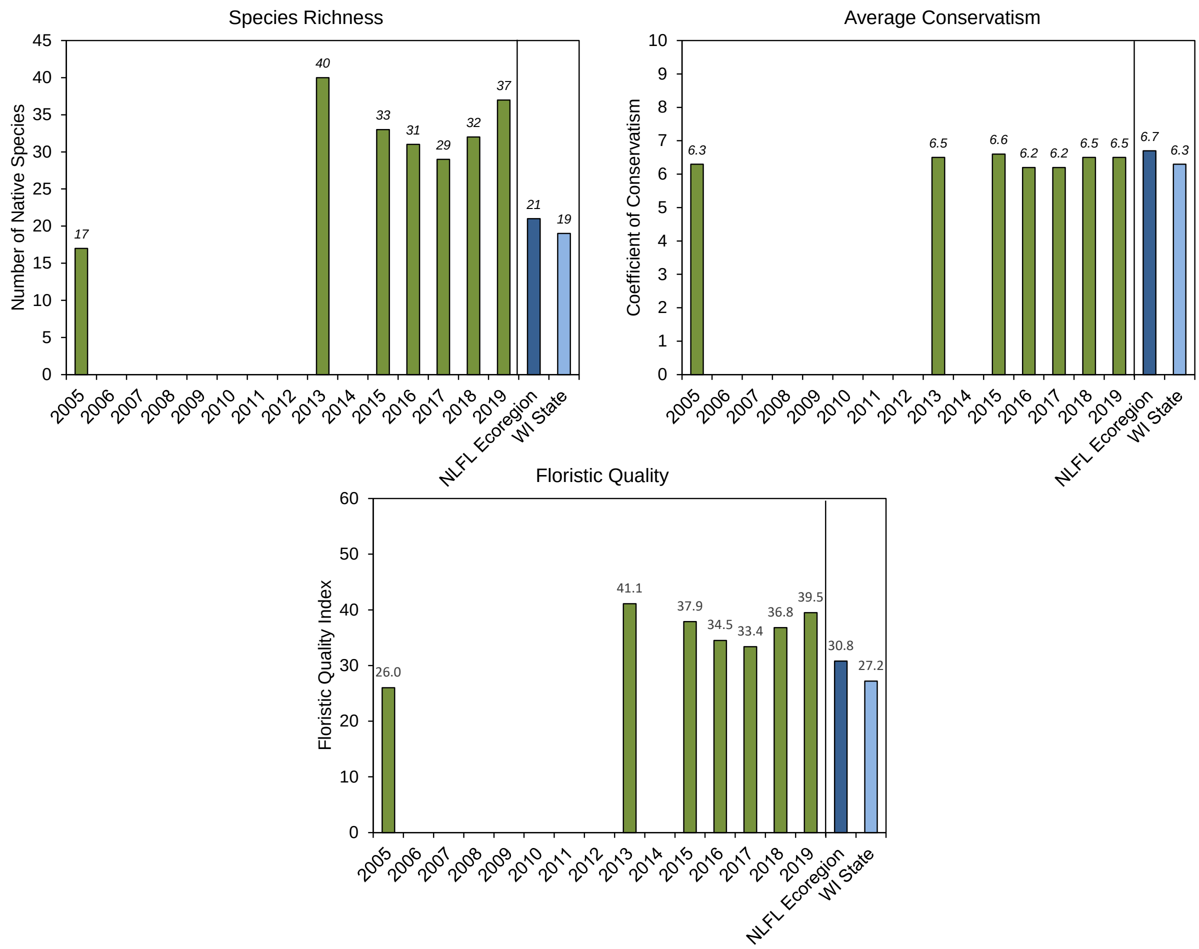


Figure 3.5-14. Shawano Lake species richness, average conservatism, and floristic quality. Analysis following Nichols (1999) where NCHF = North Central Hardwood Forests Ecoregion.

The high quality of Shawano Lake's plant community is also indicated by the abundance of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The emergent and floating-leaf plant communities were first mapped by Onterra in 2013. The 2013 community mapping survey indicates that approximately 226.3 acres (3.6%) of the 6,215 acre-lake contain these types of plant communities (Maps 3 & 4). There were 19 floating-leaf and emergent plant species located on Shawano Lake during this survey, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft. The full species list from this survey is included in table 3.5-1. Unless prompted by a specific rational, Onterra generally recommends completion of emergent and floating-leaf mapping surveys approximately every 10 years to allow sufficient time for changes to manifest.

Photograph 3.5-12 Square-stem spikerush (*Eleocharis quadrangulata*). Photo credit Onterra

During the 2013 emergent and floating-leaf community mapping survey an emergent species listed as endangered in Wisconsin was identified and recorded. The state-endangered square-stem spike-rush (*Eleocharis quadrangulata*) was located in a few locations around Shawano Lake in 2013 (Figure 3.5-13). Square-stem spike-rush is listed as uncommon globally and can only be found in a handful of locations in Wisconsin. Because of the threat of extirpation from Wisconsin, this species is listed as critically imperiled in the state, and removal of this plant without an endangered species permit is illegal in Wisconsin. This species was observed forming relatively large contiguous stands, which provide structural habitat for wildlife, stabilize bottom sediments, and buffer the shoreline from wave action. Another aquatic plant species, American shoreweed, has been documented from Shawano Lake that is listed as a species of special concern.

Because the community mapping survey represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Shawano Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-Native Aquatic Plants in Shawano Lake

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

Curly-leaf pondweed

Some basic life-cycle information for curly-leaf pondweed (CLP) was provided in the primer of the Aquatic Plants section. As mentioned previously, CLP (Photograph 3.5-13) is typically at peak growth early in the growing season. The advanced growth in spring gives the plant a significant head start over native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition (James et al. 2002). However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

Photograph 3.5-13. Curly-leaf pondweed. Photo credit Onterra

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes multiple years (5 or more) of controlling the same area to deplete the existing turion bank within the sediment. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

The point-intercept surveys conducted on Shawano Lake have occurred at the end of July or later. At this time of year, CLP has almost completely died back for the year and therefore cannot be assessed through these surveys. Therefore, an Early Season AIS (ESAIS) Mapping Survey is used to document the population of CLP within Shawano Lake.

During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >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* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

It is not known when CLP was first introduced to Shawano Lake, but studies conducted in 1993 documented its presence indicating it has been present in Shawano Lake for at least 20 years. Onterra ecologists conducted the Early-Season Aquatic Invasive Species Survey in early June, 2013. During this meander-based survey of Shawano Lake's littoral zone, areas of CLP were located and mapped (Map 6). In 2013, CLP was located in areas of the littoral zone that were comprised of soft sediments to a maximum depth of 14 feet, mainly the western and extreme eastern portions of the lake.

In total, approximately 1,543 acres of colonized CLP were mapped in Shawano Lake in June 2013, of which approximately 496 acres (32%) were classified as *dominant* or greater (Figure 9). The largest surface-matted CLP colony was located off shore from the Swan Acre Drive boat landing, along the south shore in the eastern portion of the lake. The CLP within this area was extremely dense, making navigation through this area nearly impossible. Another large surface-matted area of CLP was located off the southern shore in the western portion of the lake, along with a number of *highly dominant* and *dominant* colonies. While large, dense colonies of CLP were located in 2013, the majority of the CLP located was comprised of *scattered* or *highly scattered* colonies. While CLP populations fluctuate from year to year, this survey provides sufficient information to understand the level of CLP within the system.

Eurasian Watermilfoil

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, 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. 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 was officially documented in Shawano Lake in 1994, though studies conducted prior to 1994 indicated its presence in the lake. Genetic analysis has indicated that Shawano Lake contains populations of both pure-strain EWM and populations of hybrid EWM (*Myriophyllum spicatum x sibiricum*, HWM). Although an exhaustive and systematic study of hybridity was not conducted on Shawano Lake, the vast majority of samples analyzed on Shawano Lake consist of pure-strain EWM and this genotype potentially comprise the majority of the invasive milfoil population of the lake. Unless specifically indicated, this report will use "EWM" when discussing the invasive milfoil (EWM and HWM) population of Shawano Lake.

Shawano Lake 2016 Whole-Lake 2,4-D Amine Treatment

Starting in 2013, management strategies targeting EWM were discussed within strategic planning sessions, with SAWM expressing their desire to attempt to manage the entire EWM population within Shawano Lake. EWM management is difficult on any lake, but numerous factors about the Shawano Lake ecosystem compound the difficulty of achieving management goals. Ultimately, it was determined to pursue a whole-lake 2,4-D amine treatment strategy to manage EWM on Shawano Lake. A trial 2,4-D spot treatment was conducted in 2014 to evaluate some of the implementation challenges present in the system.

Whole-lake treatments have become more widely utilized by many lake managers (and public sector regulatory partners) as they impact the entire EWM population at once. This minimizes the repeated need for exposing the lake to herbicides as is required when engaged in an annual spot treatment program. Liquid 2,4-D amine whole-lake treatments are the most common form of whole-lake treatment in Wisconsin, as they are economical and numerous case studies exist to help understand potential target and non-target impacts. Properly implemented whole-lake 2,4-D treatments can be highly effective, with minimal EWM, often zero, being detected for a year or two following the treatment (Figure 3.5-15, left frame). Some whole-lake 2,4-D treatments have been effective at reducing EWM populations for 5-6 years following the application. Following the same herbicide use pattern, lakes that had a hybrid EWM (HWM) component to their invasive watermilfoil populations were reduced the year following treatment to a lesser degree than similar pure EWM populations (Figure 3.5-15, right frame). In almost all HWM populations, rebound took less time and the rebounded populations were at much higher frequencies than EWM populations. As discussed above, Shawano Lake contains a mixed population of EWM and HWM.

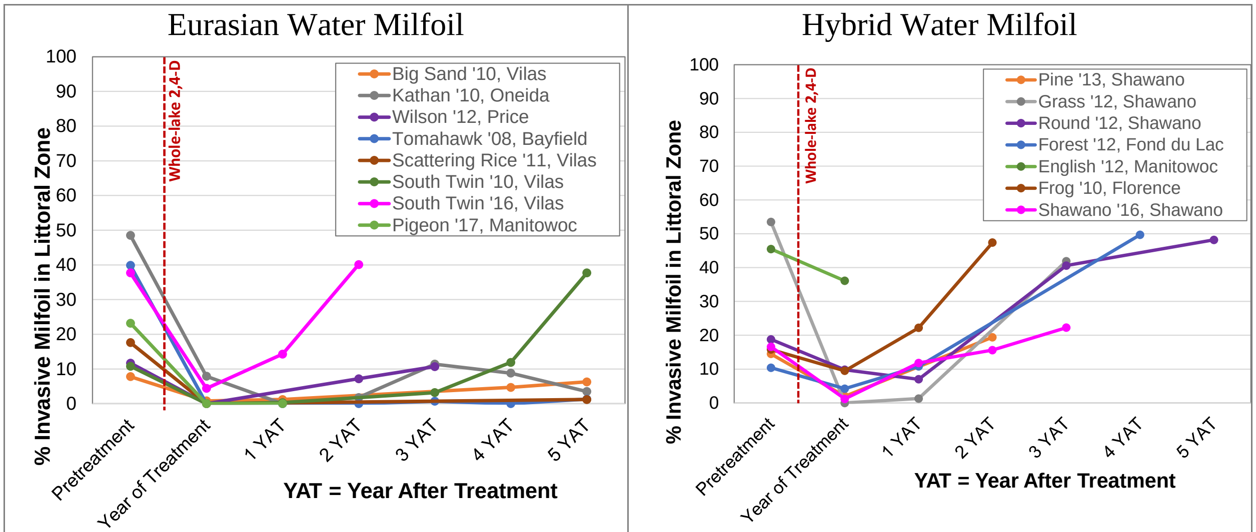


Figure 3.5-15. Littoral frequency of occurrence of invasive milfoil in lakes managed with large-scale 2,4-D treatments.

During the planning process, Onterra and SAWM investigated three possible large-scale herbicide treatment options: 2,4-D, combination of 2,4-D and endothall, and fluridone. Ultimately, the decision was made to use liquid 2,4-D amine in Shawano Lake in 2016. The decision was based off the desire to balance EWM control, native plant selectivity, and overall cost of implementation. SAWM and Onterra believe that the predicted outcomes of 2,4-D use (efficacy and selectivity) are better understood than the other options explored. That being said, concerns over a higher EWM recovery potential exist following the treatment.

The whole-lake 2,4-D treatment on Shawano Lake was designed with a target lake-wide concentration of approximately 0.35 ppm ae. The observed 1-7 day after treatment (DAT) average surface 2,4-D concentration during the 2016 treatment on Shawano Lake was 0.452 ppm ae, falling above the target lake-wide concentration. This was one of the largest intentionally planned whole-lake 2,4-D treatment that has ever occurred, so there were uncertainties if the same principals of dissipation and mixing would scale up. Onterra believes the execution of the treatment plan went well. However, the herbicide exposure time was much shorter than was projected.

In some cases, the biological breakdown of 2,4-D through microbial activity has been slower or faster than typically observed. Nault et al. 2018 indicated the 2,4-D half-life was shown to range from 4-76 days within the 28 lakes studies, with the "rate of herbicide degradation to be slower in lower-nutrient seepage lakes" (Nault et al. 2018). Adding 13 additional Onterra-monitored projects to this dataset yields a mean 2,4-D half-life of approximately 30 days. The 2,4-D half-life was 8 days on Shawano Lake and by 14 DAT, the herbicide degraded to levels at or near the minimum detection limit. This extremely fast herbicide degradation pattern was greater than anticipated. Overall, the target whole-lake concentration was met (actually exceeded), but the exposure time was far shorter than expected. Additional information on the planning and implementation of the control action can be found within *2016 EWM Monitoring & Control Strategy Assessment Report* (Mar29-2016) and *2016-2017 Final EWM Monitoring & Control Strategy Assessment Report* (April5-2018).

Point-intercept surveys in 2013 and 2015 indicate that the EWM population of Shawano Lake was approximately 17% of the lake where plants grow (littoral zone) (Figure 3.5-16). The 2016 *year of treatment* point-intercept survey found the EWM littoral frequency of occurrence to be 1.2%, representing a statistically valid decrease (92.9% decline) in the EWM population from 2015 to 2016. EWM population rebound occurred in the years following the treatment, with the 2018 littoral frequency of occurrence being just slightly below pretreatment levels and 2019 being slightly higher than pretreatment.

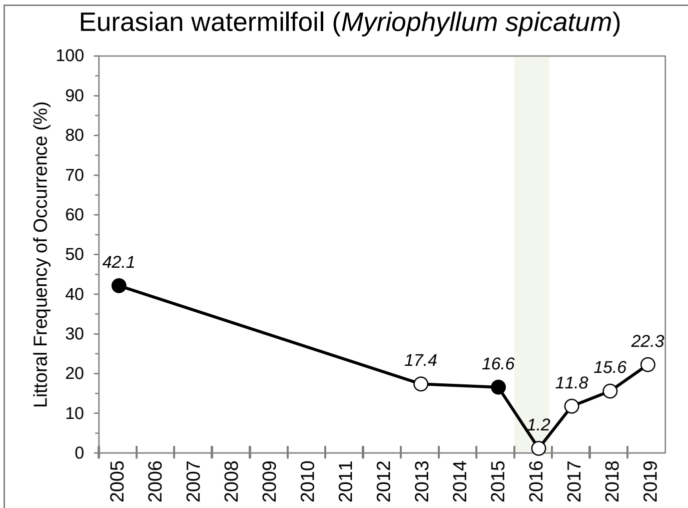


Figure 3.5-16. Littoral frequency of occurrence of EWM from 2005-2018. Open circle represents statistically valid change from previous survey.

Photograph 3.5-15. EWM fragment with adventitious roots. Photo credit Onterra.

Late-Season EWM Mapping Survey

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake to understand where recreation and navigation impairment exists and how to direct management activities. Within this project, a series of AIS mapping surveys allowed this level of data to be understood.

Following the same general methodologies as outlined for the Early Season AIS Survey (for CLP mapping), the Late-Season EWM Mapping Survey is completed in late-summer when EWM is typically at its peak-biomass for the growing season.

Onterra ecologists have conducted annual Late-Season EWM Mapping Surveys on Shawano Lake since 2013. Map 7 shows the most recent EWM mapping survey results. Figure 3.5-17 shows the acreage of colonized EWM as well as the distribution of each density rating. Please note that this figure only represents only the acreage of mapped EWM polygons, not EWM mapped within point-based methodologies (*single or few plants, clumps of plants,* or *small plant colonies*).

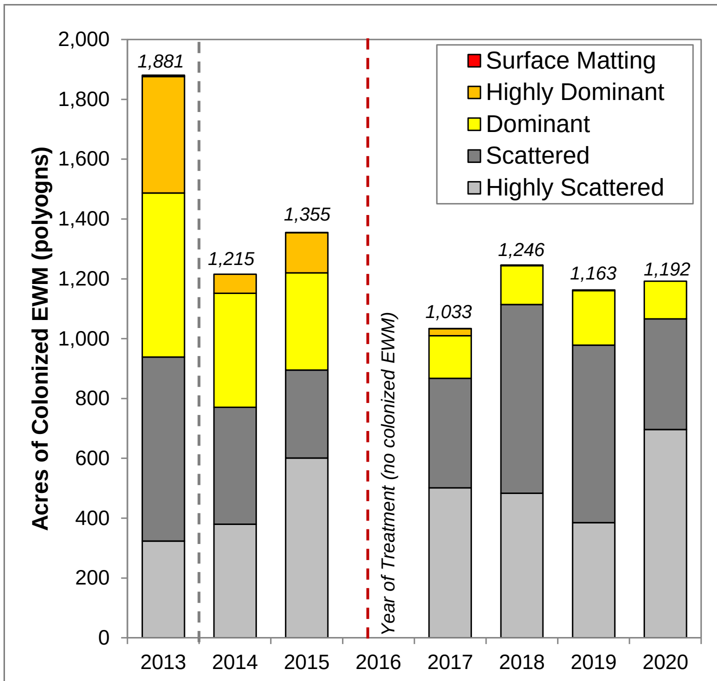


Figure 3.5-17. Acreage of mapped EWM colonies on Shawano Lake from 2013 to 2020. Grey dashed-line indicates 145-acre spot treatment, red dashed-line indicates whole-lake treatment.

During the summer of 2014, an approximately 145-acre 2,4-D amine spot treatment occurred on Shawano Lake, reducing dense EWM within and around the application area (Figure 13). While the EWM within the targeted area was mostly still absent in 2015, some of the EWM colonies adjacent rebounded. During the year of the 2016 whole-lake 2,4-D treatment, only non-colonized EWM was detected. Surveys in 2017-2020 indicate that while EWM has rebounded throughout much of its 2015 footprint, the EWM exists at lower densities.

WDNR Long-Term EWM Trends Monitoring Research Project

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. This information is presented here to understand how unmanaged systems in this ecoregion compare to Shawano Lake.

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). Figure 3.6-18 shows the EWM populations of three unmanaged EWM lakes in the Northern Central Hardwood Forests ecoregion. To clarify, these lakes have not conducted herbicide treatments or any other forms of strategic EWM management. The EWM population of Montana Lake (Oconto-Marinette counties) has been variable over time, whereas the EWM population of Crystal Lake (Marquette County) has been extremely stable at around 20% during the timeframe of study. After first being detected in 2005, the EWM population of Crooked Lake (Adams County) was below 3% for at least 10 years, and then increased to 7.4% in 2019 after being in the lake for 14 years.

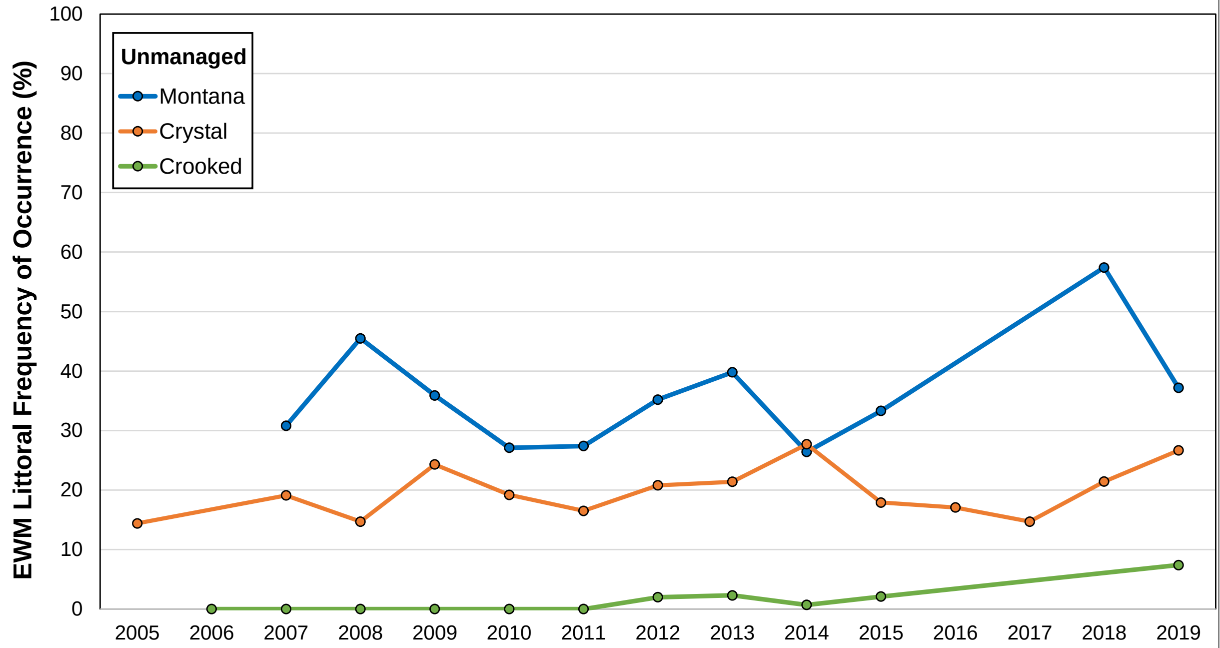


Figure 3.5-18. Littoral frequency of occurrence of Unmanaged EWM populations in the Northern Central Hardwood Forests ecoregion. Data provided by and used with permission from WDNR.

The Science Behind the "So-Called" Super Weed (Nault 2016)

In 2015, the WDNR investigated the most recent point-intercept data from almost 400 Wisconsin Lakes that had confirmed EWM populations. These data show that approximately 65% of these lakes had EWM populations of 10% or less (Figure 3.5-19). At these low population levels, there is not likely to be impacts to recreation and navigation, nor changes in ecological function. At the time of this writing, Shawano Lake's most recent point-intercept survey (2019) yielded EWM at 22.3% of the littoral sampling locations. Only approximately 15% of the lakes in the survey had EWM populations of 30% or higher. This may be due to the fact that the EWM population on some lakes may never reach that level or that management activities may have been enacted to suppress the EWM population to lower levels.

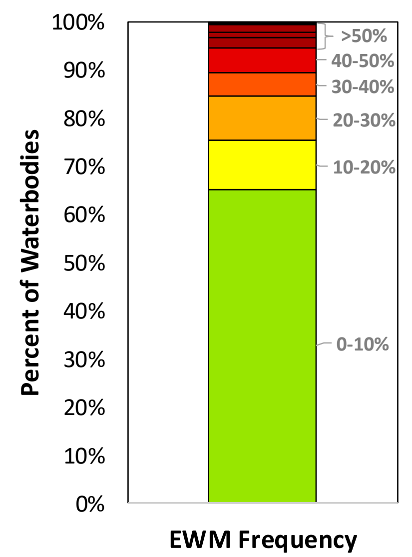


Figure 3.5-19. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

Shawano Lake Future EWM Management Discussions

During the Planning Committee meetings, Onterra outlined three broad EWM population management perspectives for consideration, including a generic potential action plan for each (Figure 3.5-20). Onterra extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the SAWM to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Shawano Lake ecosystem. These chapters are included as Appendix E. The SAWM Planning Committee will reviewed these management perspectives in the context of perceived riparian stakeholder support, which is discussed in the subsequent sub-section.

1. **No Coordinated Active Management**
   (Let Nature Take its Course)
   - Focus on education of manual removal methods for property owners
2. **Reduce EWM Population on a lake-wide level**
   (Lake-Wide Population Management)
   - Would likely rely on herbicide treatment strategies (risk assessment)
   - Will not "eradicate" EWM
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment**
   (Nuisance Control)
   - May be accomplished through professional hand-harvesting of areas or lanes
   - Hand-harvesting may not be able to accomplish this goal and herbicides or a mechanical harvester may be required

Figure 3.5-20. Potential EWM Management Perspectives

<u>Let Nature Take its Course:</u> In some instances, the EWM population of a lake may plateau or reduce without conducting active management, as shown in the WDNR Long-Term EWM Trends Monitoring Research Project on Figure 3.5-21. Some lake groups decide to periodically monitor the EWM population, typically through a semi-annual point-intercept survey, but do not coordinate active management (e.g., hand-harvesting or herbicide treatments). This requires that the riparians tolerate the conditions caused by the EWM, acknowledging that some years may be problematic to recreation, navigation, and aesthetics. Individual riparians may choose to hand-remove the EWM within their recreational footprint, but most often the lake group chooses not to assist financially or with securing permits (only necessary if Diver Assisted Suction Harvest [DASH] is used). In some instances, the lake group may select this management goal, but also set an EWM population threshold or "trigger" where they would revisit their management strategy if the population reached that level. Said another way, the lake group would let nature take its course up until populations reached a certain lake-wide level or site-specific density threshold. At that time, the lake group would investigate whether active management measures may be justified.

<u>Lake-Wide Population Management:</u> 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 be 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. It must also be acknowledged that some lake managers and natural resource regulators question whether that is an achievable goal as management actions have unintended collateral impacts.

In early EWM populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. A lake-wide population management strategy was implemented in 2016. However, the management action yielded only a few years of reduced EWM as measured by the point-intercept survey. The EWM mapping surveys document a wide-scale presence in the lake, but at lower densities than before the treatment.

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 the EWM population on their lake is the reduced recreation, navigation, and aesthetics compared to before EWM 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 these cultural ecosystem services.

A nuisance control strategy typically involves creating a strategic network of common use lanes and riparian spokes through EWM colonies, typically with a mechanical harvesting (i.e., weed cutting machine). SAWM has used a combination of mechanical harvesting and herbicide treatments to target nuisance aquatic plant conditions on Shawano Lake, but not specifically for EWM management.

Pale-yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.6-14). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin’s wetland areas forming large monotypic colonies and displacing valuable native wetland species.

Photograph 3.5-14. Clump of the non-native pale-yellow iris mixed with the native blue-flag iris. Photo credit Onterra.

Pale-yellow iris is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated. Specific surveys aimed at documenting the population of pale-yellow iris on

Shawano Lake have not taken place. However, this species has been documented within Shawano County from both upstream and downstream locations.

Purple loosestrife

Purple loosestrife 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.

Isolated, scattered populations of purple loosestrife were located along the shorelines of Shawano Lake in 2013 (Maps 5 & 6). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by non-native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the removal of the plant from the shorelines around Shawano Lake

Navigability Issues on Shawano Lake

As discussed within the introduction strategy, SAWM has been conducting a nuisance control strategy utilizing aquatic herbicides and mechanical harvesting form many years. The goal of these activities has been solely to provide increased navigational abilities within particular areas. As a part of this program, herbicides are applied in the form of 100-ft wide lanes in which watercraft can travel through areas of dense aquatic plant growth (Map 8). Applied in early-summer, the control actions are likely targeting CLP that has not died back yet, as well as EWM, common waterweed, southern naiad, and miscellaneous pondweeds.

Map 8 shows the seven navigation lanes that SAWM has historically maintained, primarily through the use of herbicide application (but also with mechanical harvesting). Successful implementation of this strategy would result in the greatest control (plant mortality) within the lanes where the herbicide was directly applied. Secondary impacts (plant injury) may also occur in nearby areas to the treatment lanes, but these plants typically fully recover in 4-6 weeks following the treatment. If plant regrowth occurs within the treatment lanes, adequate herbicide concentration and exposure times were not met resulting in plant injury vs plant mortality.

Advantages of herbicide use in this situation include the immediacy and longevity of results. Disadvantages include, the plant biomass is not removed from the waterbody, but instead the plant tissue is left to decay; high per acre cost; and the use of herbicides is often controversial among stakeholders.

The abundance of largely non-rooted plants such as common waterweed and southern naiad produce large floating mats of these species in many areas of the lake. In the past, SAWM would use its mechanical harvesting equipment to pick up these *floaters* using the mechanical harvester in its shallowest setting. Aside from targeting the floating plant fragments, mechanical harvesting activities are focused on assisting individual land owners. These management activities are supported by the current management planning effort. While mechanical harvesting does produce fragments, the amount of fragments caused by this method is extremely small in comparison with those made from wind/wave action.

As with all aquatic plant management techniques, harvesting has its advantages and disadvantages. Advantages include the removal of plants and associated nutrients from the waterbody, immediate relief of nuisance plants, harvesting is less controversial than chemical use, and specific areas can be targeted accurately. Disadvantages include sediment re-suspension, fragmentation of plants, and need for repeated cuttings within a single year. Mechanical harvesting in areas that contain pioneering aquatic invasive species populations may increase the rate of spread of these species as it 'drags' cut fragments to other parts of the system. This is not applicable to Shawano Lake, as the EWM and CLP populations of Shawano Lake have been well established for many years and already occur in all areas of the lake that contain suitable habitat.

Stakeholder Survey Responses to Aquatic Vegetation in Shawano Lake

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 2020 survey was 53% and the 2015 survey was 56%. In instances where stakeholder survey response rates are 60% or above, the results can generally be interpreted as being a statistical representation of the population. While the survey response rate may not be sufficient to be a statistical representation of the Shawano Lake property owners, the SAWM believe the sentiments of the respondents is sufficient to provide a loose indication of riparian preferences and concerns. Said another way, these are the best quantitative data the SAWM has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

In both 2015 and 2019, riparian and SAWM members were asked how often aquatic plant growth negatively impacts their enjoyment of Shawano Waterways (Figure 3.5-21). Perceptions appear relatively stable, with most respondents indicating some level of native impact from aquatic plants.

Question 15 (2015) & 23 (2019): During open water season how often does aquatic plant growth, including algae, negatively impact your enjoyment of the Shawano Waterways?

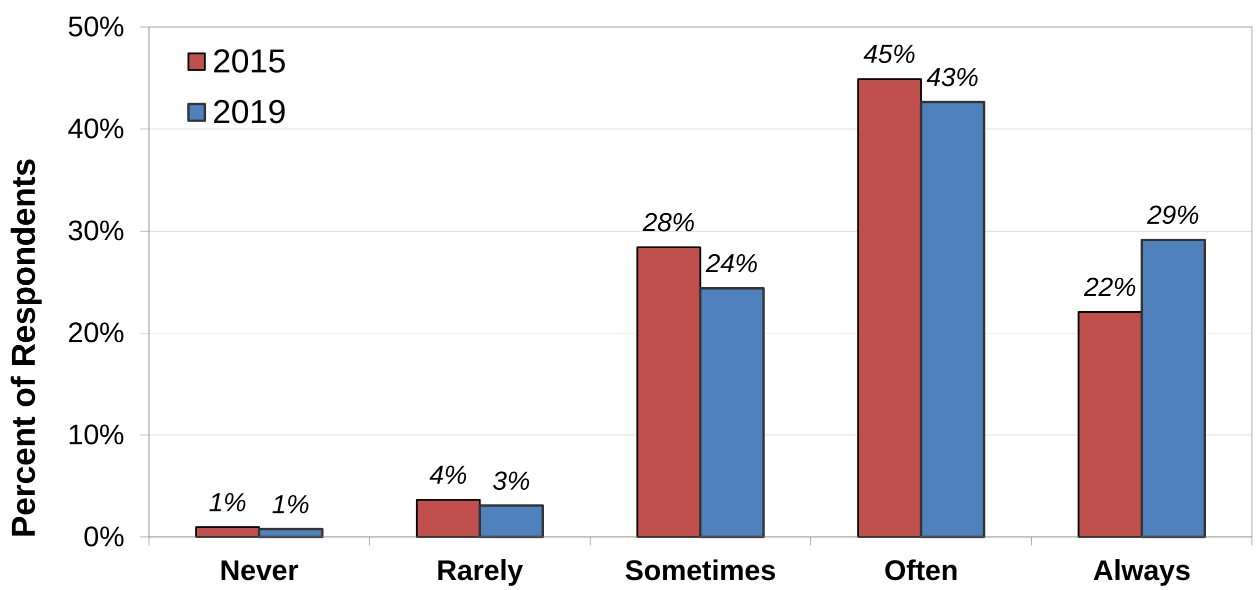
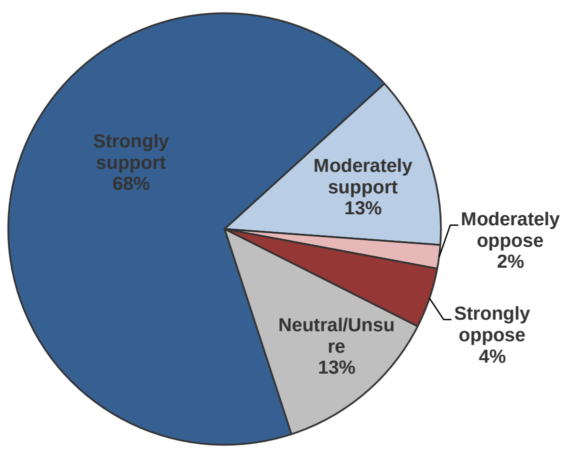


Figure 3.5-21. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

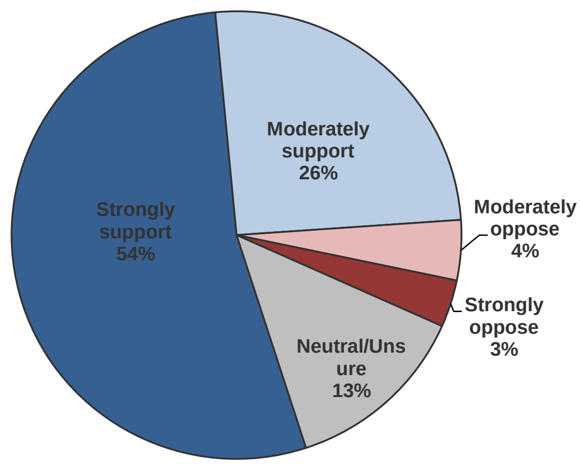
In both 2015 and 2019, riparian and SAWM members were also asked about a number of management techniques for managing non-native aquatic plants. Figure 3.5-22 highlights the responses for herbicide treatment and mechanical harvesting. Looking at the pooled "moderate" and "strong" responses for support vs opposition, the general position on herbicide treatment has remained the same over this time period. The level of support has shifted slightly, with moderate support in 2019 having a larger proportion than it did in 2015. The level of support for mechanical harvesting (pooled *moderately support* and *strongly support*) has increased from 70% in 2015 to 80% in 2019.

Question 21 (2015) & 27 (2019): Invasive, non-native aquatic plant species may be managed using several techniques. What is your level of support for the responsible use of the following techniques on the Shawano Waterways for the purposes of managing invasive, non-native aquatic plant species?

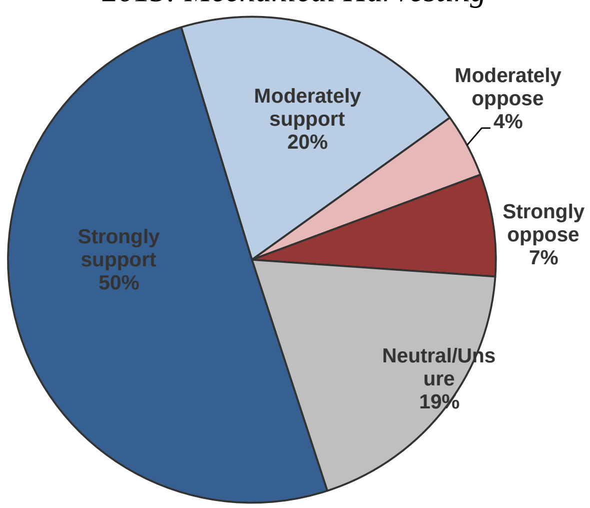
2015: Herbicide Treatment



2019: Herbicide Treatment



2015: Mechanical Harvesting



2019: Mechanical Harvesting

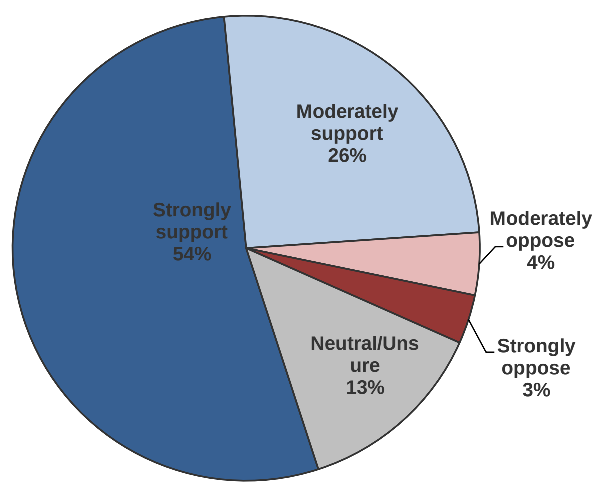


Figure 3.5-22. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Starting in 2013, SAWM embarked on a project to potentially impact the entire lake's population of EWM. This non-native plant was thought to be a major contributor to the nuisance aquatic plant conditions on the system. A whole-lake 2,4-D treatment occurred during the spring of 2016. Following the 2016 whole-lake 2,4-D treatment, post treatment assessments indicate that while EWM has rebounded throughout much of its 2015 footprint, the EWM exists at lower densities. The data clearly show a reduction during the year of treatment, with rebound occurring as soon as the year after treatment. As measured by the point-intercept survey, the EWM was almost back to pretreatment frequencies by the third summer after treatment. The EWM mapping data indicate that EWM occupies a slightly smaller footprint compared to pretreatment and is at a lower overall density.

Prior to the treatment, planners discussed a long-term goal of achieving 3-5 years of reduced EWM. For Shawano Lake, the point-intercept method indicates 2-3 years of reduced EWM and the EWM mapping surveys indicate 4 or more years. The 2020 stakeholder survey asked riparians if they believed the 2016 whole-lake treatment met short-term (1 year) and long-term (3 years) reductions. Approximately 61% of respondents believed that short-term goals were met, but only 15.5% believed long-term goals were met (Figures 3.5-23 and 3.5-24). The majority of respondents (53%) were unsure if the 2016 treatment was successful after three years. The respondents' perceptions closely align with the results of the professional monitoring surveys.

Question 29: Do you believe the herbicide treatment described above was successful in controlling Eurasian watermilfoil short-term (one year)?

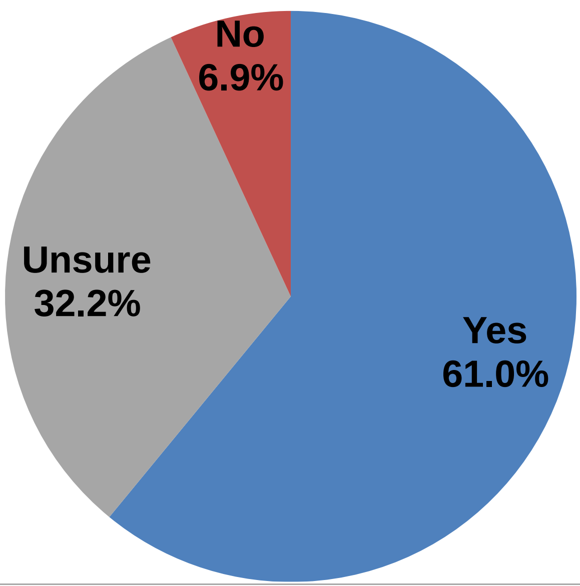


Figure 3.5-23. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 30: Do you believe the herbicide treatment described above was successful in controlling Eurasian watermilfoil long-term (three years)?

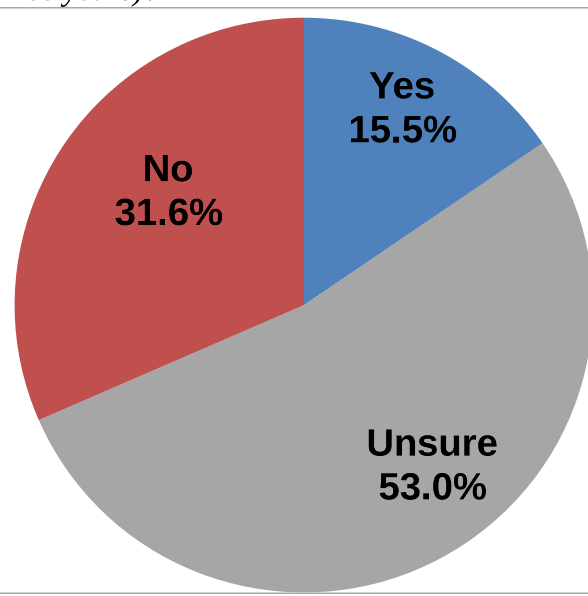


Figure 3.5-24. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

The SAWM planning committee wanted to understand stakeholder perceptions as it relates to future herbicide management of EWM. Approximately 83% of respondents indicate support (pooled *moderately support* and *strongly support*) for this form of management (Figure 3.5-25). Of those respondents that indicated opposition for a future targeted EWM herbicide treatment, potential impacts to non-plant species was the most commonly cited reason, followed by potential impacts to human health, and future impacts are unknown (Appendix B, Question # 32).

Question 31: What is your level of support or opposition for future aquatic herbicide use to target Eurasian watermilfoil in Shawano Lake?

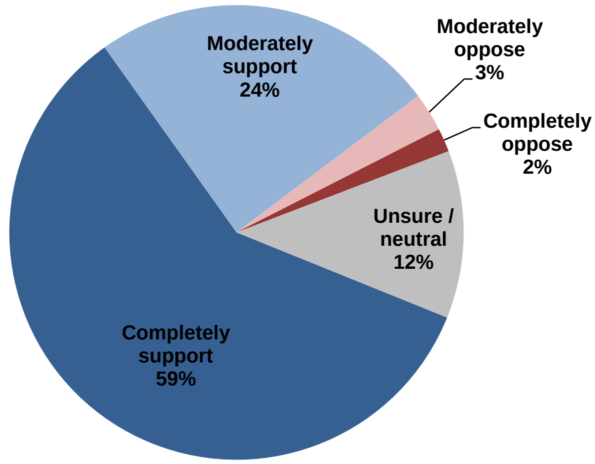


Figure 3.5-25. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.6 Aquatic Invasive Species in Shawano Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Shawano Lake within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are 10 AIS present (Table 3.6-1).

Table 3.6-1. AIS present within Shawano Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil/ Hybrid watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Reed canary grass	*Phalaris arundinacea*	Section 3.5 – AIS (below)
	Giant reed	*Phragmites australis subsp. australis*	Section 3.5 – AIS (below)
Invertebrates	Zebra mussel	*Dreissena polymorpha*	Section 3.1 – Water Quality
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 – AIS (below)
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 – AIS (below)
	Banded mystery snail	*Viviparus georgianus*	Section 3.5 – AIS (below)
	Faucet snail	*Bithynia tentaculata*	Section 3.5 – AIS (below)
Fish	Common carp	*Cyprinus carpio*	Section 3.5 – AIS (below)

Figure 3.6-1 displays the aquatic invasive species that Shawano Lake stakeholders believe are in Shawano Lake. Only the species present in Shawano Lake are discussed below or within their respective locations listed in Table 3.6-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS 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

Reed Canary Grass

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

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

Giant Reed

Giant reed (*Phragmites australis* subsp. *australis*) is a non-native perennial grass that can grow up to 20' tall. Its seeds are easily dispersed by wind and water, and it also spreads by rhizome "runners" or fragments. Once introduced, it can take over rapidly, creating dense stands that outcompete native plants. Invasive *Phragmites* can alter wetland hydrology, increase fire hazard potential, and degrade wildlife habitat due to its dense growth and monoculture tendency (USDA-NRCS 2012). Shawano Lake contains populations of both non-native and native giant reed (*Phragmites australis* subsp. *americanus*). In general, the non-native occurrences are along the shoreline and roadway ditches, where the native occurrences are in off-shore emergent plant communities (Maps 3 & 4).

Aquatic Animals

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell (Photograph 3.6-1). They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

Photograph 3.6-1. Rusty crayfish. Photo credit: GLIFWC

Mystery snails

There are four types of mystery snails found within Wisconsin waters, with the brown mystery snail (*Campleoma decisum*) being the only species native. They are called mystery snails because they give birth to fully developed snails that mysteriously appear in spring. The two primary non-native mystery snails in Wisconsin are the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). 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 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

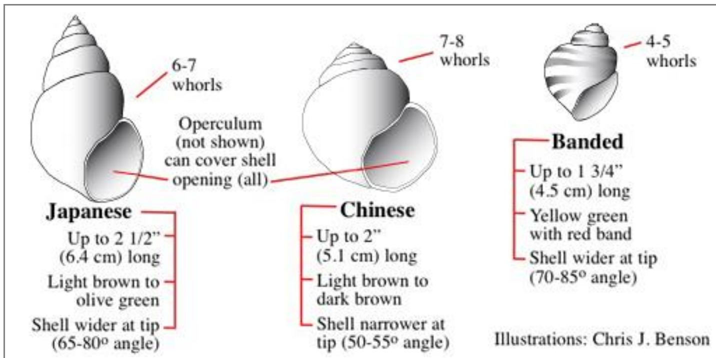


Figure 3.6-1. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (http://www.seagrant.umn.edu/ais/mysterysnail).

Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009). Currently the Japanese mystery snail (*Cipangopaludina japonica*) has only been documented from a handful of waterbodies in northwestern Wisconsin. Chinese and banded mystery snail have both been documented from Shawano Lake, whereas Japanese mystery snail has not.

Faucet snails

Faucet snails (*Bithynia tentaculata*) are small snails with spiral shells that have 4-5 coils, or whorls on them. They are light brown to black, grow to a half-inch long, and are longer than they are wide. They look similar to non-native New Zealand mudsnails, and can be hard to differentiate from several native snail species as well. Faucet snails are native to Europe and were first recorded in the Great Lakes in the 1870s. They can live up to three years, and are intermediate hosts for intestinal trematodes, which cause death in ducks and coots. Faucet snails are primarily spread through the movement of water-related equipment. They are able to close their shell and survive out of water for multiple days. Diligent cleaning of watercrafts and other water-related equipment and gear in between visiting different waterbodies will minimize the chance of spreading these small invaders. Currently, there is no effective population control method for faucet snails (MNDNR 2020). Faucet snails have been identified in approximately 42 waterbodies in Wisconsin including the Lake Winnebago and Mississippi systems. New Zealand mudsnails have been confirmed from less than 20 waterbodies in Wisconsin, primarily around and west of Madison. Faucet snails have both been documented from Shawano Lake, whereas Japanese New Zealand mudsnails have not.

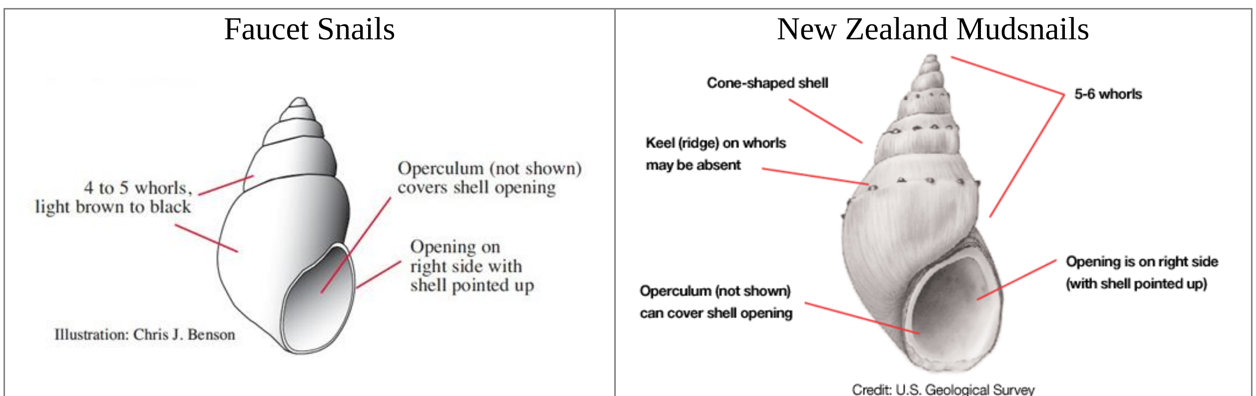


Figure 3.6-2. Identification of non-native faucet snails and New Zealand mudsnails. Courtesy of Minnesota Sea Grant:
(http://www.seagrant.umn.edu/ais/faucetsnail)
(http://www.seagrant.umn.edu/ais/newzealand_mudsnail)

Common Carp

Since the introduction of common carp (*Cyprinus carpio*), an invasive species which originates from Eurasia, to waterbodies in the United States and other countries around the world, numerous studies have documented the deleterious effects these fish have on lake ecosystems. Common carp can survive in a wide range of waterbody conditions, but they reach their greatest densities in shallow, eutrophic systems like Shawano Lake. Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber and Brown 2011).

Following the introduction of common carp to a waterbody, studies have documented declines in submersed aquatic vegetation and increases in total phosphorus and suspended solids, and a shift from a clear, submersed aquatic plant-dominated state to a turbid, algae-dominated state (Bajer and Sorensen 2015). Common carp directly increase nutrients within the water by physical resuspension of bottom sediments through foraging and spawning behavior as well as through excretion (Fischer and Krogman 2013). Common carp foraging behavior also creates more flocculent sediments which are more prone to resuspension from wind. In addition, sediments are also more prone to wind-induced resuspension as aquatic vegetation declines through physical uprooting and decline in light availability due to increases in water turbidity (Lin and Wu 2013). Zooplankton which feed on algae also decline as their refuge from predators within aquatic vegetation disappears. Common carp create a positive feedback mechanism: the direct physical resuspension and uprooting of vegetation indirectly increases the susceptibility of bottom sediments to wind-induced resuspension, and the increased turbidity further decreases aquatic vegetation.

Question 26: Which aquatic invasive species do you believe are in Shawano Lake? Red bars indicate species which have been verified in Shawano Lake; blue bars indicate species which have not been verified in Shawano Lake.

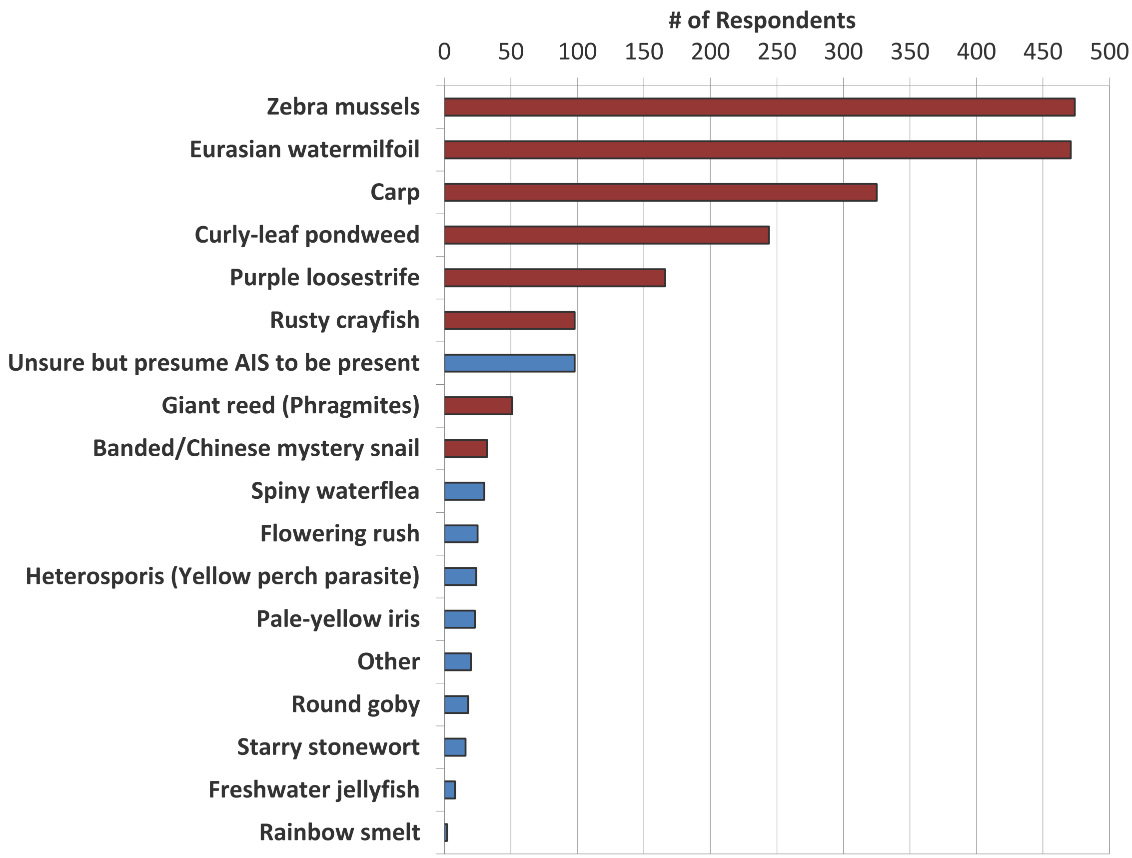


Figure 3.6-3. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.7 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 Shawano Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish 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) personal communications with DNR Fisheries Biologist Jason Breeggemann (WDNR 2020).

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

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

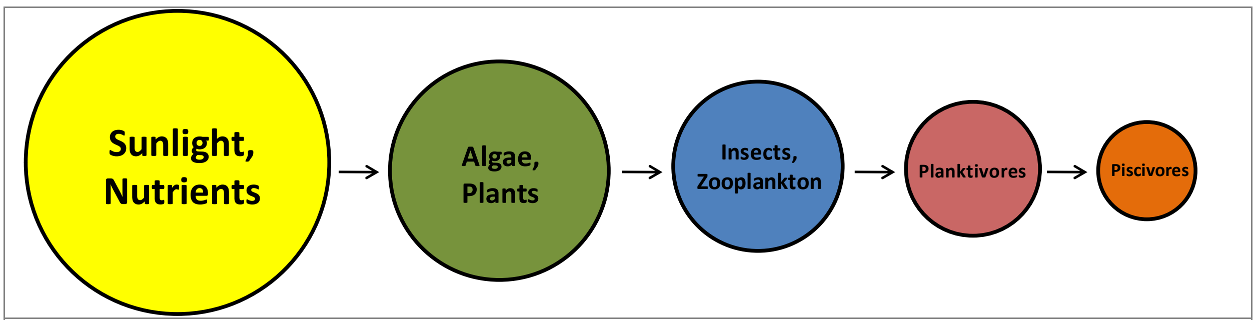


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Shawano Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Shawano Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.7-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past WDNR surveys of Shawano Lake include longnose gar (*Lepisosteus osseus*), rock bass

(*Ambloplites rupestris)*, sturgeon (*Acipenser fulvescens)*, white sucker (*Catostomus commersonii)*, and the yellow bullhead (*Ameiurus natalis*). The invasive common carp (*Cyprinus carpio*) is also present in Shawano Lake, see Section 3.5 for more information.

Shawano Lake also harbors the lake chubsucker (*Erimyzon sucetta*) which is considered a vulnerable species in Wisconsin due to a restricted range, few populations, recent declines or other factors. Its global status, however, is considered secure and at a very low risk for extinction.

Table 3.7-1. Gamefish present in Shawano Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black bullhead *(Ameiurus melas)*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie *(Pomoxis*	7	May - June	Near Chara or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill *(Lepomis macrochirus)*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Bowfin *(Amia calva)*	30	Late April - Early June	Vegetated areas from 2 - 5 ft with soft rootlets, sand or gravel	Fish, crayfish, small rodents, snakes, frogs, turtles
Brown Bullhead *(Ameiurus nebulosus)*	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Largemouth Bass *(Micropterus*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge *(Esox masquinongy)*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike *(Esox lucius)*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed *(Lepomis gibbosus)*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch *(Perca flavescens)*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

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 done, often 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.

Photograph 3.7-1. 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. Shawano Lake has been stocked from 1973 to 2019 with muskellunge, walleye and northern pike (Table 3.7-2).

Photograph 3.7-2. Muskellunge fingerling.

Future stocking efforts of walleye are projected to be consistent following Shawano Lakes' inclusion in the Wisconsin Walleye Initiative. The Initiative was made possible by the governor's office, Department of Natural Resources and statewide partners to maintain the walleye population in Wisconsin's lakes and improve walleye fisheries in lakes capable of sustaining the sportfish (WDNR 2014). Lakes chosen to be included are selected based upon anticipated fingerling survival, natural reproduction opportunities, public access, tribal interest (for ceded territory lakes) and potential impacts to tourism. Stocking rates are randomly assigned to chosen lakes and stocked every other year to avoid competing year classes. Beginning in 2013 and odd years thereafter Shawano Lake was selected to receive a stocking rate of 5 extended growth walleye/acre as funding allows (WDNR 2013).

Table 3.7-2. Stocking data available in Shawano Lake (1973-2019).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1973	Muskellunge	Unspecified	Fingerling	500	11
1974	Muskellunge	Unspecified	Fingerling	500	5
1993	Muskellunge	Unspecified	Fingerling	2400	10.8
1995	Muskellunge	Unspecified	Fingerling	1590	8.8
1997	Muskellunge	Unspecified	Large Fingerling	2500	11.2
2001	Muskellunge	Unspecified	Large Fingerling	6063	10.65
2002	Muskellunge	Unspecified	Large Fingerling	6059	10.63
2003	Muskellunge	Unspecified	Large Fingerling	2496	10.9
2005	Muskellunge	Unspecified	Large Fingerling	2494	10.6
2007	Muskellunge	Upper Wisconsin River	Large Fingerling	1667	13
2009	Muskellunge	Upper Wisconsin River	Large Fingerling	2499	10.6
2011	Muskellunge	Upper Wisconsin River	Large Fingerling	1495	9.4
2013	Muskellunge	Upper Wisconsin River	Large Fingerling	2000	9.7
2018	Muskellunge	Upper Wisconsin River	Large Fingerling	2246	11.7
2011	Walleye	Lake Michigan	Large Fingerling	9,765	6.45
2012	Walleye	Lake Michigan	Fry	1,169,000	0.3
2013	Walleye	Lake Michigan	Fry	500,062	0.3
2013	Walleye	Lake Michigan	Large Fingerling	22,308	7.14
2015	Walleye	Lake Michigan	Large Fingerling	33,358	7.7
2017	Walleye	Lake Michigan	Fry	5,196,000	0.75
2017	Walleye	Lake Michigan	Large Fingerling	31,141	7.75
2018	Walleye	Lake Michigan	Fry	4,448,000	0.75
2019	Walleye	Unspecified	Fry	5,796,000	-
2019	Walleye	Unspecified	Large Fingerling	31,057	7.3
2016	Northern Pike	Mud Lake - Madison Chain of Lakes	Large Fingerling	5,524	8.6

Fishing Activity

Based on data collected from the 2020 riparian stakeholder survey fishing (open-water) was the third most important reason for owning property on or near Shawano Lake (Question #15, Appendix B). Figure 3.7-2 displays the fish that Shawano Lake stakeholders enjoy catching the most, with bluegill/sunfish, crappie and yellow perch being the most popular. Approximately 77% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.7-3). Approximately 85% of respondents who fish Shawano Lake believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.7-4).

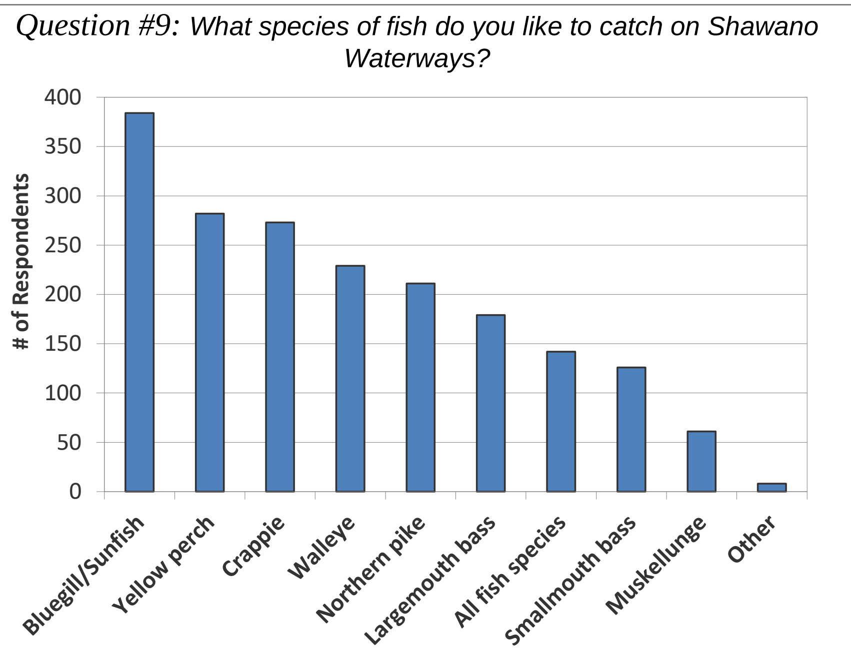


Figure 3.7-2. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

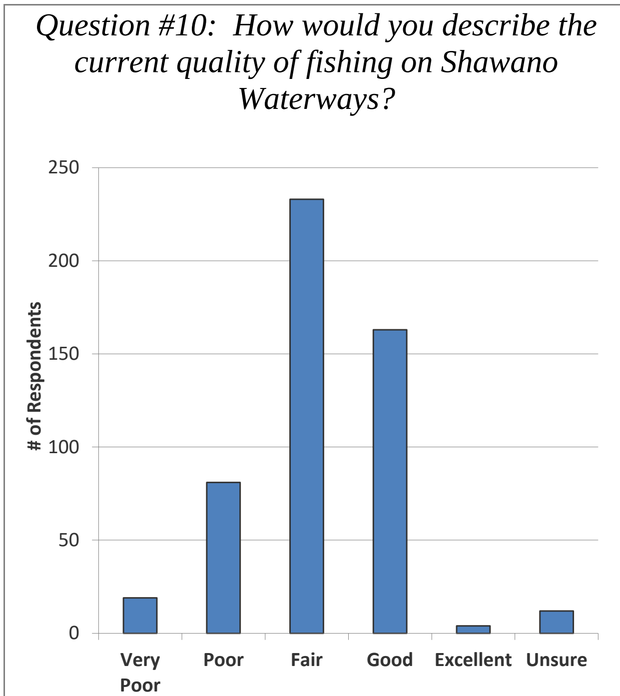


Figure 3.7-3. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

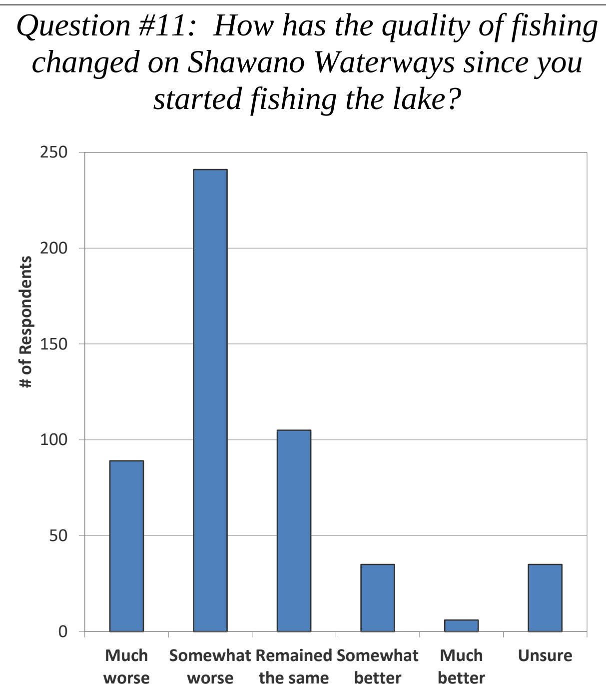


Figure 3.7-4. Select survey responses from the Shawano Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on Shawano Lake represent different population dynamics depending on the species. The results for the stakeholder survey show the gamefish landowners prefer to catch is walleye on Shawano Lake (Figure 3.7-2). Brief summaries of gamefish with fishable populations in Shawano Lake are provided based off of the reports submitted by WDNR fisheries biologist Jason Breeggemann following the fisheries survey completed in 2018. These WDNR summaries are located in Appendix F of this report.

Walleyes are a valued sportfish in Wisconsin. The population estimate for Shawano Lake has increased since the last survey completed in 2014. However, the population density is relatively low at 0.5 adult walleyes per acre. The 2018 data indicates adult walleyes decreased in size by nearly 2 inches since the 2014 survey. This may be an indicator of smaller walleye in the system due to extensive stocking by the WDNR and Walleyes for Tomorrow. Primarily the walleye fishery is supported by stocking efforts (Figure 3.7-2).

Muskellunge, like walleye, are also considered a valued sportfish of Shawano Lake. The 2018 survey results showed a low – moderate density of muskellunge with optimal size structure. This species is meeting the WDNR's management goal of maintaining a trophy muskellunge fishery.

Largemouth bass were captured in moderate to high densities with good size structure in Shawano Lake. No management actions are needed at this time.

Northern Pike were captured in moderate densities but catch rates have declined since the 2014 survey. A significant amount of northern pike spawn in the Shawano Lake Outlet Channel which was not included in the 2018 spring fyke net survey. Consequently, the 2018 survey data may not be representative of the entire population.

Panfish

The panfish present on Shawano Lake represent different population dynamics depending on the species. The results for the stakeholder survey show anglers prefer to catch bluegill/sunfish, yellow perch, and crappie on Shawano Lake (Figure 3.7-2). Brief summaries of panfish with fishable populations in Shawano Lake are provided based off of the reports submitted by WDNR fisheries biologist Jason Breeggemann following the fisheries survey completed in 2018.

Bluegill were also captured in moderate to high densities during the spring fyke netting survey. Growth rates, however, for this species is slow compared to statewide data.

Black crappie is another panfish in moderate to high densities. The size structure for this species increased since the 2014 survey, however, the population is still dominated by smaller sized individuals. Growth rates were slow, this is likely being driven by strong younger year classes and the high density of individuals.

Fish Kills

Columnaris is a bacterial infection that can cause significant mortality in fish. It is a common disease in spring, especially during spawning time and during rapid warming of the water. It can afflict multiple species at one time. Columnaris fish kills on Shawano Lake spring are quite common. In fact since 2007, WDNR records indicate 5 separate spring Columnaris fish kills with 2 kills causing significant mortality (750-1000+ dead fish documented in small sections of shoreline). All these past kills occurred between May 27 and June 6.

Soon after the 2016 whole-lake herbicide treatment was initiated, a complaint was issued to a local news channel over a "large" fish kill on Shawano Lake and the premise that it was caused by a reduction in dissolved oxygen as a result of plant die-off from the herbicide treatment. Al Niebur, WDNR Fisheries Biologist at that time, conducted a semi-formal survey of Shawano Lake soon after the news story aired and counted over 300 dead fish largely comprised of bluegill and pumpkinseed. Dissolved oxygen data collected during this timeframe confirm sufficient levels of dissolved oxygen exist in the lake and was not the cause of the fish kill. Mr. Niebur indicated that "the likely explanation for the fish kill may be linked to a Columnaris fish disease outbreak.

Shawano 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 2019, 73% of the substrate sampled in the littoral zone of Shawano Lake were soft sediments, 27% was composed of sand and 1% were composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009). A Summer 2019 survey documented eight land parcels which contained pieces of coarse woody habitat along the shores of Shawano Lake. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible.

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 3.7-3. 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 and 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 and 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 Shawano Area Waterways Management, 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 Shawano Lake.

Fishing Regulations

Regulations for Shawano Lake fish species as of March 2020 are displayed in Table 3.7-3. 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 3.7-3. WDNR fishing regulations for Shawano Lake (As of March 2020).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	May 2, 2020 to March 7, 2021
Smallmouth bass	5	14"	May 2, 2020 to March 7, 2021
Largemouth bass	5	14"	May 2, 2020 to March 7, 2021
Muskellunge and hybrids	1	45"	May 23, 2020 to December 31, 2020
Northern pike	5	None	May 2, 2020 to March 7, 2021
Walleye, sauger, and hybrids	3	The minimum length is 18"	May 2, 2020 to March 7, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks,

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.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.7-5. 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 3.7-5. 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/)

Fishery Management & Conclusions

The WDNR's recommendations for Shawano Lake are to continue working with WDNR staff and local management organizations to manage aquatic invasive plants (Breeggemann 2018). Maintaining or increasing predator densities will help manage high numbers of panfish. The next comprehensive fish survey by the WDNR for Shawano Lake is planned for 2022.

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 Shawano 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 Shawano Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Shawano Lake ecosystem, the folks that care about the lakes, and what steps can be taken by the SAWM to protect and enhance the system.

Shawano Lake contains *Excellent* water quality compared to other shallow lowland drainage lakes. Total phosphorus, and chlorophyll-a parameters are less than mean values of other deep lowland drainage lakes and lower than the mean values of lakes in the North Central Hardwood Forests ecoregion. Water clarity is much higher than comparative lakes of the same type and with the same ecoregion. Water clarity is minimally influenced by staining compounds from the watershed, but likely clearer due to the high prevalence of zebra mussels. Shawano Lake periodically receives pulses of phosphorus from internal sources such as the die-back of curly-leaf pondweed in early July and a natural process called internal nutrient loading. Shawano Lake is a productive system, able of supporting a high biomass of plants and animals.

Sediment core analysis indicates that sedimentation rates peaked in early 1900s, likely as a result of land clearing practices. Increases in sedimentation rates increased again in 1980s responding to increased development as the original cottages were rebuilt into larger vacation homes. The biological fossil data suggest that the amount of aquatic plants in the lake has increased since 1950 and that algal concentrations, especially blue-green algae became more common in the 1980s.

Shawano Lake falls within the Wolf River Watershed which ultimately drains to the Lake Winnebago System. Shawano Lake contains a relatively small watershed compared to the size of the lake, with approximately eight acres of land draining to each acre of the lake. Past studies updated as a part of this planning project indicate that some of the greatest phosphorus inputs from the watershed are from stream inputs (particularly Pickerel Creek and Loon Creek) found within agricultural landscapes. Having a small watershed, the land use around the immediate shoreline areas has a large influence over the lake's water quality. Of the 1003 parcels on Shawano Lake proper, 935 contained manicured lawn at various levels. It is fundamental to the health of Shawano Lake to preserve the few natural shorelands and take steps towards shifting the proportion of developed shorelines into less impactful categories.

Shawano Lake is a popular destination for anglers that target a range of fish species. Shawano Lake is particularly popular for transient users during the winter ice fishery. While riparian stakeholders believe the fishery is currently *fair* to *good*, they also believe that the fishery has *gotten worse* since they first started fishing the lake. Fisheries managers and SAWM have invested large amounts of time and effort into Shawano Lake's fishery including stocking efforts and monitoring programs.

Changes in aquatic plant abundance within Shawano Lake have been noted on Shawano Lake. Following the establishment of rusty crayfish in the late 1970s, universal accounts of vegetation declines were noted. Rusty crayfish populations continue to impact native aquatic vegetation within the lake. Having a woodier base, EWM is less impacted by rusty crayfish than native vegetation. Although specific surveys have not been conducted to confirm, the primary aquatic plant biomass within Shawano Lake is currently EWM. EWM inhabits the littoral band around Shawano Lake in waters of approximately 6-15 feet where more organic sediments exist.

The SAWM, in conjunction within WDNR grants, have invested a large amount of money attempting to manage the EWM population of Shawano Lake with herbicides. SAWM sponsored a large trial spot treatment in 2014 leading up to the eventual whole-lake 2,4-D treatment in 2016. Post treatment assessments indicate that while EWM has rebounded throughout much of its pretreatment footprint, the EWM exists at lower densities since the 2016 treatment. Prior to the treatment, planners discussed a long-term goal of achieving 3-5 years of reduced EWM. The data suggest that the longevity of control was closer to 3 years than 5 years. If SAWM wanted to pursue another whole-lake herbicide treatment in the future, an alternative chemistry to 2,4-D would need to be considered, which means a much higher cost of implementation would be associated.

In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to established EWM populations. Instead of chasing the entire EWM population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress to the lake. As part of this planning effort, SAWM created a plan for alleviating nuisance conditions caused by EWM through a combination of mechanical harvesting and herbicide treatments.

As a part of this planning effort, SAWM has outlined coordinated and calculated steps to increase its capacity to protect and manage Shawano Lake. This includes enhance its organizational capacity, intent to form standing committees, bolster communication abilities, and pursue additional communication avenues. As grant funding opportunities become more competitive and the cost of lake management activities increase, it will be important for the Shawano Lake Waterways Management to operate in a strong and efficient manner.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the SAWM Planning Committee and ecologist/planners from Onterra. It represents the path the SAWM 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 Shawano 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 SAWM's Capacity to Communicate with all Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Enhance organizational capacity through consistent and effective board structure
Timeframe:	Ongoing
Facilitator:	Board of Directors
Description:	SAWM board members and are at work year-round to deliver SAWM's Vision and Mission. The Vision is "Caring for Shawano Lake Now and for Generations – restore, protect, and maintain the chemical, biological and physical integrity of the Shawano Waterways." Over the past decade, SAWM has continued to increase its capacity and would benefit from review of its current organizational structure. Below are aspects that the SAWM Board of Directors would investigate and consider addressing: • Composition – Most lake association consist of a President, Vice President, Secretary, Treasurer, and 4-6 at-large directors, and the past president. • Terms – Director positions are three years. • Elections – Staggered anonymous elections should occur at the annual meeting. • Board Meetings – Set schedule for regular board meetings (at least quarterly), with the option for special meetings. Utilize Roberts Rule of Order during official meetings. • Create Standing Committees – This plan discusses the potential of creating two standing committee as they pertain to lake management. Additional committees, such as a finance committee, social committee, boating safety committee may also be considered. Written and or verbal committee reports would

	be given at board meetings and annual meeting. Committees need to have at least one board member, which does not have to be the chair. • Bylaws Review – It is important to periodically review bylaws (typically every 5 years) to ensure they are current and reflect any organizational changes made. The WDNR Surface Water Grant Program has made changes to bylaw requirements, so it is also important ensure the bylaws meet those standards Organizational capacity workshops are held annually as part of the Wisconsin Lakes Partnership Convention. SAWM has had past board members receive training through the UW Extension Lakes' Lake Leaders Institute and should continue to be a participant in this program: www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/lakeleaders/default.aspx SAWM may consider hiring a part-time Executive Director to assist with maintaining continuity in the organization, assist with marketing and outreach, and be a point of contact for SAWM-related inquiries.
Action Steps:	
	See description above

Management Action:	Give consideration to the creation of an *Education Committee*
Timeframe:	Related to bylaw discussion, ambition to put in motion by end of 2021
Facilitator:	Board of Directors
Description:	By demonstrating a clear mission, the *Education Committee* would be responsible for marketing and public relations, educating its constituents, and overall increasing the SAWM's capacity to influence Shawano Lake. The *Education Committee* would be the facilitator for a number of management actions outlined below. The *Education Committee* would deliver an oral report at the association's annual meeting of the previous year's accomplishments and the direction being considered for the following year. This committee would be comprised of 2-4 individuals, with at least one member being on the SAWM board of directors.
Action Steps:	
	See description above.

Management Action:	Bolster communication abilities and pursue additional communication avenues
Timeframe:	In Progress
Facilitator:	Board of Directors or Education Committee
Description:	Education represents an effective tool to address many lake issues. The SAWM aims to send out regularly distributed newsletters (at least once per year) and maintain an updated website (sawm.org). The webpage is a useful repository for association information; including meeting minutes and announcement, general association information, and educational materials. However, it requires that the interested individual check back for updates periodically; therefore, it is not reliable for disseminating information quickly. SAWM also maintains and moderates a dedicated SAWM Facebook Page, allowing another resource for building a sense of community, as well as providing information on upcoming events or providing links to educational pieces posted on the website. This can include announcements, pictures, short videos, and links to websites. Links to websites are useful because they allow the association to keep their followers informed regarding updates and additions made to the SAWM webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. As social media platforms and use evolves, investigate opportunities for the SAWM to use additional and/or alternative platforms to provided content to its audience. Email is another useful form of electronic communication that allows the association to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web. The SAWM has made it a priority to build a complete and updated email list, which will allow more rapid and cost-effective means of providing information to association members. The association is considering additional ways to improve upon its communication capacity, such as employing a Constant Contact email marketing campaign. These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings. SAWM may consider hiring an Executive Director or Marketing Director to assist with these efforts.
Action Steps:	
	See description above

Management Action:	Participate in annual Wisconsin Lakes and Rivers Convention.
Timeframe:	Annually
Facilitator:	SAWM Board of Directors
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and associations. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/association. SAWM has historically and will continue to sponsor the attendance of 1-3 association members annually at the convention. Following the attendance of the convention, the members will report specifics to the Board of Directors regarding topics that may be applicable to the management of Shawano Lake and operations of the SAWM. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the association membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/default.aspx
Action Steps:	
	See description above.

Management Action:	Routinely educate and communicate with all lake stakeholders
Timeframe:	Starting 2021
Facilitator:	Board of Directors or Education Committee
Description:	The SAWM will make the education of lake-related issues a priority. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan* to all lake stakeholders, allowing it to be better understood by association members. To accomplish this task, the Education Committee plans to highlight key

	topics from the plan and share educational materials on the subjects over time. The SAWM believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative.
	
	As a part of the planning process, the SAWM identified key topics which they believe the association members would appreciate additional educational opportunities. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support.
	
	Example Educational Topics
	• Importance of natural landscapes
	• Boating regulations & safety
	    o Augmented enforcement
	• Development of a courtesy code
	    o Engine volumes
	    o Wakeboarding
	    o Night bow fishing
	• General lake ecology
	• Aquatic invasive species identification
	• Shoreline habitat restoration and protection
	• Litter, especially on ice
	• Noise and light pollution
	• Fishing regulations and overfishing, particularly ice fishing
	• Minimizing disturbance to spawning fish
	• Shoreline erosion – individuals, wildlife
	• Algae blooms and blue-green algae
	• Swimmers itch
	• Septic maintenance in watershed

Action Steps:	
	See description above.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years, corresponding with management plan updates
Facilitator:	Board of Directors or Education Committee
Description:	Formal riparian stakeholder user surveys have been performed by the association in 2015 and 2019. Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Shawano Lake riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be

	critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2019, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Action:	Continue SAWM's involvement with other entities that have responsibilities in managing (management units) Shawano Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The purpose of the SAWM is to maintain, protect, and improve the quality of lakes for the landowners and those that use the lake for recreation purposes. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the SAWM actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page.
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Shawano County Land Services Department	County Conservationist (Scott Frank- 715.526.4632)	Oversees land & water conservation projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
City of Shawano	Deputy Clerk (Lisa Bruette – 715.526.5751)	Local unit of government	Annual and as needed: (cityofshawano.com)	Aspects that involve the government such as building and zoning, municipal sewer, funding opportunities, grant applications, CBCW, events, ordinances etc. SAWM board members provide regular updates to these municipalities on the health of Shawano Lake and our efforts to maintain it.
Village of Cecil	Clerk/Treasurer (Teri Westerfield – 715.745.4429)		Annual and as needed. (villageofcecil.com)	
Town of Wescott	Clerk (Angela Vreeke – 715.526.9755)		Annual and as needed. (townofwescott.com)	
Town of Washington	Clerk (Kara Skarlupka - 715.851.6592)		Annual and as needed. (townofwashington.com)	
Town of Richmond	Clerk (Richard Stadelman) – 715.526.6527		Annual and as needed. (richmondwi.com)	
Chamber of Commerce	715.524.2139	Local business organizations	As needed (shawanocountry.com)	Strong local business support (financial and participation), especially for the annual SAWM golf outing fundraiser
Rotary Club of Shawano	Aaron Wallrich		As needed (shawanorotary.org)	
Waterways Association of Menominee and Shawano Counties (WAMSCO)	Shanda Hubertus (wamsco@gmail.com)	Local collaboration of associations and districts	Attend annual meeting, or as needed. (wamsco.org)	Relevant local information related to maintaining and restoring waterways. Sharing research, education, and resources.
Fox-Wolf Watershed Alliance	Regional Watershed Coordinator (Emily Henrigillis - 920.851.6472)	Non-profit organization	As needed. Visit website (fwwa.org)	Working to protect and improve the Fox-Wolf River watershed
Walleyes for Tomorrow - Shawano Chapter	Chapter Chairman - Ken VanDenPlas (vandenwft@gmail.com)	Non-profit organization	As needed	Works with clubs, agencies, and DNR to improve quality of walleye fishing. Operates Cecil portable fish hatchery.
Shawano Bassmasters	715.881.0113	Local fishing club	As needed	Organization of bass anglers interested in habitat and population management.
NE WI Hydro, an Eagle Creek Renewable Energy Co.	David Fox (david.fox@eaglecreekre.com)	Dam operator	As needed	Maintains the dam that controls Shawano Lake's water levels and residence time.
Shawano Ski Sharks	admin@skisharks.org	Local ski club	As needed. (shawanoskisharks.org)	SAWM has partnered for fundraising and volunteerism needs
Shawano Community High School	715.526.2175	High School	As needed: (shawanoschools.com/o/schs)	SAWM has partnered to involve students in monitoring activities, particularly the Clean Boats Clean Waters program, where students perform 200 hours of inspections annually.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
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 (Jason Breeggemann - 920.420.4619)	Manages the fishery of the system.	Once a year, or more as issues arise.	Stocking, surveys, volunteer opportunities for improving fishery.
	Lakes Coordinator (Brenda Nordin-920.360.3167)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants r permits, and to seek advice on other lake issues.
	Warden (Jacob Cross - 715.701.8034)	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.
	CLMN Director (Brenda Nordin-920.360.3167)	CLMN training and assistance.	Twice a year or more as needed.	Training, planning of monitoringm and reporting of data.
	AIS Regional Coordinator (Chris Kolasinski)	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 Aquatic Vegetation on Shawano Lake

Management Action:	Give consideration to the creation of an *Aquatic Plant and AIS Management Committee*
Timeframe:	Related to bylaw discussion, ambition to put in motion by end of 2021
Facilitator:	Board of Directors
Description:	The creation of a dedicated committee will ensure that division of labor occurs within the SAWM. The *Aquatic Plant and AIS Management Committee* would be charged with AIS management, Clean Boats Clean Waters watercraft inspections, future AIS aquatic plant and animal monitoring activities. The *Aquatic Plant and AIS Management Committee* would also deal with funding, cost analysis, risk assessment, treatment strategy, and data review. This committee would be comprised of 2-4 individuals, with at least one member being on the SAWM board of directors.
Action Steps:	
	See description above.

Management Action:	Periodically monitor the EWM population
Timeframe:	Periodic: every 2-3 years or when prompted

Facilitator:	Board of Directors or Aquatic Plant & AIS Management Committee
Description:	As the name implies, the Late-Season EWM Mapping Survey is completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For Shawano Lake, this survey would likely take place in mid-August to the end of September, dependent on the growing conditions of the particular year. This survey would include a complete meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late- Season EWM Mapping Surveys have been conducted annually on Shawano Lake proper since 2013, allowing for lake stakeholders to understand annual EWM populations as well as population dynamics which proved to be useful. These surveys are used as the trigger within the previous management goal for management. Unless prompted by a specific rationale, such as areas suspected to have reached the trigger for management discussed above, SAWM will conduct this mapping survey at 2-3 year intervals on the entirety of Shawano Lake. This will allow the dataset to stay current but balances the financial costs of the effort. SAWM will consider expanding the survey to include the Wolf River Pond and Outlet if conditions arise warranting EWM management considerations. Further, SAWM may chose to surveys a focused part of the lake that may be considered for management in a subsequent season. SAWM will also investigate grant funding opportunities to help fund this survey in the future. This will likely consist of a Surface Water Grant, which offers a WDNR cost share. Grant applications are due on November 1 of each year, with intent materials being due 60 days prior (September 2).
Action Steps:	
	See description above.

Management Action:	Coordinate Periodic Point-Intercept Surveys
Timeframe:	Periodic: every 3-5 years
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been conducted on Shawano Lake in 2005

	(slightly different protocol), 2013, and 2015-2019. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. With the amount of management and recreational pressure Shawano Lake endures, a more frequent schedule of plant surveys is recommended, perhaps every 3 years. SAWM will also investigate grant funding opportunities to help fund this survey in the future. This will likely consist of a Surface Water Grant, which offers a WDNR cost share. Grant applications are due on November 1 of each year, with intent materials being due 60 days prior (September 2).
Action Steps:	
	See description above.

Management Action:	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Period: every 10-15 years or when prompted
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. This survey has been conducted on Shawano Lake in 2013. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Shawano Lake, a community mapping survey would be conducted approximately every 10-15 years unless a specific rationale prompts a shorter interval. This survey would also identify non-native emergent shoreline plants, such as purple loosestrife and phragmites grass, both of which are known from around Shawano Lake.

Action Steps:	
	See description above.

Management Goal 3: Manage Aquatic Invasive Species and Prevent Establishment of New Aquatic Invasive Species

Management Action:	Periodically Update Aquatic Plant Management Plan
Timeframe:	Periodic
Facilitator:	Board of Directors or Aquatic Plant & AIS Management Committee
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that 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. The WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years. This allows a review of the available data from the lake, as well as to consider changing BMPs. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. Therefore, the WDNR requires those aspects of the plan to be updated every 5 years in order to be eligible for grants and permits. Typically, this more-focused *Aquatic Plant Management Plan* will outline new BMPs and monitoring practices until another *Comprehensive Plan* is developed.
Action Steps:	
	See description above.

Management Action:	Monitor Shawano Lake entry points for AIS.
Timeframe:	Ongoing
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	Shawano Lake is an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of a watercraft inspection program would not only be to prevent additional invasive species from entering the Shawano Lake through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the system. The goal would be to cover the landings during the busiest

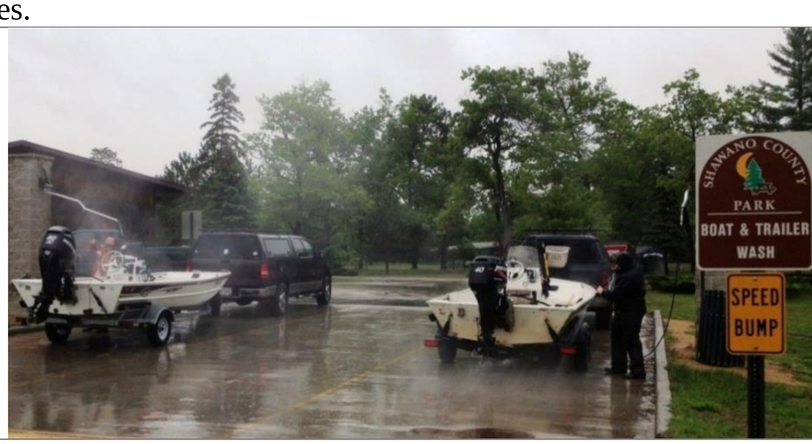
times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. SAWM's Clean Boats Clean Waters program has been well organized, with numerous watercraft inspections occurring annually (Table 5.0-1)

Table 5.0-1. Watercraft inspections conducted on Shawano Lake. Data from WDNR, SWIMS.

	Boats Inspected										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shawano Lake Outlet - Nr County HHH	2	2	0	0	0	0	0	0	0	0	0
Nr Cattau Beach Dr	0	6	5	5	0	0	0	0	0	1	2
Nr County HHH And Lake Dr	0	7	0	0	0	0	0	0	0	0	0
Nr Stark Rd And Washington Lake	0	13	372	0	0	0	0	0	27	22	5
Nr Swan Acre Dr	0	116	327	187	0	327	0	202	73	747	0
Off Hwy H Nr Sunset Circle	0	205	114	0	0	1	0	0	639	0	0
Nr Freeborn St. and Pickerel Creek (Cecil)	26	82	212	132	0	0	847	0	0	0	0
Shawano County Park Access	0	8	274	247	0	0	0	0	42	119	62
Access at Huckleberry Harbor	0	144	238	304	308	12	20	0	27	24	782
	28	**583**	**1542**	**875**	**308**	**340**	**867**	**202**	**808**	**913**	**851**

Based upon modeling by the University of Wisconsin Center for Limnology, Shawano Lake is one of the state's top 300 AIS Prevention Priority Waterbodies. This means that Shawano Lake has a high number of boats arriving from lakes that have AIS (receiving) and a high number of boats moving from Shawano Lake to uninvaded waters (sending). Therefore, the WDNR encourages additional supplemental prevention efforts above just watercraft inspections, offering additional grant funds for these activities for applicable lakes. Supplemental prevention efforts such as decontamination stations (e.g., pressure washer) and remote video surveillance (e.g., I-Lids™) could be funded through this program.

The Shawano County Park has installed and currently maintains two power washers at its boat and trailer washing station, offered to lake visitors free of charge. Boat owners are encouraged to power wash their watercrafts prior to entering the lake, limiting Shawano Lake's exposure to new AIS. Boats should also be power washed after visiting Shawano Lake, to ensure the AIS from Shawano Lake are not exposed to other lakes.



Photograph 5.0-1. Boat and trailer washing station at Shawano Lake. Photo credit: Onterra.

	SAWM would consider additional supplemental prevention efforts, including additional boat and trailer washing stations at other landings.
Action Steps:	
	See description above.

Management Action:	Conduct nuisance management actions towards EWM
Timeframe:	Ongoing
Facilitator:	Aquatic Plant and AIS Management Committee
Description:	SAWM participated in the forefront of field research, engaging in projects with the WDNR, US Army Corps of Engineers Research and Development Center (USACE), and Onterra that aimed to increase the efficacy and longevity of herbicide management of EWM. As discussed in the Aquatic Plant Section (3.5), a whole-lake 2,4-D amine treatment occurred in 2016 on Shawano Lake. The treatment targeted all the EWM in Shawano Lake. The data clearly show a reduction during the year of treatment, with rebound occurring as soon as the year after treatment. As measured by the point-intercept survey, the EWM was almost back to pretreatment frequencies by the third summer after treatment. The EWM mapping data indicate that EWM occupies a slightly smaller footprint compared to pretreatment and is at a lower overall density. **Whole-Lake Treatment** If SAWM wanted to pursue another whole-lake herbicide treatment, rotation away from 2,4-D is recommended. The 2,4-D concentrations during the 2016 treatment rapidly declined to zero within weeks following treatment, likely the reason the longevity of results fell short of meeting expectations. A future strategy should consider an herbicide that had a different mode of degradation, such as one that breaks down photolytically (i.e., by sunlight exposure). This would produce a more predictable degradation curve. In lakes like Shawano Lake that contain both EWM and hybrid watermilfoil (HWM), concern exists that the more-easily controlled EWM component of a lake's invasive milfoil population may be controlled by herbicide treatment, but the slightly less-susceptible HWM component will survive, rebound in a short period of time, and then comprise a larger proportion of the invasive milfoil population. 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. Concern exists that the past use-history of 2,4-D on Shawano Lake may have resulted in a population of more-tolerant invasive watermilfoils to auxin hormone mimic herbicides, which also includes triclopyr. With much less genetic diversity being present within pure-strain EWM populations, it is unclear if herbicide tolerance shifts can occur in these populations.

SAWM has outlined a threshold (i.e., trigger) where a whole-lake treatment may be considered

> *Point-intercept survey yields EWM at approximately 25% or more of littoral sampling points*

If SAWM's trigger is reached, they would start educating themselves on what is considered a best management practice (BMP) for whole-lake EWM management at that time.

<u>Spot Treatment</u>

In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to established EWM populations. Instead of chasing the entire EWM population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress to the lake. The WDNR supports using the management method that will impart the least stress on the overall ecosystem.

SAWM has outlined a threshold (i.e., trigger) where EWM management with herbicides would be considered.

1) *colonized areas of EWM with a density of dominant or greater*
2) *EWM is within high use areas of the lake or along riparian frontage*
3) *areas that cannot be reasonably managed with mechanical harvesting*

If SAWM's trigger is reached, they would start educating themselves on what is considered a BMP for EWM spot herbicide management. This would likely include devising a strategy where a sufficiently large treatment area can be constructed to hold concentration and exposure times for exposed sites. Protected areas would consider additive impacts within an Area of Potential Impact (AOPI), such that if levels reach whole-basin concentrations, they are accounted for in the treatment and monitoring strategy.

	Future spot herbicide treatments 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 invasive watermilfoil control in Wisconsin. 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.
	
	SAWM and regional WDNR have been investigating the potential for herbicide treatments with barrier curtains. Although these commonly take place with an economical-priced herbicide like 2,4-D, Shawano Lake's historic use with this chemistry suggests switching away from this chemistry. As new herbicides, use-patterns, and techniques emerge; SAWM will investigate their applicability for EWM management on Shawano Lake.
	
	If SAWM decides to pursue future herbicide management towards EWM, the following set of bullet points would occur:
	
	• Early consultation with WDNR would occur.
	• The preceding annual AIS monitoring report would outline the precise control and monitoring strategy.
	    • Monitoring EWM efficacy by comparing annual late-summer EWM mapping surveys.
	    • Give consideration to pretreatment invasive watermilfoil genetic testing (i.e., fingerprinting), as both EWM and HWM are known from Shawano Lake.
	    • 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)* – Click Here
	
	    This generally consist of collecting quantitative point-intercept sub-sampling on sites before the treatment (pre) and summer following the treatment (post). Herbicide concentration monitoring may also occur surrounding the treatment in these instances. Whole-lake treatments would require whole-lake point-intercept surveys the *year prior to treatment* and the *year after treatment*. Conducting this survey during the *year of treatment* may be considered, but may not be required by WDNR.

	• An herbicide applicator firm would be selected in late-winter and a conditional permit application would be applied to the WDNR. • 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. • 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, and is after Native American open-water spear harvest has concluded.
Action Steps:	
	See description above.

Management Goal 4: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality parameters through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors and/or David Zelinger
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. Most volunteer-based water quality monitoring on lakes is conducted as a part of the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. At a specified location in the lake, typically at the deep hole, the volunteer collects Secchi disk transparency three times during the summer and once during the spring. If the lake is enrolled in the advanced CLMN program, additional chemistry samples (chlorophyll-*a*, and total phosphorus) are collected at these intervals and sent to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. SAWM is collecting water samples as part of the WDNR Long Term Trends (LTT) monitoring program. In addition to the advanced CLMN

		monitoring, the LTT program includes collecting a temperature and dissolved oxygen profile at each sampling interval, as well as water samples for additional water chemistry parameters once each summer (conductivity, pH, alkalinity, color, nitrate-nitrite, and total kjeldahl nitrogen). Every five years, water samples are tested for calcium and magnesium. As a part of either the CLMN or LTT program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).
Action Steps:		
	1.	Trained volunteer collects data, enters data into SWIMS, and report results to association members during annual meeting.
	2.	Volunteer and/or SAWM board would facilitate new volunteer as needed

<u>Management Action:</u>	Investigate feasibility of reducing nutrients from stream inputs to Shawano Lake
Timeframe:	Ongoing, may be added component of next planning project
Facilitator:	Board of Directors
Description:	Past studies updated as a part of this planning project indicate that some of the greatest phosphorus inputs from the watershed are from stream inputs (particularly Pickerel Creek and Loon Creek). SAWM volunteers conduced three years of stream monitoring that showed elevated levels of phosphorus entering the lake. Without an action plan, the data collection ceased for a period of time but has now resumed through Shawano County. SAWM will investigate the feasibility of conducting a project designed to reduce nutrients from these stream sources. This may include feasibility of installing retention basins or working with the agriculture sector to institute agricultural best management practices for watershed health (e.g., conservation tillage, manure spreading).
Action Steps:	
	See description above.

Management Goal 5: Improve Lake and Fishery Resource

Management Action:	Educate stakeholders on the importance of shoreland condition and shoreland restoration and protection
Timeframe:	Summer 2021
Facilitator:	Board of Directors or Education Committee
Description:	The shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. As discussed in the Shoreland Condition Section (3.3), the Healthy Lakes & Rivers Grant program provides cost share for implementing the following best practices: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program are included within the Shoreland Condition Section (3.3) and can be found at: https://healthylakeswi.com The *Education Committee* would focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative. SAWM has been an advocate for shoreland restoration including working with and donating funds to Whispering Pines (Concordia College) to install a shoreland restoration site within the past few years. SAWM has hosted presentation and tours of this demonstration site in an effort to bolster more interest in shoreland restoration practices. Subsequently, SAWM financially partnered with two prominent land owners on the south shore, and partnered with one on the north shore to install a large native restoration project. The *Education Committee* would continue to promote these and additional shoreland restoration sites to lake users so they may want to follow suit on their properties. On large lakes like Shawano Lake, erosion and ice shoves can be extremely damaging to valuable shoreline properties. They also have

	impacted shoreland restoration attempts. Therefore, circumstances arise where shoreland modifications to protect property are warranted. The WDNR favors properly implemented rip-rap/rock to satisfy this need, but sometimes also succumb to erosion and ice shoves. Property owners may then consider a ramped concrete seawall, which is discussed within the Shoreland Condition Section (3.4) of this document. Seawall and rip-rap/rock installation and repair require a WDNR permit, which SAWM would like to be a pragmatic firewall between the WDNR and property owner. SAWM encourages shoreline modification projects be the smallest footprint possible and use the least impactful practice. In addition. SAWM encourages shoreland buffers be added above the shoreline modification practice and is considering offering financial assistance to further promote their installment. Privately owned areas of Shawano Lake could also be the focus of preservation efforts. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Shawano County Land & Water Conservation Department. Several websites of interest include: • Conservation easements or land trusts: (www.landtrustalliance.org) • UW-Extension Shoreland Restoration: (https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/) WDNR land acquisition grants are available to pay for the costs of property purchases and conservation easements. Brenda Nordin (WDNR lakes biologist) or Christine Kozik (WDNR environmental grants specialist) can be contacted with questions about this specific grant program.
Action Steps:	
	See description above

Management Action:	Initiate a Loon Watch program
Timeframe:	To be determined
Facilitator:	Board of Directors
Description:	The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. The SAWM has passively monitored Loon activity and has interest in enrolling in the Loon Watch Program in conjunction with the Sigurd Olson Environmental Institute from Northland College. This program would include placement of artificial loon nesting platforms, as well as monitoring according to the Loon Watch Program. The SAWM would ensure that a dedicated volunteer is in place to send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen.
Action Steps:	
	See description above

Management Goal 6: Maintain Navigability on Shawano Lake

Management Action:	Maintain recreational use through planned and permitted mechanical harvesting activities
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Directors
Description:	The SAWM understands the importance of native aquatic vegetation within Shawano Lake. However, nuisance aquatic plant conditions exist in certain parts of the lake, caused largely aquatic invasive species (CLP and EWM/HWM) and loosely or up-rooted native vegetation (coontail, common waterweed, southern naiad, water celery). The SAWM supports the reasonable and environmentally sound actions to facilitate navigability on the Shawano Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact anymore shoreland or lake surface area than absolutely necessary.

The WDNR oversees the management of aquatic plants on inland lakes. The manual cutting and raking of native aquatic plant species within a 30-foot-wide area containing a pier, boatlift, or swim raft is exempt from a state permit provided that the cut plants are removed from the lake. However, the use of mechanized or mechanical devices requires a WDNR permit.

Current management of nuisance levels of aquatic plants occurs on Shawano Lake using two association-owned mechanical harvesters, one that operates in Shawano Lake proper and one that is dedicated to the outlet channel and Wolf River/Pond.

Within the April Annual Membership Form, a landowner may request mechanical harvesting during a given year, for a fixed cost per cutting. The cost is set high enough to deter those without true nuisance conditions. Map 9 shows the riparian harvest activity from 2020. Map 10 shows the riparian harvest footprint from the past 5 years, with a breakdown of spatial location in Figure 5.0-1. Map 11 is the full available mechanical harvesting areas used within the permitting process.

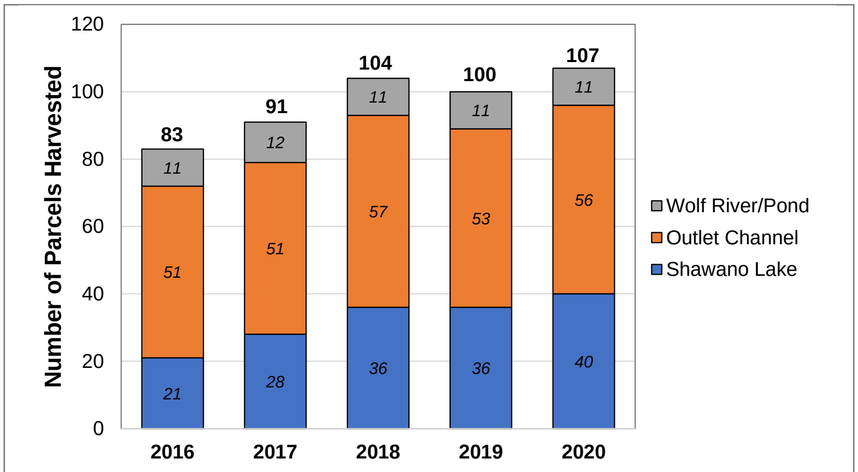


Figure 5.0-1. Shawano Lake riparian mechanical harvest breakdown.

The bulleted list below outlines the Mechanical Harvesting Permit guidelines that will be followed:

- A map of riparian properties that will receive mechanical harvesting will be provided to the WDNR in advance of cutting as part of the permit application process. A physical map of riparian harvest locations will be on the mechanical harvester at all times. The SAWM is investigating onboard GPS guidance to increase efficiency and assist with tracking. This has also been conveyed by WDNR as a future permit requirement.

	• Mechanical harvesting will only be allowed in the areas specified in the permit and may be revised upon WDNR approval in subsequent years. • Submerged plants are the target for this permit and removal of (e.g. bulrushes) and floating-leaf (e.g. water lilies) species needs to be limited because of their ecological value and niche occupation. • Dislodged aquatic plant *floaters* can be picked up using the mechanical harvester in its shallowest setting. This effort needs to be accounted for in summary reports. • Aquatic plants that are cut must be removed from the water, with special care in removing EWM and CLP fragments and turions. • Harvesting operations shall not disturb spawning or nesting fish. Harvesting shall be done in a manner to minimize accidental capture of fish. Any game fish accidentally captured shall be released immediately. Attempts should be made to release all other species. • Reports summarizing harvesting activities shall be given to the Department by November 30, each harvesting season. The report shall include a map showing the areas harvested, the total acres harvested and the total amount of plant material removed from the body of water. The report shall also include a summary of the composition and quantity of plants removed. This can be done by recording the daily percent of the total of individual species harvested (primary species that are causing the need for harvesting), and then calculating the pounds harvested per day. At the end of the month, you can then calculate the percentage and weight of all species harvested.
Action Steps:	
	See description above

Management Action:	Increase recreational use through herbicide treatment lanes
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Directors
Description:	In addition to the mechanical harvesting activities outlined in the previous management action, SAWM uses herbicide application by an association-employed applicator to restore watercraft navigation patterns. The lanes displayed on Map 8 were digitized by Onterra using a collective of information; however, the position of the lanes may not be completely spatially accurate from year-to-year.

	The herbicide applications have used non-selective herbicide use patterns, namely late-June applications of diquat. Moving forward, an onboard hand-held GPS will be used by the association-employed applicator during the herbicide application to ensure proper dosing and herbicide coverage, provide proper records of where the activities took place, and to allow lake managers and stakeholders to create and modify treatment lanes prior to implementation.
Action Steps:	
	See description above

<u>Management Action:</u>	Work with applicable agencies and entities to establish a permanent pool elevation of 802.9 ft msl
Timeframe:	Continuation of Current Effort
Facilitator:	Board of Directors
Description:	Shawano Area Waterways Management and North Eastern Wisconsin Hydro (an Eagle Creek Renewable Energy Company) have agreed to pursue a multi-year temporary amendment to the Shawano Paper Mill Dam (FERC Project 8015) Federal Energy Regulatory Commission (FERC) Exemption to allow the pool elevation at the dam to be maintained at its historic level of 802.9 ft msl year-round. North Eastern Wisconsin Hydro plans to submit the temporary amendment application in mid-May, 2021. If approved, it is expected that the pool elevation of 802.9 ft msl would be implemented in June 2021. Concurrent with the temporary amendment, North Eastern Wisconsin Hydro plans to apply for a permanent amendment to allow the normal pool elevation to be maintained at 802.9 msl in perpetuity. It is expected that the permanent amendment application would be submitted to FERC for review and approval by the fourth quarter of 2021. During spring 2021, SAWM board approved spending up to $30,000 to help offset Eagle Creek's cost to develop the plans FERC requires to address the proposed change.
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 Shawano Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred once in spring and three times during the summer. In addition to the samples collected by SAWM members, professional water quality samples were collected with a 3-liter Van Dorn bottle at subsurface (S) and near bottom (B) depths once in spring, summer, winter, and fall. Although SAWM members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. During each professional sampling event, a temperature and dissolved oxygen profile was completed using a HQ30d with a LDO probe. Secchi disk transparency was also included during all monitoring visits.

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

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Shawano 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 – (Homer et al. 2016)) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Shawano 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) (Hauxwell et al. 2010) was used to complete this study.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Shawano Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver 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.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*

7.0 LITERATURE CITED

Bajer, P. G., and P. W. Sorensen. 2015. Effects of common carp on phosphorus concentrations, water clarity, and vegetation density: a whole system experiement in a thermally stratified lake. *Hydrobiologia*, 2015: 746: 30-311.

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

Canter, L. W., D. I. Nelson, and J. W. Everett. 1994. Public perception of water qality risks-influencing factors and enhancement opportunities. *Journal of Environmental Systems*, 1994: 22(2).

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

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

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

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

Fischer, J. R., and R. M. Krogman. 2013. Influences of native and non-native benthivorous fishes on aqatic ecosystem degredation. *Hydrobiologia*, 2013: 711:187-199.

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

Garrison, P., et al. 2008. *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest.* PUB-SS-1044, Wisconsin Department of Natural Resources Bureau of Sciences Services , 2008.

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

Gross, E. M., D. Erhard, and E. Ivanyi. 2003. Allelopathic activity of Ceratophyllum demersum L. and Najas marina spp. intermedia (Wolfgang) Casper. *Hydrobiologia*, 2003: 506:583.

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

Hauxwell, J., et al. 2010. *Recommended baseline monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications.* PUB-SS-1068, Madison, WI: Wisconsin Department of Natural Resources, 2010.

Homer, Collin G., et al. 2016. Conternminous United States land cover change patterns 2001-2016 from the 2016 National Land Cover Database. *ISPRS Journal of Photogrammetry and Remote Sensing*, 2016: 162:184-199.

James, W. F., J. W. Barko, H. L. Eakin, and P. W. Sorge. 2002. Phosphorus budget and management strategies for an urban Wisconsin Lake. *Lake and Reservoir Managmenet* 18 (2002): 149-163.

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

Johnson, P. T. J., J. D. Olden, C. T. Solomon, and M. J. Vander Zanden. 2009. Interactions among invaders: community and ecosystem effects of multiple invasive species in an experimental aquatic system. *Oecologia*, 2009: 159:161-170.

Lacoul, P., and B. Freedman. 2006. Environmental influences on aquatic plants in freshwater ecosystems. *Environmental reviews*, 2006: 14(2):89-136.

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

Lin, Y., and C. H. Wu. 2013. Response of bottom sediment stability after carp removal in a small lake. *International Journal of Limnology*, 2013: 49:157-168.

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

MNDNR. 2020. *Faucet snail (Bithynia tentaculata) information page.* Minnesota Department of Natural Resources. 2020. https://www.dnr.state.mn.us/invasives/aquaticanimals/faucet_snail/index.html (accessed 2020).

Nault, M. E., et al. 2018. Evolution of large-scale low-concentration 2,4-D treatments for Eurasian and hybrid watermilfoil control across multiple Wisconsin lakes. *Lake and Reservoir Management*, 2018: 34(2):115-129.

Nault, M. 2016. The science behind the "so-called" super weed. *Wisconsin Natural Resources*, 2016: 10-12.

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

Neuswanger, D., and M. A. Bozek. 2004. *Preliminary assessment of Effects of Rock Habitat Projects on Walleye Reproduction in 20 Northern Wisconsin Lakes.* A Summary of Case Histories, Wisconsin Department of Natural Resources, 2004.

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

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

Owens, C., W. James, J. Skogerboe, and M. Smart. 2007. *Distribution and Abundance of Eurasian Watermilfoil and Curly-leaf Pondweed in Shawano Lake, Wisconsin.* U.S. Army Corps of Engineers, 2007.

Panuska, J.C., and J.C. Kreider. 2003. *Wisconsin Lake Modeling Suite Program Documentation and User's Manual Version 3.3.* PUBL-WR-363-94, Wisconsin Department of Natural Resources, 2003.

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

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

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In *Encyclopedia of Inland Waters*, by Gene E. Likens, 1: 60-69. Oxford: Elsevier, 2009.

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

SEH. 2010. *Big Chetac Lake Comprehensive Lake Management Plan.* Short Elliott Hendrickson Inc., 2010.

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

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

Solomon, C.T., J.D. Olden, Johnson. P.T.J, R.T. Dillion Jr., and M.J Vander Zander. 2010. Distribution and commmunity-level effects of the Chinese mystery snail (Bellamya chinensis) in northern Wisconsin lakes. *Biological Invasions*, 2010: 12:1591-1605.

Turyk, N., K. Foster, D. Hoverson, and P. McGinley. 2008. *Watershed Assessment of Shawano Lake, Shawano County, Wisconsin.* Stevens Point: University of Wisconsin - Center for Watershed Science and Education, 2008.

USDA-NRCS. Phragmites Field Guide: Distinguishing native and exotic forms of common reed (Phragmites australis) in the United States. Technical Note Plant Materials No. 56, 2012.

USEPA. 2009. *National Lakes Assessment: A collaborative Survey of the Nation's Lakes.* EPA 841-R-09-001, Washington, DC: United States Environmental Protection Agency Offiec of Water and Office of Research and Development, 2009.

USGS. 2019. *NLCD 2016 Land Cover Conterminous United States.* 2019.

Vestergaard, O., and K. Sand-Jensen. 2000. Alkalinity and trophic state regulate aquatic plant distribution in Danish Lakes. *Aquatic Botany*, 2000: 67:85-107.

WDNR. 2016. 2016 Impaired Waters List. *Wisconsin Department of Natural Resources.* 2016. http://dnr.wi.gov/topic/impairedwaters/2016ir_iwlist.html.

WDNR. 2013. *Extended Growth Walleye Stocking Fall 2013.* WDNR-Bureau of Fisheries Management, 2013.

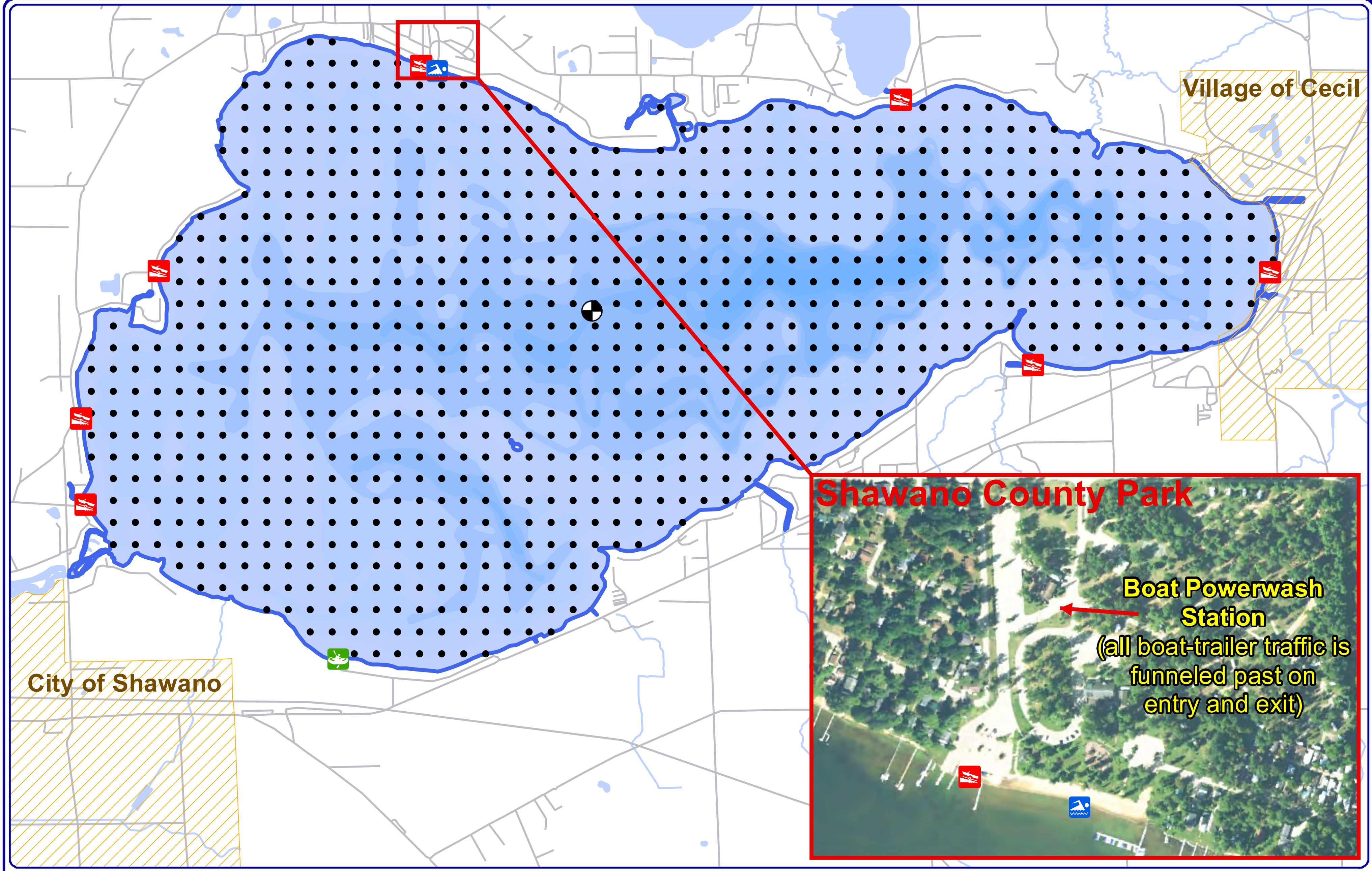
WDNR. 2019. *Wisconsin 2020 Consolidated Assessment and Listing Methodology (WisCALM).* Clean Water Act Section 303(d) and 305(b) Integrated Reporting, Wisconsin Department of Natural Resources, 2019.

WDNR. 2014. Wisconsin Walleye Initiative. (Wisconsin Department of Natural Resources) June 2014.

Weber, M J, and M L Brown. 2011. Relationships among invasive common carp, native fishes and physiochemical characteristics in upper Midwest (USA) lakes. *Ecology of Freshwater Fish*, 2011: 20(2):270-278.

Wills, T. C., M. T. Bremigan, and D. B. Haynes. 2004. Variable Effects of Habitat Enhancement Structures across Species Habitats in Michigan Reservoirs. *American Fisheries Society*, 2004: 133:399-411.

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

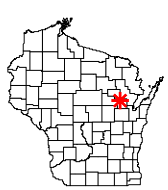


N
W E
S

3,100
Feet

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

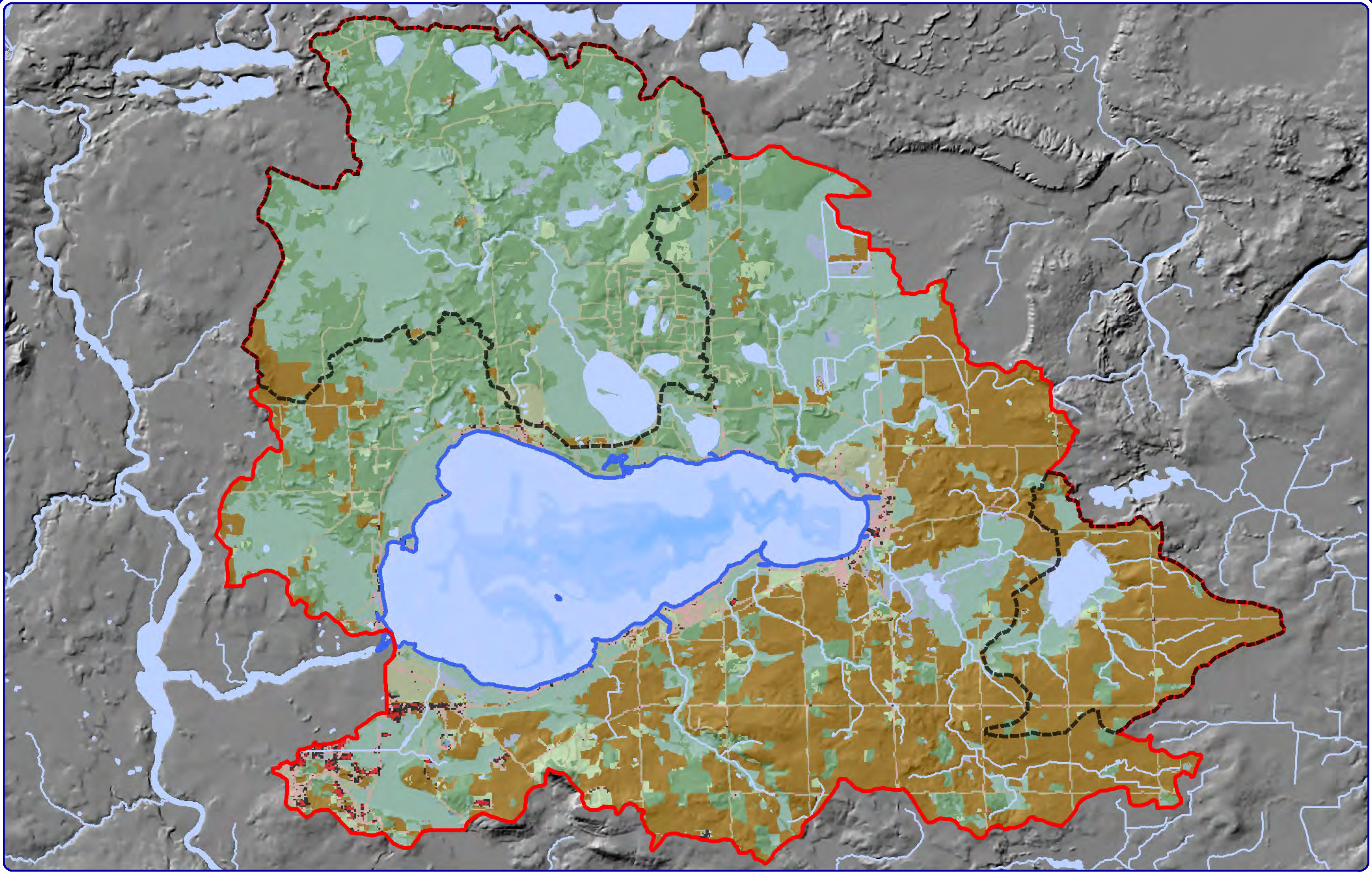
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2017
Map Date: December 3, 2018
Filename: Map1_Shawano_Location_2018.mxd


Project Location in Wisconsin

Legend

- Shawano Lake ~6,258 acres
  Ortho-corrected Definition
- Point-Intercept Survey Location
  165-meter spacing, 925 total points
- Public Boat Landing
- Carry-in Access
- Water Quality Sample Location

Map 1
Shawano Lake
Shawano County, Wisconsin
Project Location & Lake Boundaries



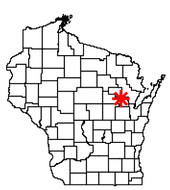
N
W E
S

10,000

Feet

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

Sources:
Hydro: WDNR
Bathymetry: WDNR/Onterra, 2018
Orthophotography: NAIP 2017
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2019
Map date: December 31, 2019 JMB
Filename: Shawano_Watershed_2019



Project Location in Wisconsin

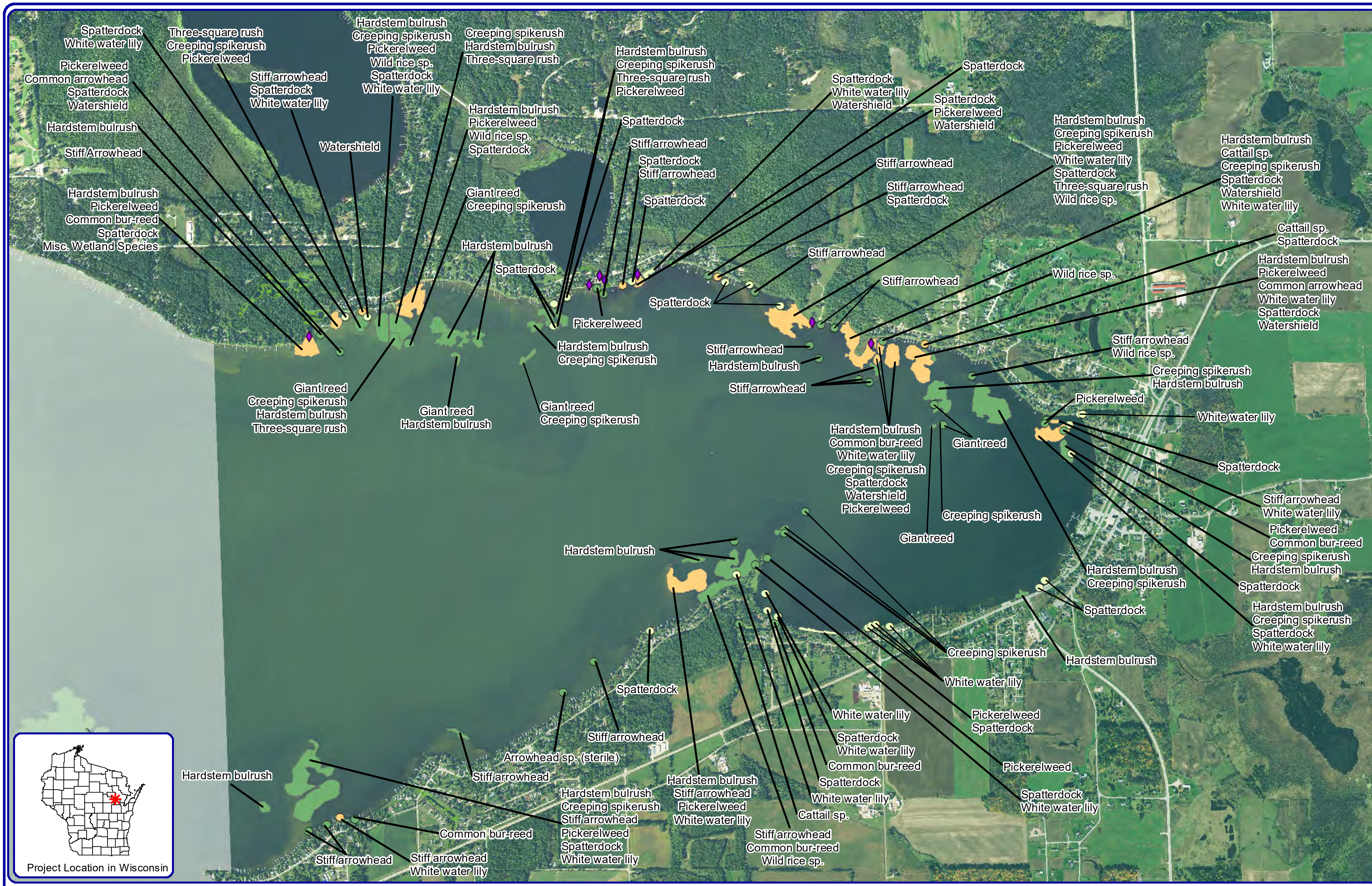
Legend

Land Cover Types

- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Medium Density Urban

- Shawano Lake Watershed Boundary
- Subwatershed Boundary

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



N
W E
S
2,300
Feet

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

Sources:
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2018
Map date: July 10, 2020

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Exotic Plant Communities
- Purple loosestrife

Map 3
Shawano Lake - East
Shawano County, Wisconsin

2013 Floating-leaf & Emergent Aquatic Plant Communities

N
W E
S

2,800
Feet

Legend

Small Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

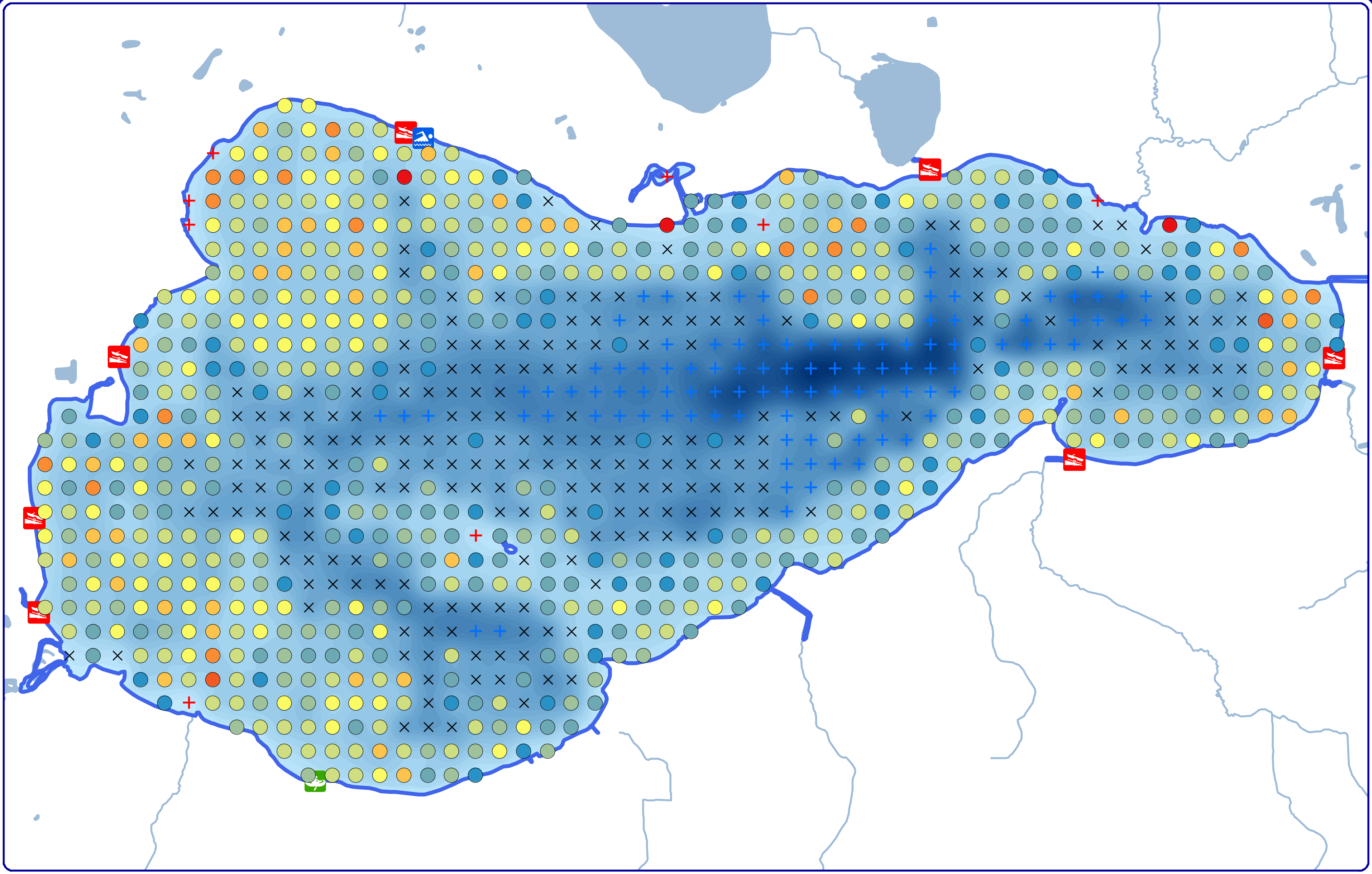
Exotic Plant Communities
- Purple loosestrife

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

Sources:
Aquatic Plants: Onterra, 2013
Orthophotography: NAIP, 2018
Map date: July 10, 2020

Map 4
Shawano Lake - West
Shawano County, Wisconsin

2013 Floating-leaf & Emergent Aquatic Plant Communities

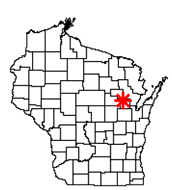


N
W E
S

3,200
Feet

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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2019
Map Date: July 10, 2020



Project Location in Wisconsin

Legend

Number of Native Species per Site

0	1	2	3	4	5	6	7	8	9
×	●	●	●	●	●	●	●	●	●

+ Too Deep

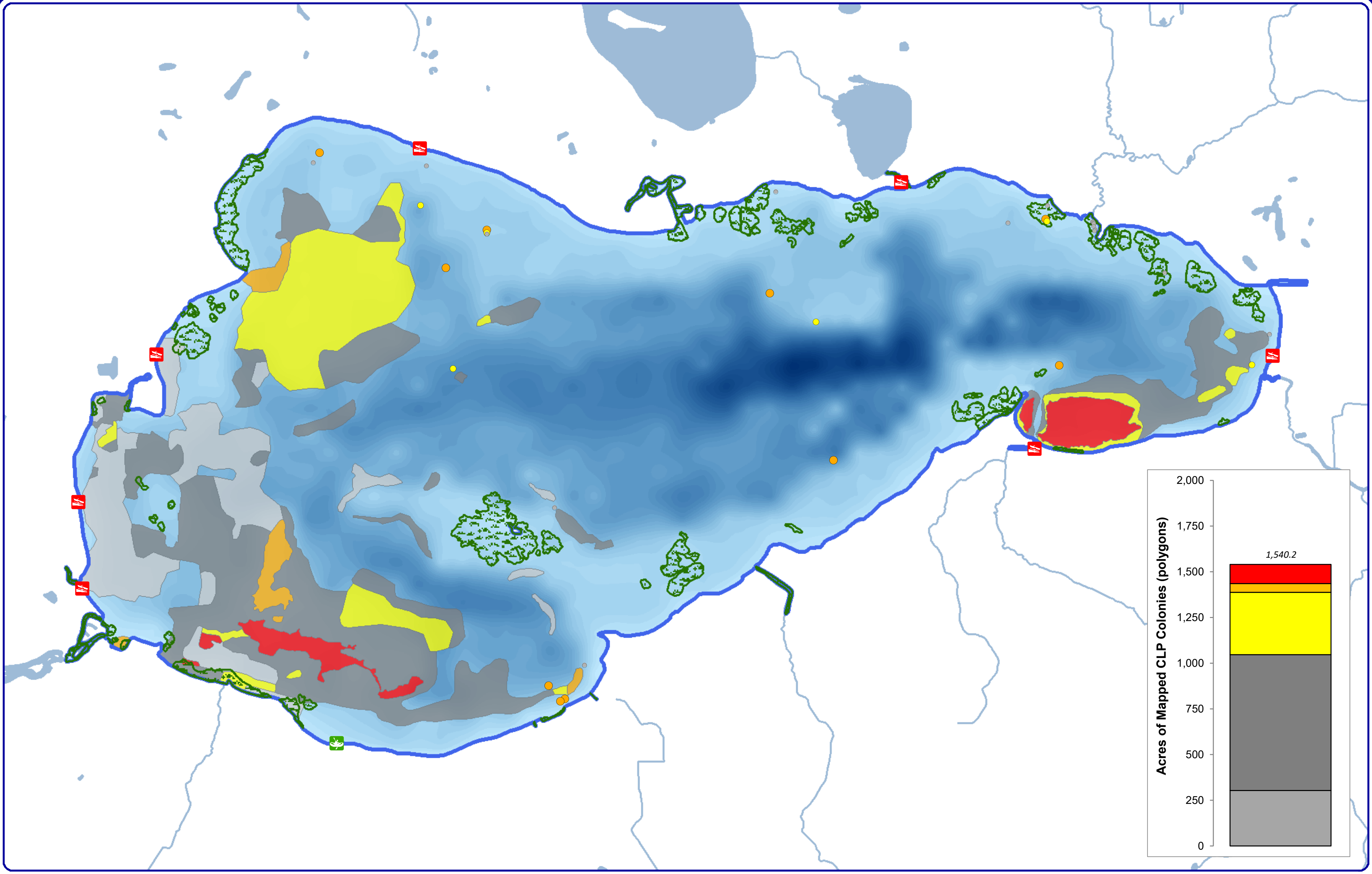
+ Non-navigable/Temporary Obstacle

Map 5

Shawano Lake

Shawano County, Wisconsin

2019 PI Survey: Native Species Richness

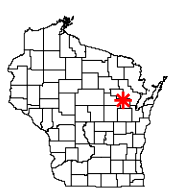


N
W E
S

3,250
Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2013
Map Date: November 1, 2013
Filename: Map6_Shawano_CLPPB_June13.mxd


Project Location in Wisconsin

Legend

Curly-leaf pondweed (June 2013)

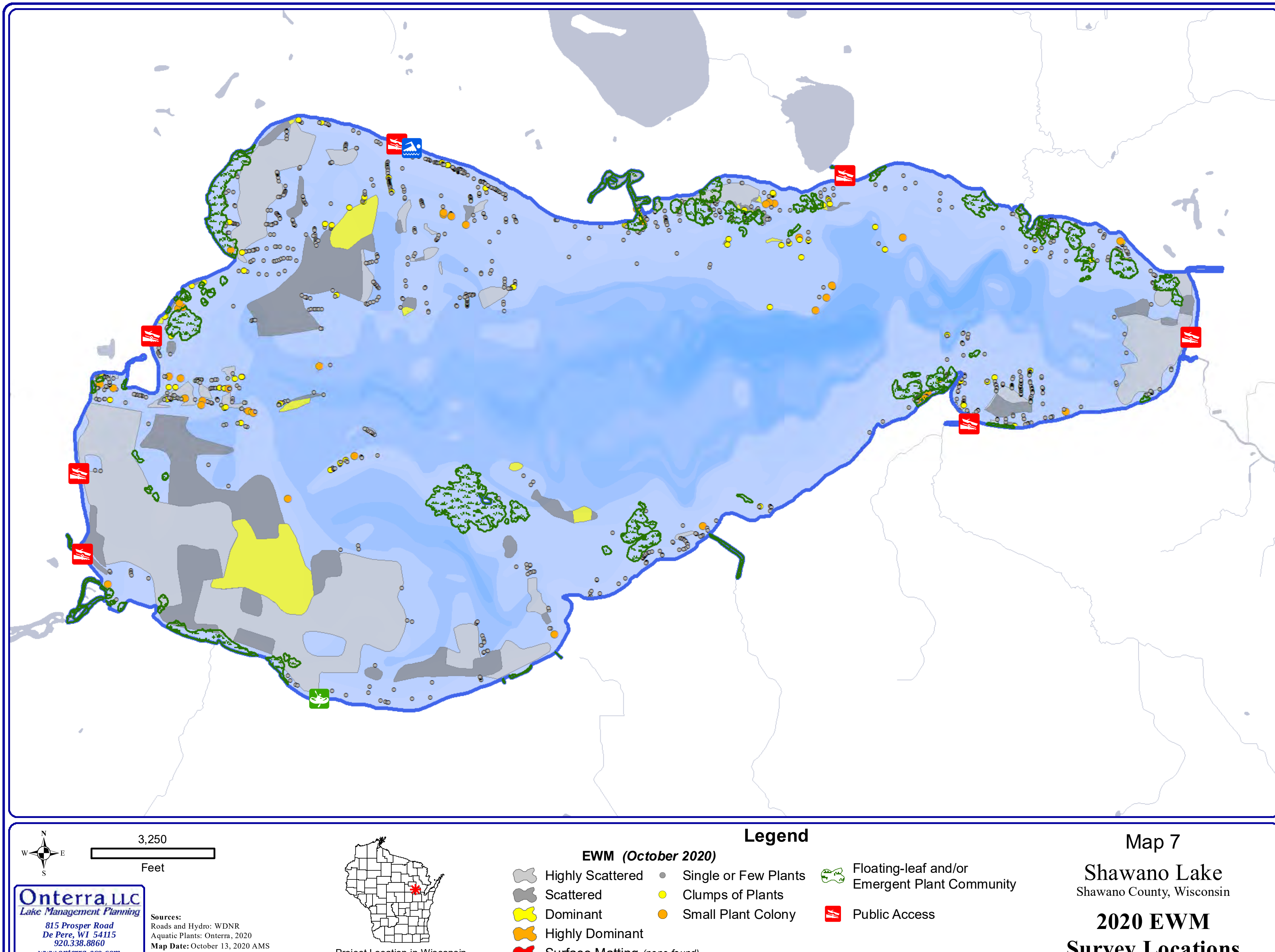
Large CLP Community
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting

Small CLP Community
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony

Floating-leaf and/or Emergent Plant Community

Map 6
Shawano Lake
Shawano County, Wisconsin

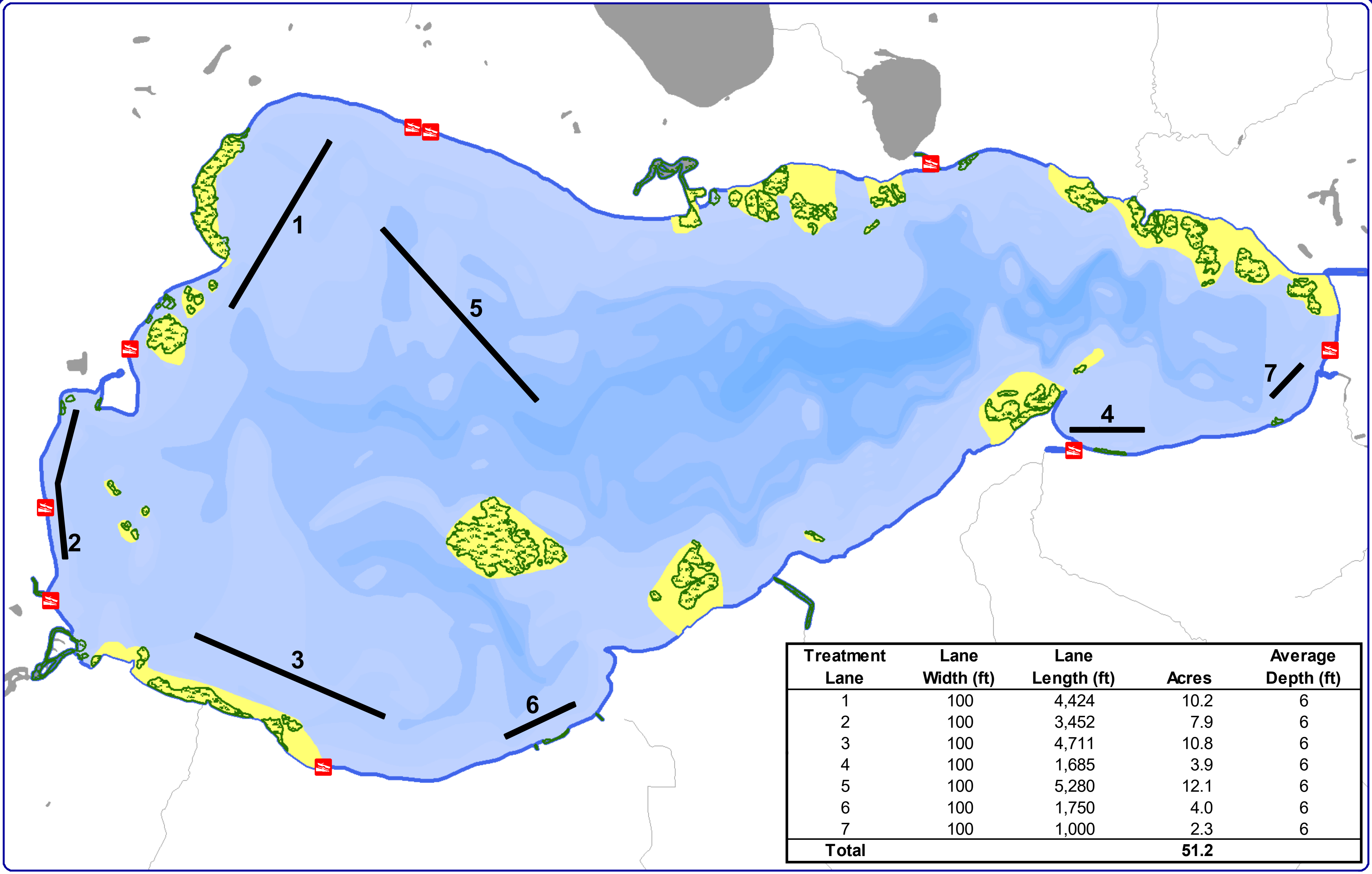
2013 Curly-leaf Pondweed Locations



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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2020
Map Date: October 13, 2020 AMS

Map 7
Shawano Lake
Shawano County, Wisconsin
2020 EWM Survey Locations



Treatment Lane	Lane Width (ft)	Lane Length (ft)	Acres	Average Depth (ft)
1	100	4,424	10.2	6
2	100	3,452	7.9	6
3	100	4,711	10.8	6
4	100	1,685	3.9	6
5	100	5,280	12.1	6
6	100	1,750	4.0	6
7	100	1,000	2.3	6
Total			**51.2**	

N W E S

3,000

Feet

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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2013
Sensitive Areas: WDNR, 2003
Nusiance Lanes: Digitized by Onterra from WDNR permit records
Map Date: December 2, 2013
Filename: Map8_Shawano_NusianceControl.mxd

Project Location in Wisconsin

Legend

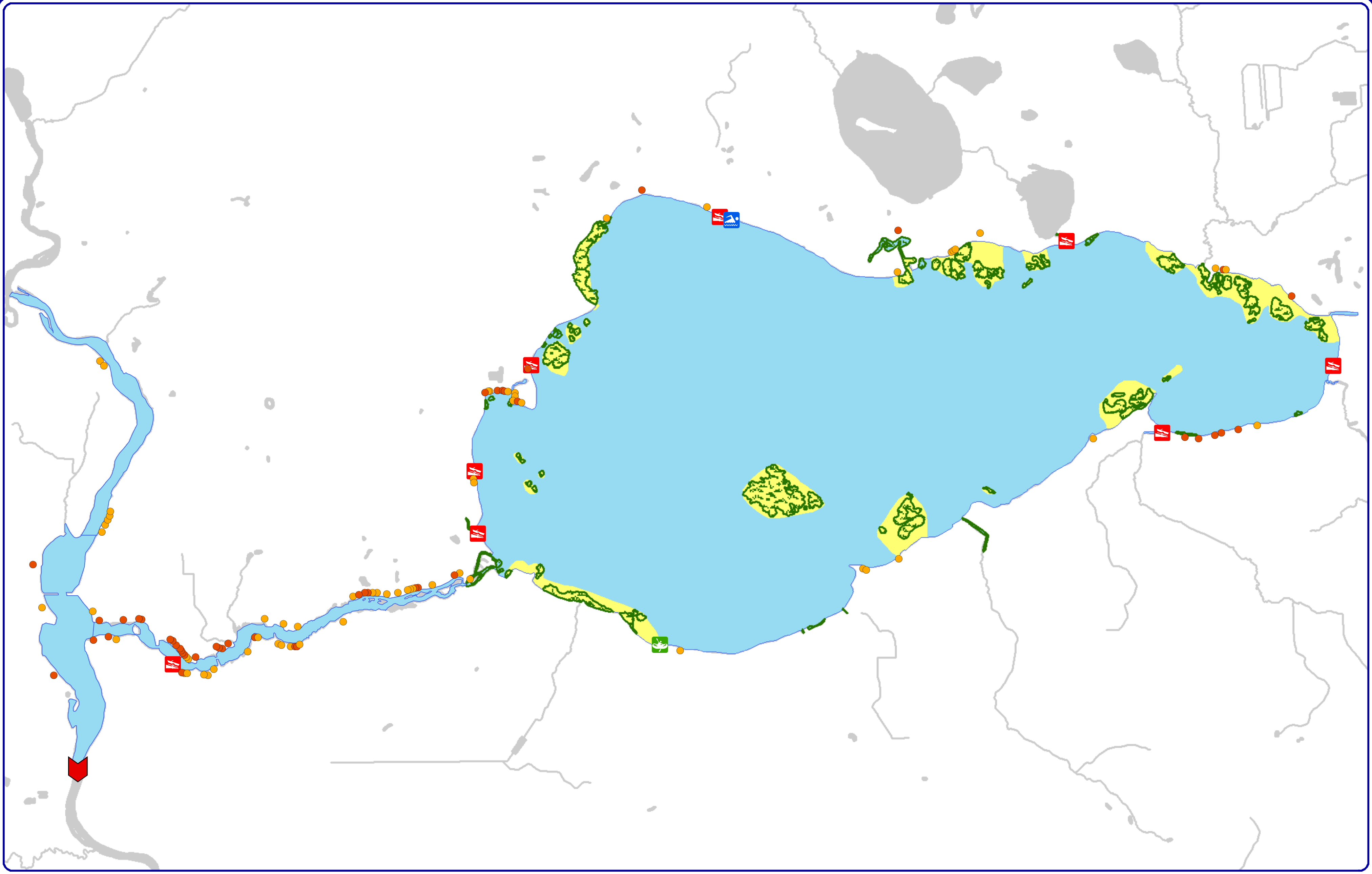
- Nusiance Navigation Treatment Lane
- Public Access
- Floating-leaf and/or Emergent Plant Community
- WDNR Sensitive Area

Map 8

Shawano Lake

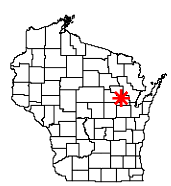
Shawano County, Wisconsin

Nuisance Navigation Herbicide Lanes



N
W E
S

4,600
Feet



Project Location in Wisconsin

Legend

2020 Riparian Harvest
(Symbol on Parcel Center)

- Single Cutting
- Two Cuttings

Floating-leaf and/or Emergent Plant Community in Shawano lake *(mapped July 2013)*

WDNR Sensitive Area *(Designated 2003)*

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

Sources:
Roads and Hydro: WDNR
Com Map: Onterra, 2013
Sensitive Areas: WDNR, 2003
2020 Harvest Sites: SAWM

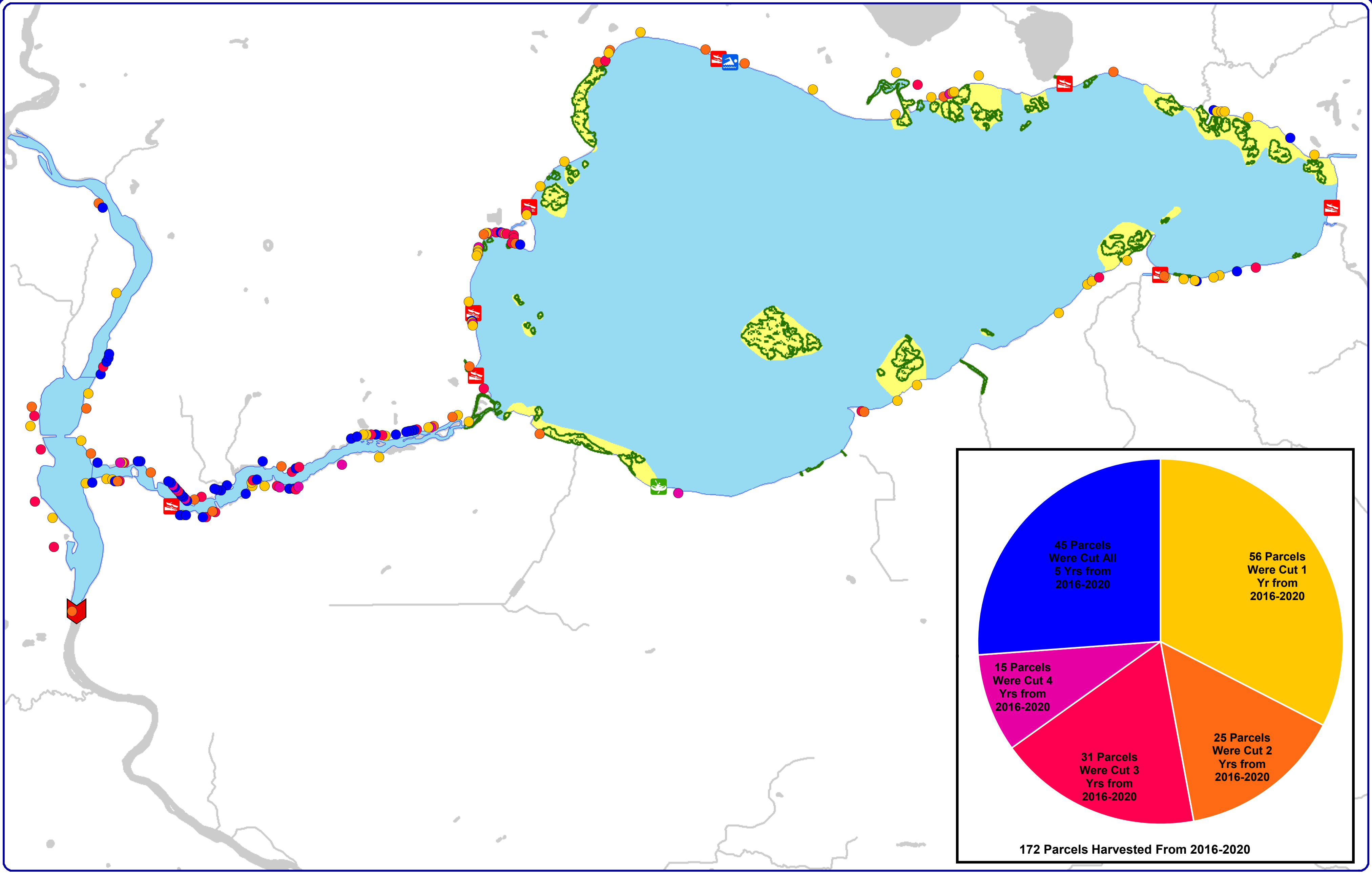
Map Date: November 23, 2020 - EJH

Map 9

Shawano Lake

Shawano County, Wisconsin

Mechanical Harvest: 2020 Riparian Cuttings

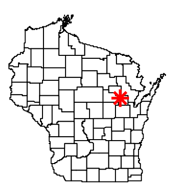


N
W E
S

4,600
Feet

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

Sources:
Roads and Hydro: WDNR
Com Map: Onterra, 2013
Sensitive Areas: WDNR, 2003
2020 Harvest Sites: SAWM
Map Date: November 23, 2020 - EJH



Project Location in Wisconsin

Legend

Riparian Harvest From 2016-2020

(Symbol on Parcel Center)

- Cut One Year
- Cut Two Years
- Cut Three Years
- Cut Four Years
- Cut All Five Years

Floating-leaf and/or Emergent Plant Community in Shawano lake *(mapped July 2013)*

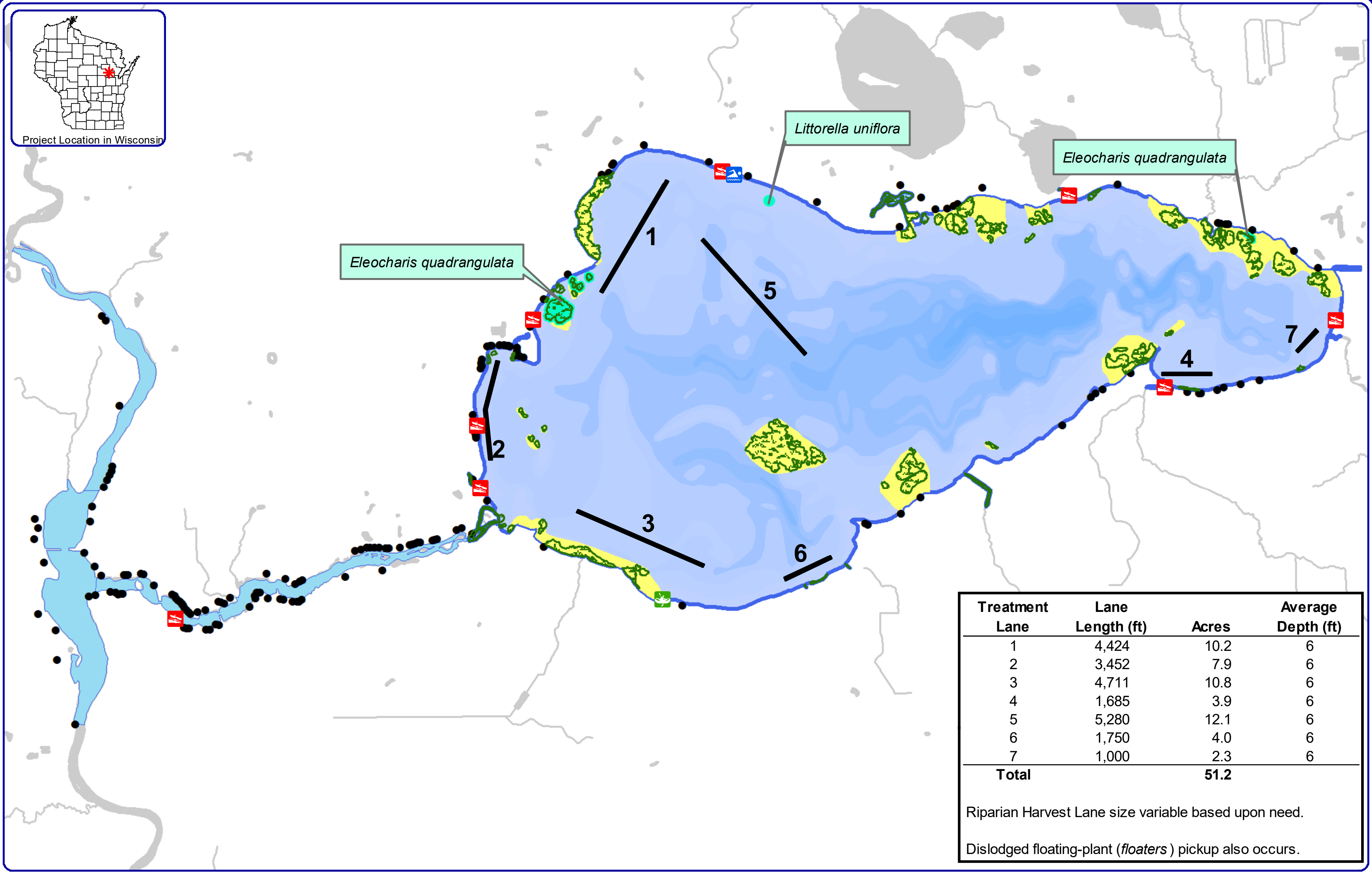
WDNR Sensitive Area *(Designated 2003)*

Map 10

Shawano Lake

Shawano County, Wisconsin

Mechanical Harvest: 2016-2020



Treatment Lane	Lane Length (ft)	Acres	Average Depth (ft)
1	4,424	10.2	6
2	3,452	7.9	6
3	4,711	10.8	6
4	1,685	3.9	6
5	5,280	12.1	6
6	1,750	4.0	6
7	1,000	2.3	6
Total		**51.2**	

Riparian Harvest Lane size variable based upon need.

Dislodged floating-plant (*floaters*) pickup also occurs.

N W E S

4,600

Feet

Legend

Nusiance Navigation Management Lane *(100ft wide)*

Riparian Harvest Location *(Symbol on Parcel Center; N=172)*

Floating-leaf and/or Emergent Plant Community *(Shawano Lake proper only; mapped July 2013)*

WDNR Sensitive Area *(Designated 2003)*

NHI Plant Species Location *(Label indicates species)*

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

Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra
Sensitive Areas: WDNR, 2003
Nusiance Lanes: Digitized by Onterra from WDNR permit records
Map Date: April 27, 2021 - EJH

Map 11

Shawano Lake

Shawano County, Wisconsin

Mechanical Harvest Locations