North and South Twin Lakes

Vilas County, Wisconsin

Comprehensive Management Plan

June 2018

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

The Twin Lakes Planning Committee

Jay Wittman – Chair	Michael Wade
Joe Fritzsche	Robert Bailey
	Peter Gloede

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1.0 INTRODUCTION

The Twin Lakes, Vilas county, are 2,883-acre and 633-acre drainage lakes, respectively. North Twin Lake has a maximum depth of 60 feet and a mean depth of 28 feet and South Twin Lake has a maximum depth of 43 feet and a mean depth of 20 feet. North Twin Lake has a relatively small watershed when compared to the size of the lake and South Twin Lake has a relatively large watershed when compared to the size of the lake. Together, the lakes contain 37 native plant species of which wild celery is the most common plant. One exotic plant species is known to exist in the Twin Lakes.

Field Survey Notes

These lakes are heavily utilized by recreationalists and anglers. The lakes have experienced change over the last few decades with established populations of rusty crayfish followed by Eurasian watermilfoil. Riparians often told us how swimmers itch was also impactful on their enjoyment of this large body of water.

Photograph 1.0-1. North Twin Lake, Vilas County

Lake at a Glance – The Twin Lakes

		North Twin Lake	South Twin Lake
Morphology	**Acreage**	2,883	633
	Max. Depth (ft)	60	43
	Volume (Acre-ft)	80,187	12,450
	Mean Depth (ft)	28	20
Vegetation	**Dominant Species**	Wild celery	Wild celery
	Number of Native Species	35	28
	Non-Native Species	Eurasian watermilfoil	Eurasian watermilfoil
	Threatened/Special Concern Species	-	-
Water Quality	**Trophic State**	Mesotrophic	Oligo-Mesotrophic
	Limiting Nutrient	Phosphorus	Phosphorus
	pH	8.13	8.09
	Sensitivity to Acid Rain	Not Sensitive	Not Sensitive
	Watershed to Lake Area Ratio	3:1	21:1

2.0 STAKEHOLDER PARTICIPATION

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

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

Planning Committee Meeting I

On June 5, 2017, Eddie Heath and Tim Hoyman of Onterra met with five members of the Twin Lakes Planning Committee for nearly four 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. All study components including Eurasian watermilfoil (EWM) management results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Planning Committee Meeting II

On July 31, 2017, Eddie Heath met with the members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Twin Lakes management plan. The primary discussion at this meeting revolved around EWM management, but also included thoughtful discussions about how to get riparians to buy-in to better stewardship of the lake through shoreland property restoration.

Management Plan Review and Adoption Process

In October 2017, a few drafts of the Implementation Plan Section Outline were provided to the Planning Committee for review and feedback. A preliminary draft of the entire plan was provided to the Planning Committee in early November 2017.

On November 27, 2017, an official first draft of the NSTLRA's Comprehensive Management Plan was supplied to the WDNR, Wisconsin Valley Improvement Company, Great Lakes Indian Fish and Wildlife Commission, Vilas County, and NSTLRA's Planning Committee for official review.

The WDNR provided comments to the draft Comprehensive Management Plan on January 19, 2018 (53 days later). A meeting between members of the NSTLRA, WDNR, and Onterra took place on January 22, 2018 to go over aspects of the WDNR's review and discuss the forthcoming grant application materials. The WDNR held a technical review team meeting on March 12, 2018 to discuss the specifics of a potential fluridone strategy that was not specifically outlined within the original draft Comprehensive Management Plan but was included within the annual report and

AIS-EPC Grant application. An additional meeting between members of the NSTLRA, WDNR, and Onterra took place on May 15, 2018 to again go over aspects of the WDNR's review. The WDNR comments and how they were integrated into the second draft of this document are included in Appendix H. The second draft officially sent for review on May 25, 2018.

A short list of WDNR comments to the second draft were provided on June 12, 2018 (18 days later). The WDNR comments and how they were integrated into the final draft of this document are included in Appendix H

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners around the Twin Lakes. The survey was designed by Onterra staff and the NSTLRA planning committee and reviewed by a WDNR social scientist. During November 2016, the nine-page, 38-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 NSTLRA volunteer for analysis. Almost 40% 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. Due to the lower than desired response rate, and without the conduct of a non-response bias check, we cannot state that the survey results are a statistically accurate (unbiased) representation of stakeholder behavior, opinions or preferences.

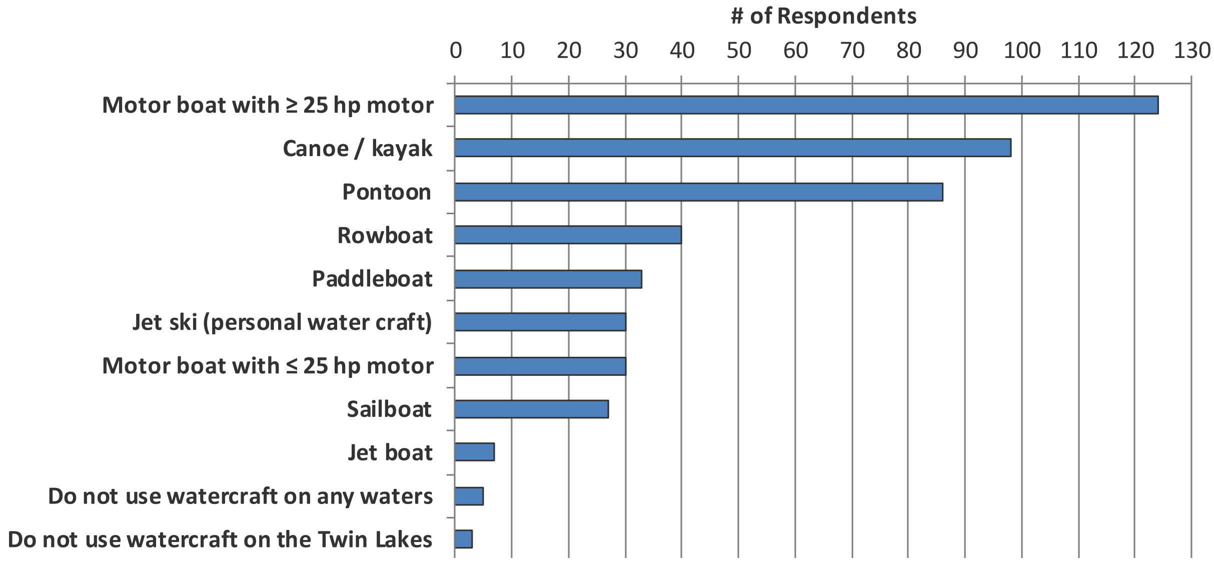
The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for the Twin Lakes. The majority of stakeholder survey respondents (30%) visit on weekends throughout the year, 29% live on the lake during the summer months only, 27% are year-round residents, 3% have undeveloped property, 2% are resort properties, and 1% are rental properties. 54% of stakeholders have owned their property for over 15 years, and 34% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a motor boat with greater than 25 horsepower motor, a canoe or kayak, a pontoon, or a combination of these three vessels on the Twin Lakes (Question 12). Rowboats were also a popular option. On a large system, the importance of responsible boating activities is very important. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 15, several of the top recreational activities on the lake involve boat use.

The introduction of invasive species to the Twin Lakes is the number one factor that stakeholder respondents believe is affecting the lakes (Question 21) and is also the top concern of stakeholder respondents (Question 22) (Figure 2.0-2). Excessive fishing pressure as well as excessive plant growth are other concerns. A concern of stakeholder respondents noted throughout the stakeholder survey (see Question 21-22 and survey comments – Appendix B) was swimmer's itch.

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



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

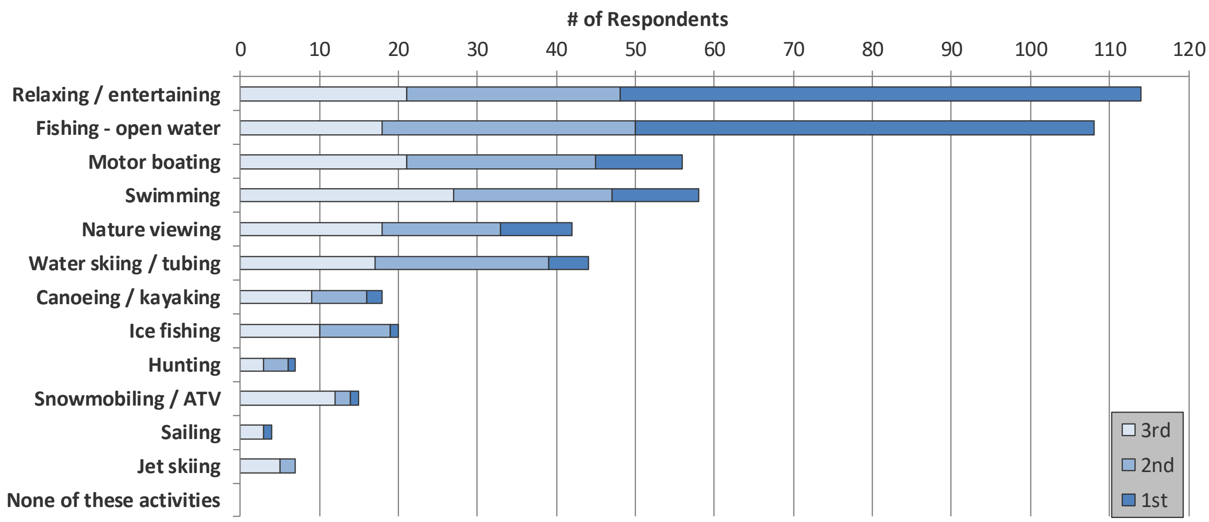
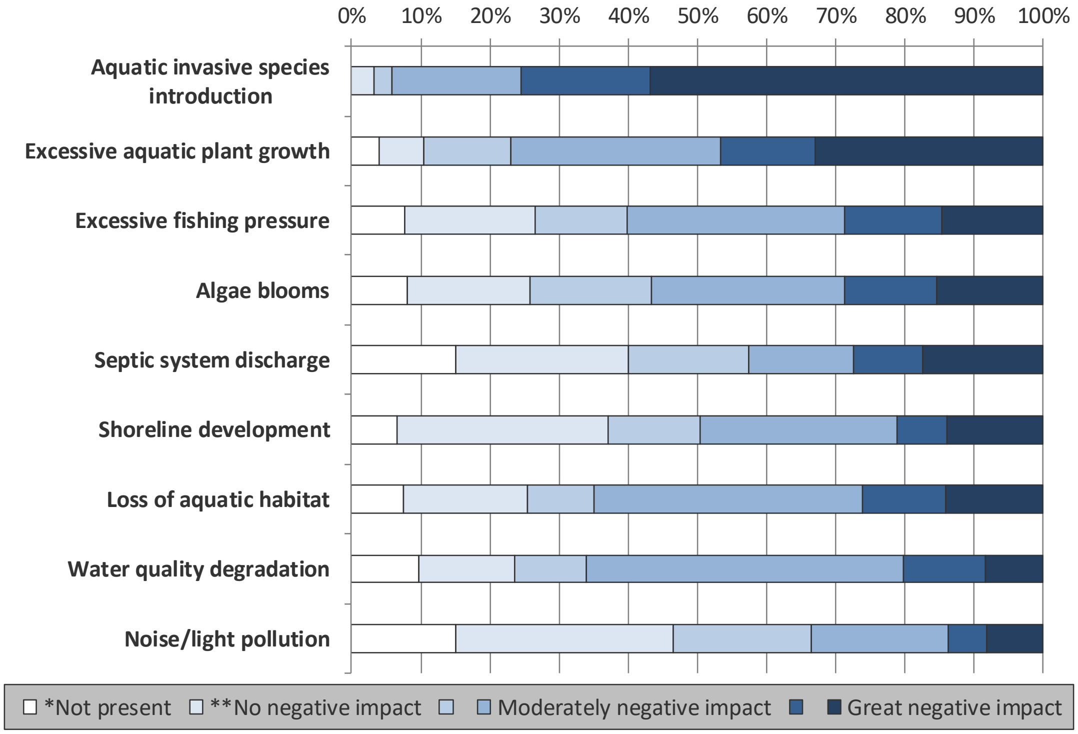


Figure 2.0-1. Select survey responses from the Twin Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 21: To what level do you believe these factors may be negatively impacting the Twin Lakes?



Question 22: Please rank your top three concerns regarding the Twin Lakes.

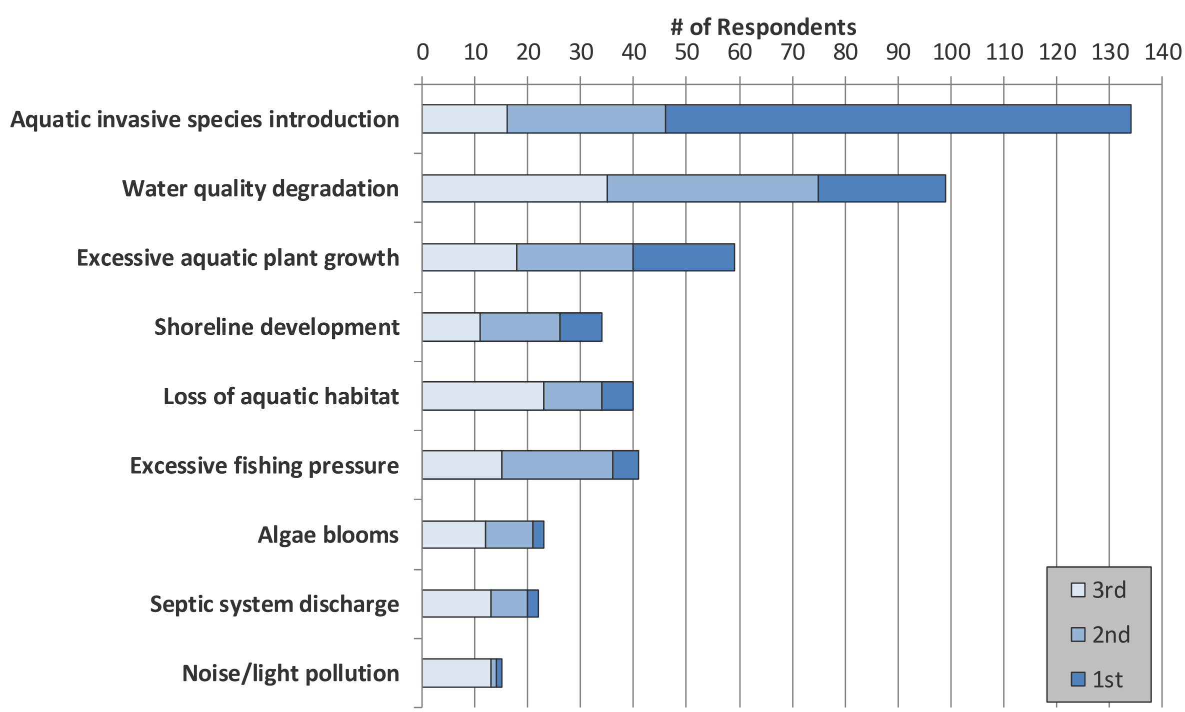


Figure 2.0-2. Select survey responses from the Twin Lakes Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

Reporting of water quality assessment results can often be a difficult and ambiguous task. Foremost is that the assessment inherently calls for a baseline knowledge of lake chemistry and ecology. Many of the parameters assessed are part of a complicated cycle and each element may occur in many different forms within a lake. Furthermore, water quality values that may be considered poor for one lake may be considered good for another because judging water quality is often subjective. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water.

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality analysis are used to indicate not only the health of the lake, but also to provide a general understanding of the lake's ecology and assist in management decisions. Each type of available analysis is elaborated on below.

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on the Twin Lakes 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 Twin Lakes' water quality analysis:

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification, the lake can be broken into three layers: The 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 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 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 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) 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 the Twin Lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

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

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

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

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

Because of their depth, hydrology, and large watershed size, both the Twin Lakes are classified as deep lowland drainage lakes (Category 5 on Figure 3.1-1); however, North Twin Lake is also a two-story lake (Category 9 on Figure 3.1-1). A two-story lake is capable of supporting both a warm water and cold water fishery. The top-story supports warmer water species such as bass and pike. The lower-story is colder, deeper, and well oxygenated and supports species such as cisco or trout. A cisco (or lake herring) population was found during a 2013 survey on North Twin Lake. There is not enough data available from two-story fishery lakes to create statewide median values, so North Twin Lake will be compared to other deep lowland drainage lakes in the state..

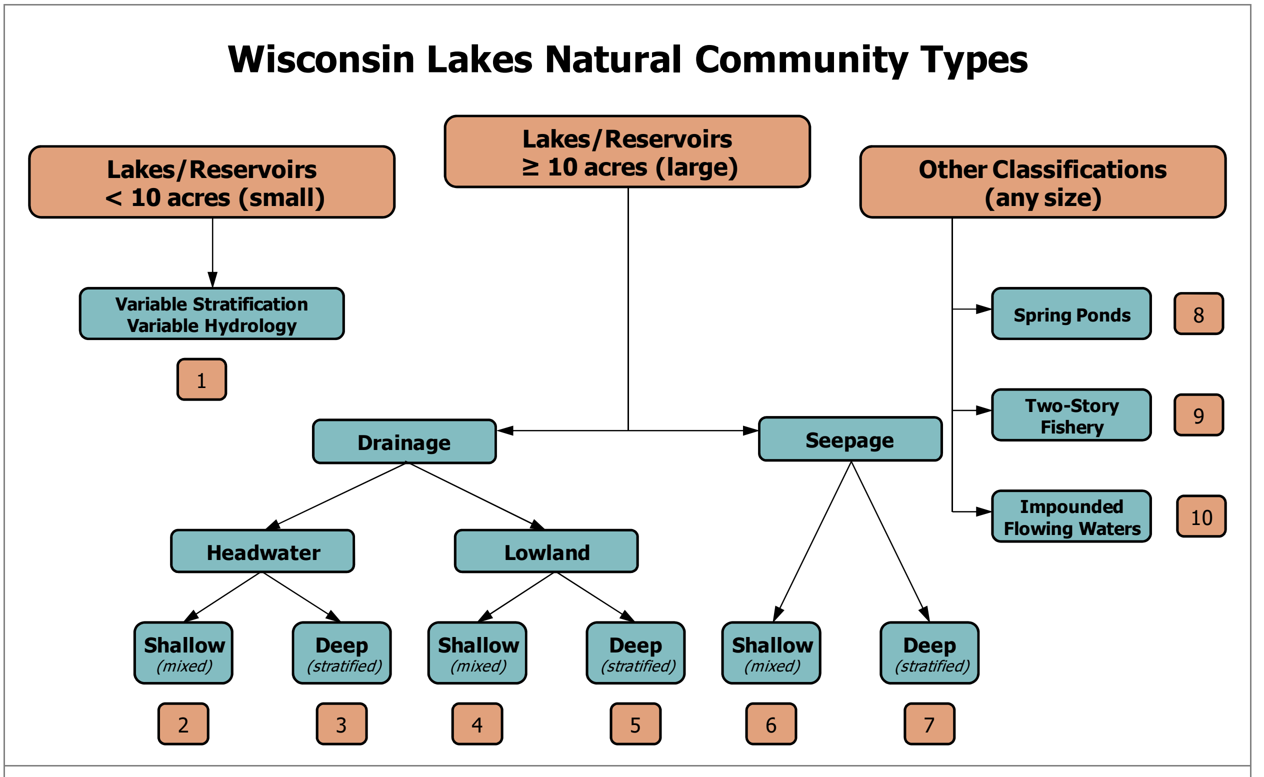


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. The Twin Lakes are within the Northern Lakes and Forests (NLF) ecoregion.

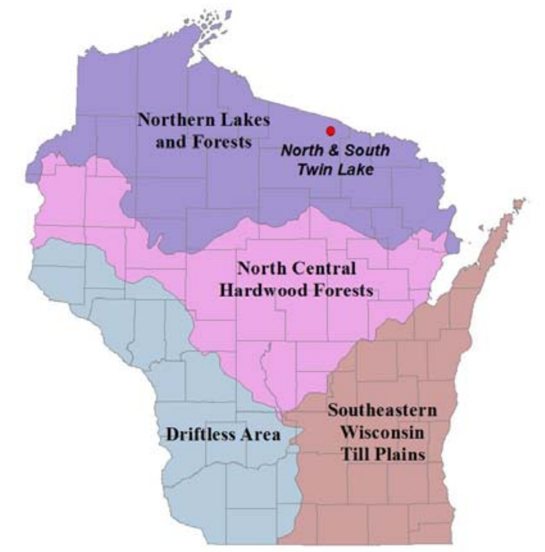


Figure 3.1-2. Location of the Twin Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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

These data along with data corresponding to statewide natural lake means, historical, current, and average data from the Twin Lakes are displayed in Figures 3.1-3 - 3.1-15. 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.

The Twin Lakes Water Quality Analysis

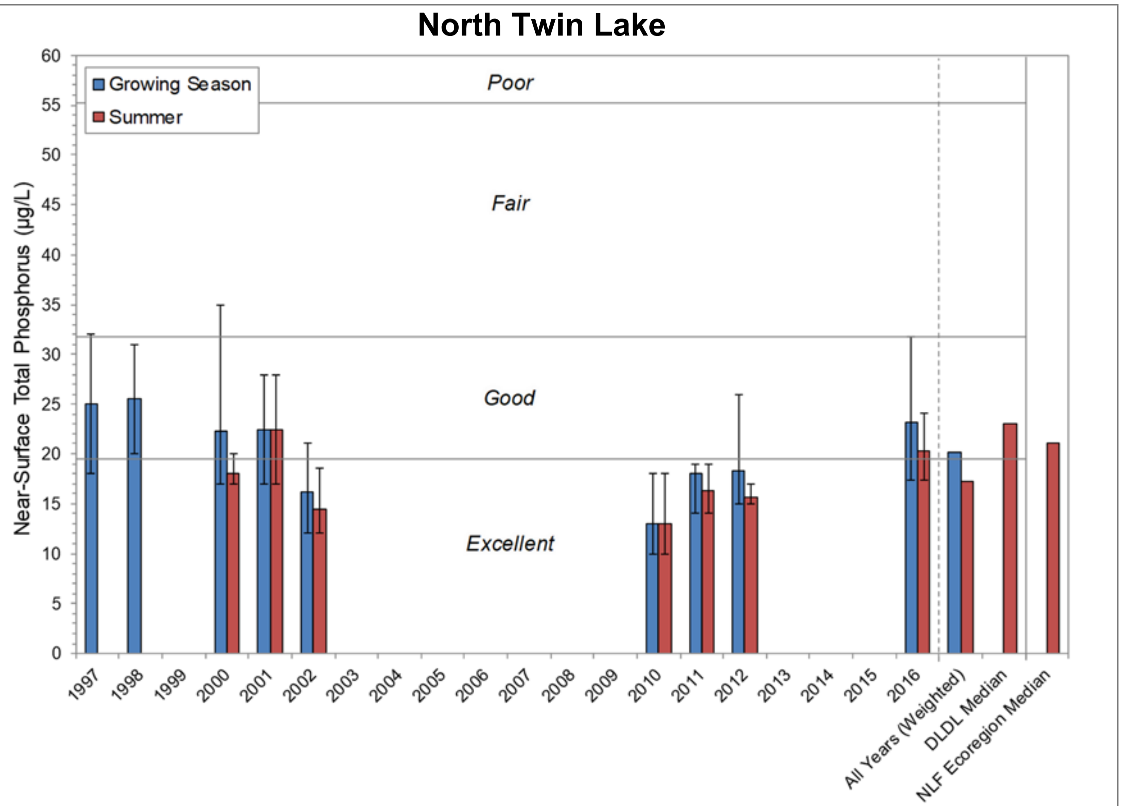
The Twin Lakes Long-term Trends

Near-surface total phosphorus data from North Twin Lake are available intermittently from 1973, 1974, 1977, 1997-2002, and 2010-2016 (Figure 3.1-3). Due to differences in analytical methods, the concentrations measured in the 1970s were significantly higher than subsequent concentrations. Because of this, the data collected in the 1970s on North Twin Lake are not included in this analysis. Average summer total phosphorus concentrations ranged from 13 μg/L in 2010 to 22 μg/L in 2001. The weighted summer average total phosphorus concentration is 17.2 μg/L and falls within the *excellent* category for Wisconsin's deep lowland drainage lakes. North Twin Lake's average summer phosphorus concentration is lower than the median concentrations for deep lowland drainage lakes in Wisconsin (23 μg/L) and for all lake types within the NLF ecoregion (21 μg/L). The average summer near-surface total phosphorus concentration measured in 2016 was slightly above average at 20.3 μg/L. The limited historical total phosphorus data make it difficult to determine if any trends in phosphorus concentration (positive or negative) are occurring over time. The historical data indicate that phosphorus concentrations can be somewhat variable from year to year in North Twin Lake, but it does not appear that phosphorus concentrations have been increasing or decreasing with time.

Near-surface total phosphorus data from South Twin Lake are available from 1979, 1996-2006, 2010-2012, and 2016 (Figure 3.1-4). Like North Twin Lake, the phosphorus data collected in 1979 from South Twin Lake were not included in this analysis. Average summer total phosphorus concentrations ranged from 10 µg/L in 1999 to 20 µg/L in 2001. The weighted summer average total phosphorus concentration is 14.7 µg/L and falls into the *excellent* category for deep, lowland drainage lakes in Wisconsin. South Twin Lake's average summer phosphorus concentration is lower than the median concentrations for deep lowland drainage lakes in Wisconsin (23 µg/L) and for all lake types within the NLF ecoregion (21 µg/L). The average summer near-surface total phosphorus concentration measured in 2016 was slightly above average at 19.1 µg/L. Trends analysis indicates that no trends, positive or negative, in phosphorus concentration is occurring over time in South Twin Lake. The lower phosphorus concentrations in South Twin Lake when compared to North Twin Lake are likely the result of the sequestration of phosphorus (e.g. sedimentation) within North Twin Lake.

Chlorophyll-*a* concentration data are available from North Twin Lake from 2000-2002, 2010-2012, and 2016 (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 2.1 µg/L in 2002 to 6.0 µg/L in 2000. The weighted summer total chlorophyll-*a* concentration is 3.9 µg/L and falls within the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's deep lowland drainage lakes. The weighted summer average chlorophyll-*a* concentration falls below the median concentrations for deep lowland drainage lakes in Wisconsin (7.0 µg/L) and all lake types within the NLF ecoregion (5.6 µg/L). The 2016 summer chlorophyll-a concentration was below the weighted average, with an average concentration of 2.1 µg/L. While average chlorophyll-*a* concentrations are slightly variable between years, the limited historical data do not indicate any apparent trends are occurring in chlorophyll-*a* concentrations over time.

Chlorophyll-*a* concentration data are available from South Twin Lake from 1979, 1996-2006, 2010-2012, and 2016 (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 1.2 µg/L in 1999 to 6.5 µg/L in 2004. The weighted summer total chlorophyll-*a* concentration is 2.8 µg/L and falls within the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's deep lowland drainage lakes. The weighted summer average chlorophyll-*a* concentration falls below the median concentrations for deep lowland drainage lakes in Wisconsin (7.0 µg/L) and all lake types within the NLF ecoregion (5.6 µg/L). The 2016 summer chlorophyll-a concentration was below the weighted average, with an average concentration of 2.6 µg/L. Like North Twin Lake, chlorophyll-*a* concentrations in South Twin Lake can be somewhat variable from year to year, but overall do not indicate a trend is occurring in chlorophyll-*a* concentration over time.



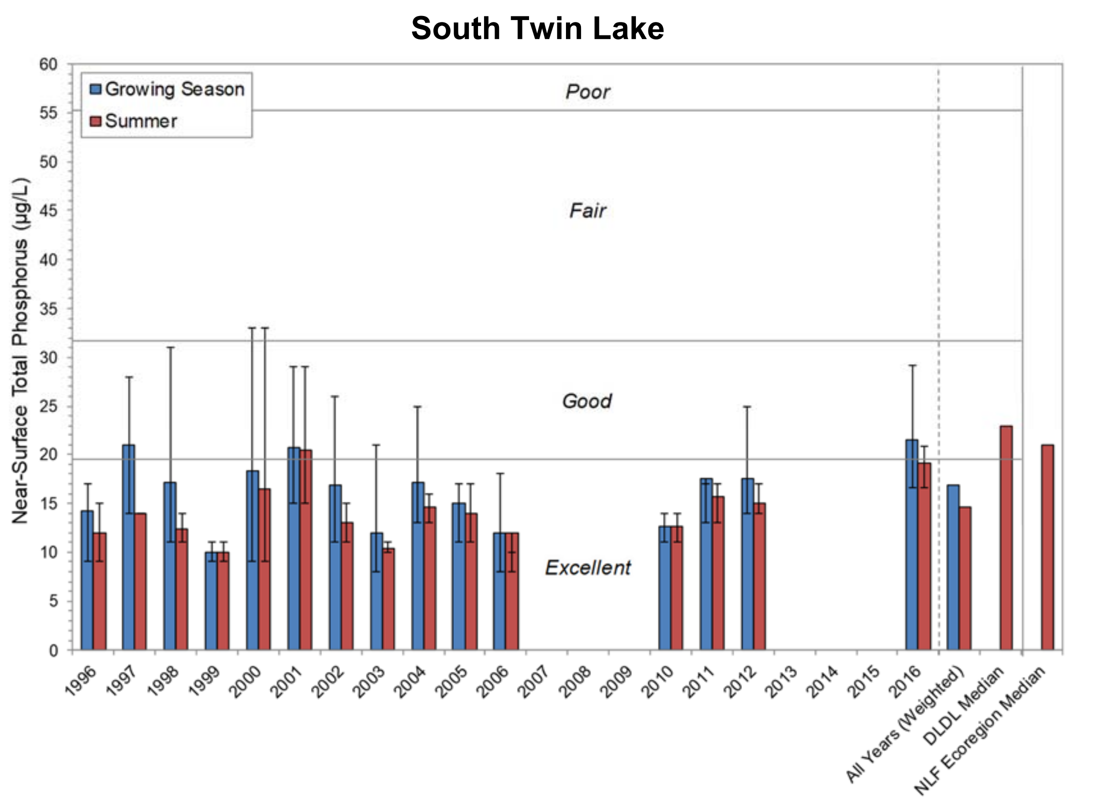


Figure 3.1-3. The Twin Lakes annual average near-surface total phosphorus and state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes median summer total phosphorus. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available from North Twin Lake from 1973-1974, 1997-1998, 2000, 2010-2012, and 2016 (Figure 3.1-5). Average summer Secchi disk depth ranged from 6.5 feet in 1974 to 15.3 feet in 2011. The weighted summer average Secchi disk depth is 13.2 feet and falls into the *excellent* category for Secchi disk depth in Wisconsin's deep lowland drainage lakes. North Twin Lake's average summer Secchi disk transparency exceeds the median values for deep lowland drainage lakes in Wisconsin (8.5 feet) and for all lake types within the NLF ecoregion (8.9 feet). Historical Secchi disk data are limited, but Secchi disk transparency is higher at present than the measurements collected in the 1970s.

Secchi disk transparency data are available from South Twin Lake from 1979, 1993-2004, 2010-2014, and 2016 (Figure 3.1-5). Average summer Secchi disk depth ranged from 7.9 feet in 2001 to 16 feet in 1979; however, this was the only Secchi disk record from 1979 and does not likely represent the annual average. The weighted summer average Secchi disk depth is 12.7 feet, which falls into the *excellent* category for Secchi disk depth in Wisconsin's deep lowland drainage lakes. South Twin Lake's average summer Secchi disk transparency exceeds the median values for deep lowland drainage lakes in Wisconsin (8.5 feet) and for all lake types within the NLF ecoregion (8.9 feet). Trends analysis of Secchi disk data from South Twin Lake indicated while average water clarity can vary from year to year, there is no significant trend (positive or negative) in water clarity occurring over time.

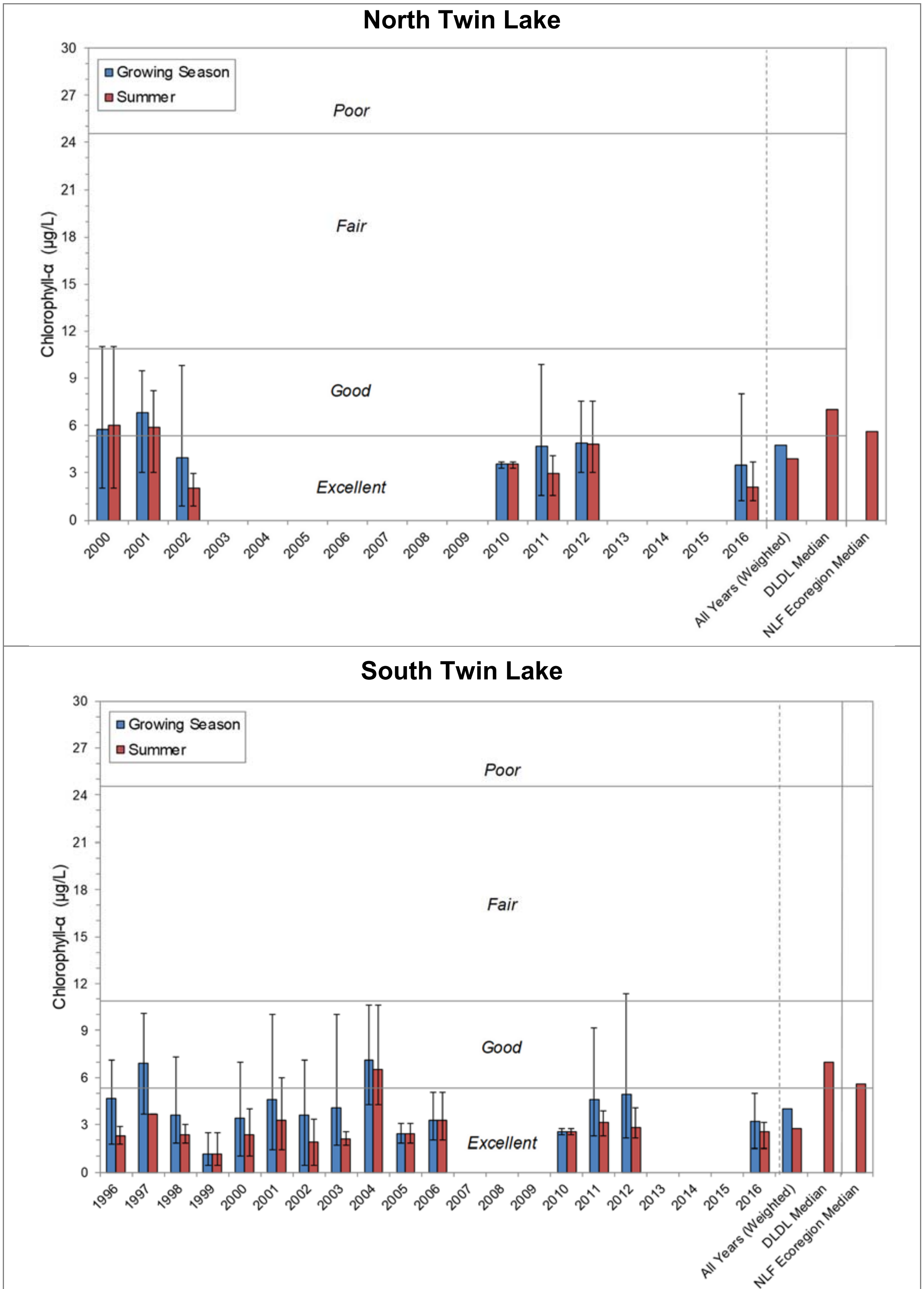


Figure 3.1-4. The Twin Lakes annual average chlorophyll-α and state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes median summer chlorophyll-α. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

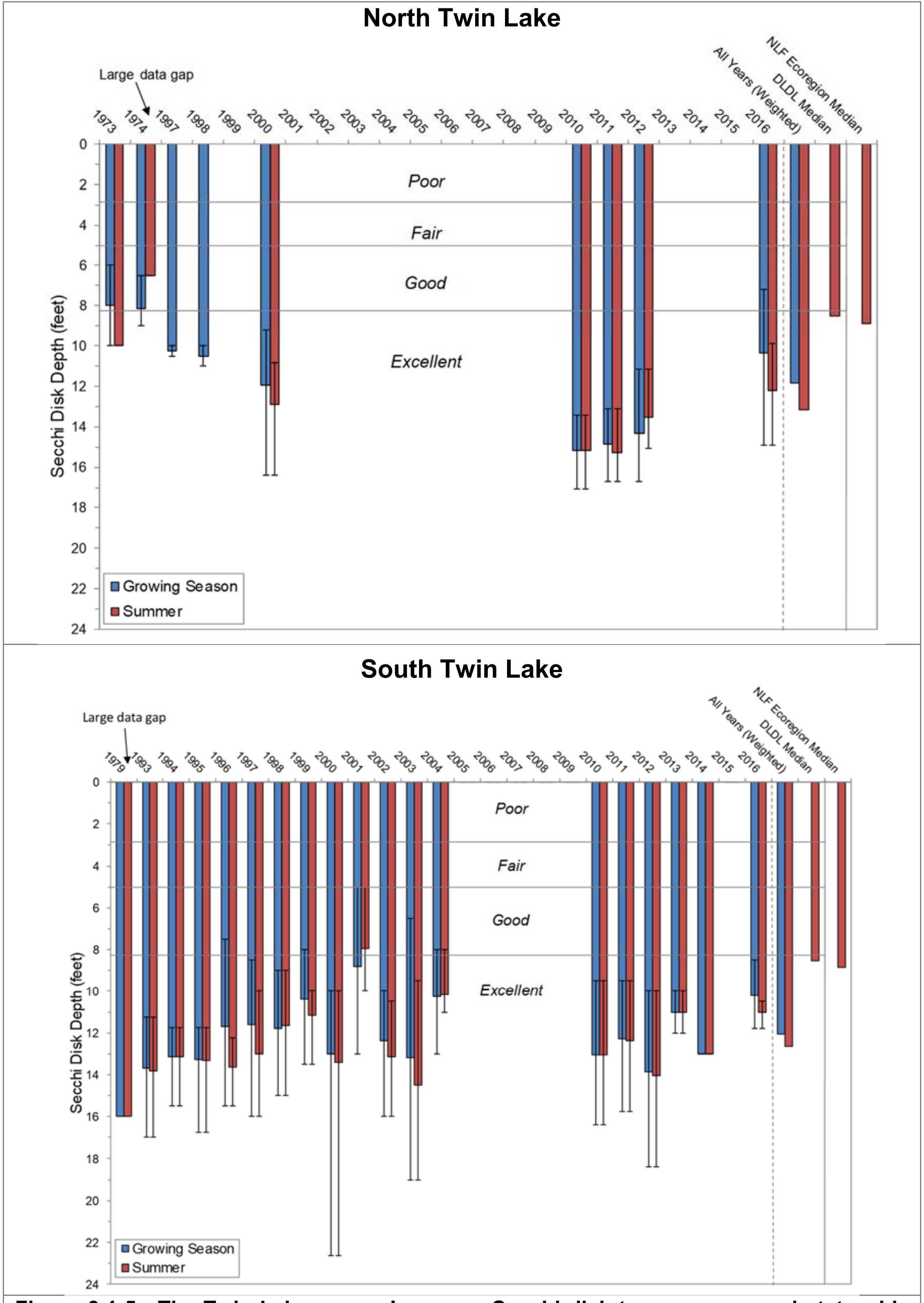


Figure 3.1-5. The Twin Lakes annual average Secchi disk transparency and state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes median summer Secchi disk transparency. Error bars represent maximum and minimum values. Water Quality Index values adapted from WDNR PUB WT-913.

Abiotic suspended particulates, such as sediment, can also influence in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in both the Twin Lakes in 2016, indicating minimal amounts of suspended material within the water. While suspended particles are minimal in the lakes, water clarity can also be influenced by dissolved compounds within the water. Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity.

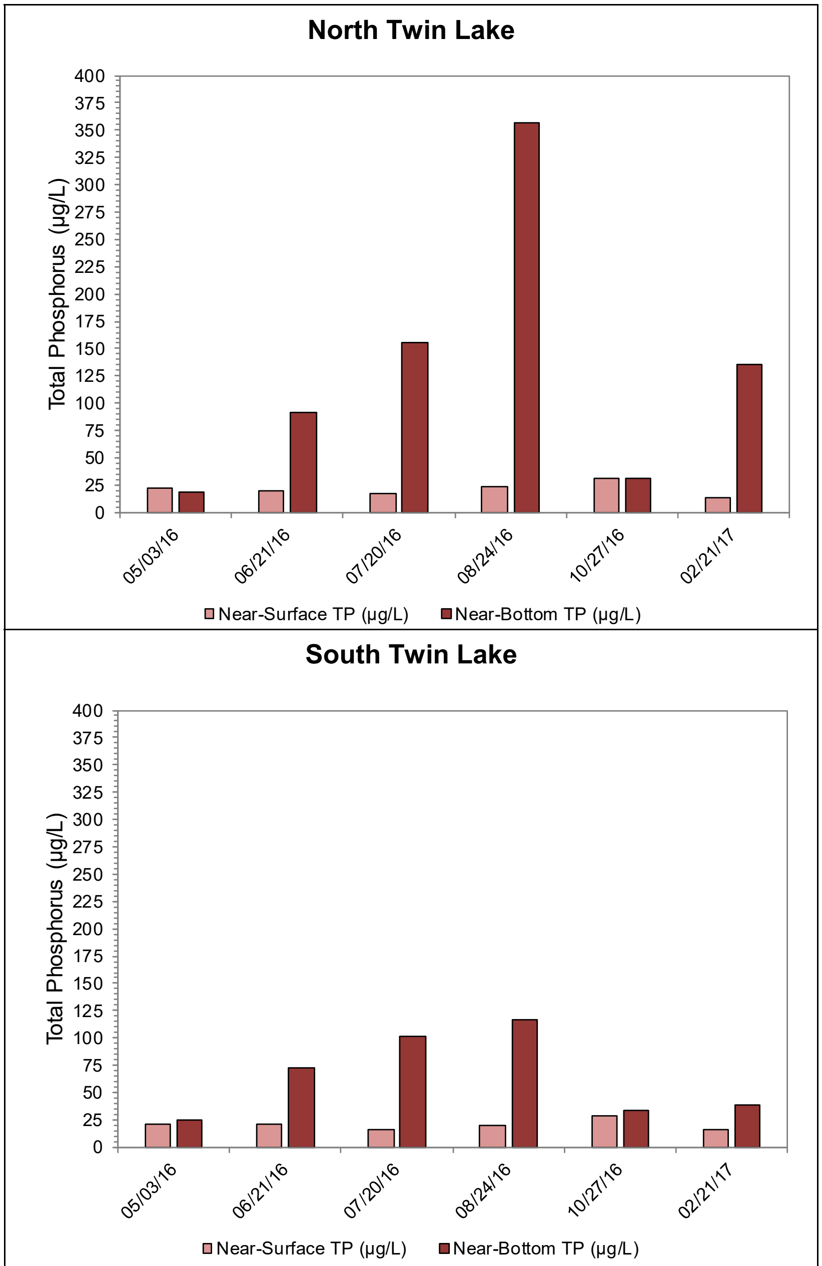


Figure 3.1-6. The Twin Lakes near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations measured in 2016.

A measure of water clarity once all 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 values measured from the Twin Lakes in 2016 averaged 7.5 and 5.0 SU (standard units), respectively, indicating each lake's water is *clear*. There are low concentrations of dissolved organic acids in the lakes.

To determine if internal nutrient loading (discussed in the *Primer* section) is a significant source of phosphorus in the Twin Lakes, near-bottom total phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on five occasions from the Twin Lakes in 2016 and once in 2017 (Figures 3.1-6). Near-bottom total phosphorus concentrations in North Twin Lake increased over the course of the growing season from 18.7 µg/L in May to 357 µg/L in August. Near-bottom total phosphorus concentrations in South Twin Lake also increased over the course of the growing season from 24.8 µg/L in May to 117 µg/L in August. As discussed in the Dissolved Oxygen subsection, both the Twin Lakes maintained stratification over the course of the summer and an anoxic hypolimnion. This allowed phosphorus to be released from bottom sediments into the overlying water within the hypolimnion.

While the near-bottom total phosphorus concentrations measured in the Twin Lakes in 2016 indicate the internal release of phosphorus from bottom sediments is occurring during summer stratification, near-surface total phosphorus concentrations from both lakes indicate the majority of this phosphorus remains within the hypolimnion and is not being mobilized to surface waters. Following fall mixing in October, there was a small increase in near-surface total phosphorus concentrations in the Twin Lakes, likely due to near-bottom phosphorus being mixed throughout the water column. While internal phosphorus loading occurs in the lakes, their morphology prevents this phosphorus from being mixed to the surface during the growing season and it does not appear to be affecting phosphorus concentrations at the surface during the summer.

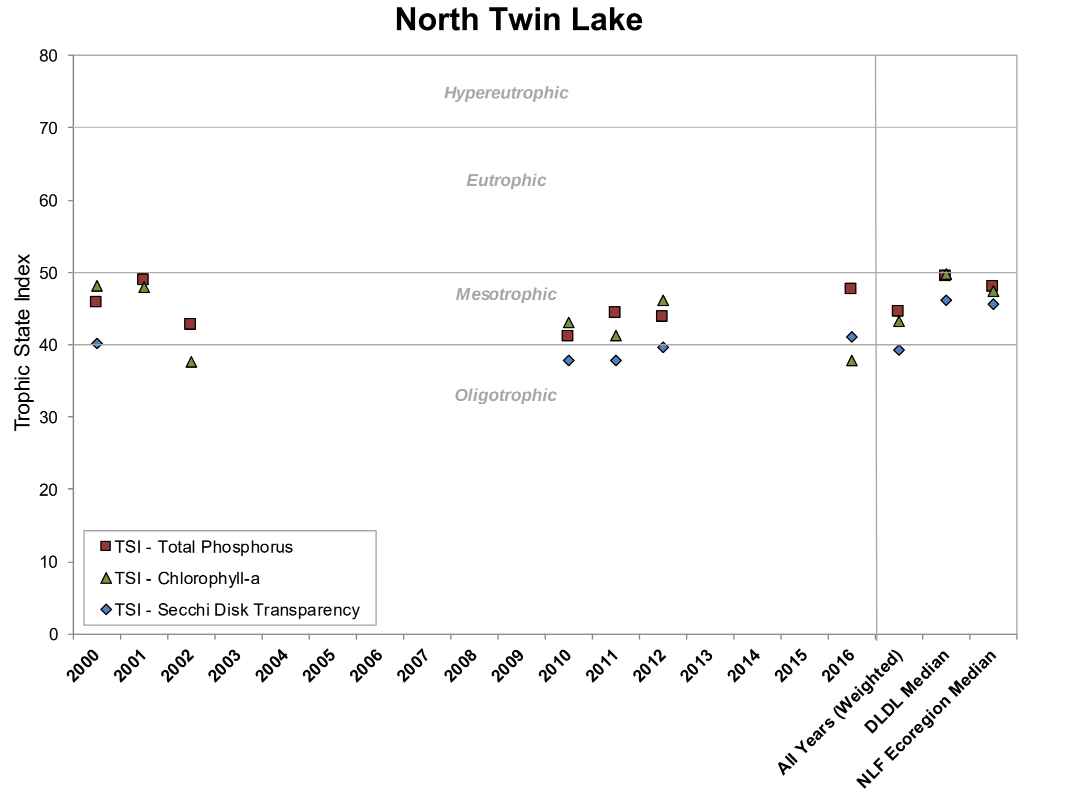
Limiting Plant Nutrient of the Twin Lakes

Using midsummer nitrogen and phosphorus concentrations from the Twin Lakes, a nitrogen:phosphorus ratio of 18:1 and 24:1 was calculated, respectively. This finding indicates that both the Twin Lakes are indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that increased phosphorus inputs into these lakes would likely lead to increase algal production and decreased water clarity.

The Twin Lakes Trophic State

Figure 3.1-7 contain the Trophic State Index (TSI) values for the Twin Lakes. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in North Twin Lake indicate the lake is at present in a mesotrophic state, while weighted TSI values for total phosphorus and chlorophyll-*a* in South Twin Lake indicate the lake is currently in an oligo-mesotrophic state (Figure 3.1-7). The productivity in these lakes is lower when compared to other lowland drainage lakes in Wisconsin and when compared to all lake types within the NLF ecoregion.



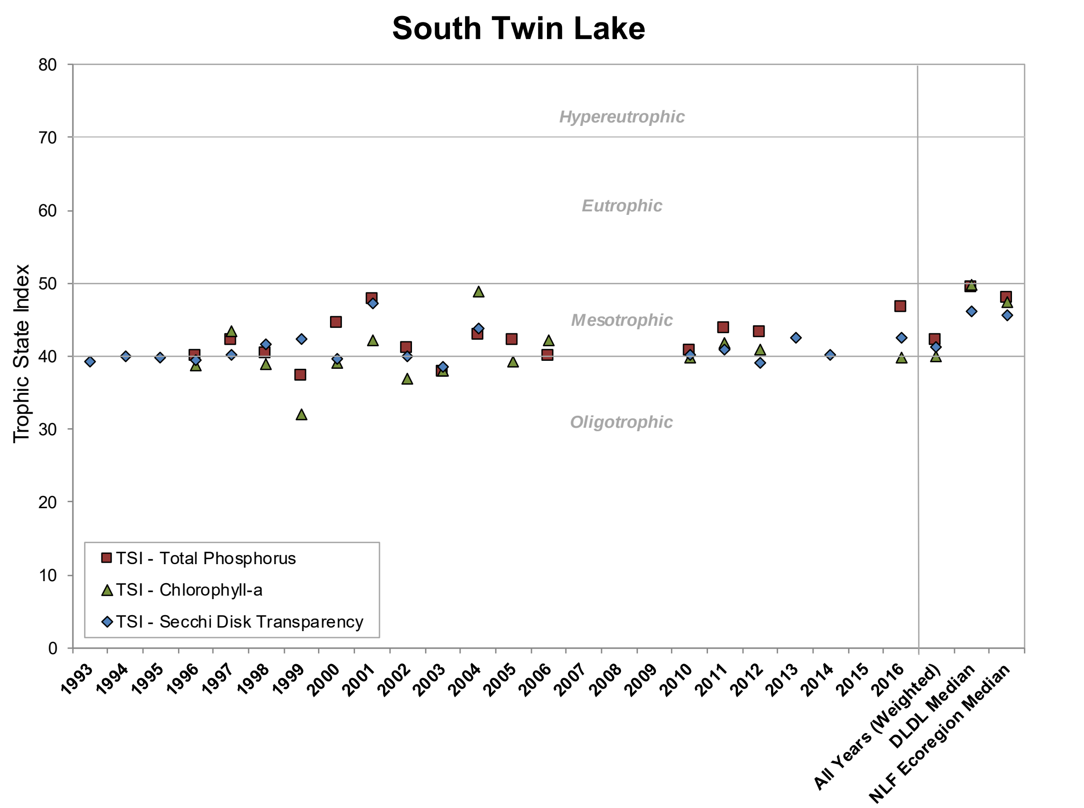


Figure 3.1-7. The Twin Lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193. DLDL= Deep Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion.

Dissolved Oxygen and Temperature in the Twin Lakes

Dissolved oxygen and temperature were measured during water quality sampling visits to the Twin Lakes by Onterra staff. Profiles depicting these data are displayed in Figures 3.1-8 and 3.1-9. The temperature and dissolved oxygen data collected in 2016 indicates that the lakes remained stratified throughout the summer. North Twin Lake develops anoxia from approximately 30 feet and deeper by mid-summer and South Twin Lake develops anoxia from approximately 25 feet and deeper by mid-summer. By October, surface temperatures had cooled and the lakes had mixed as indicated by relatively uniform temperature and dissolved oxygen throughout the water column. Dissolved oxygen collected under the ice in February 2017 indicated sufficient oxygen throughout most of the water column for aquatic life, indicating winter fish kills are likely not an issue for the Twin Lakes.

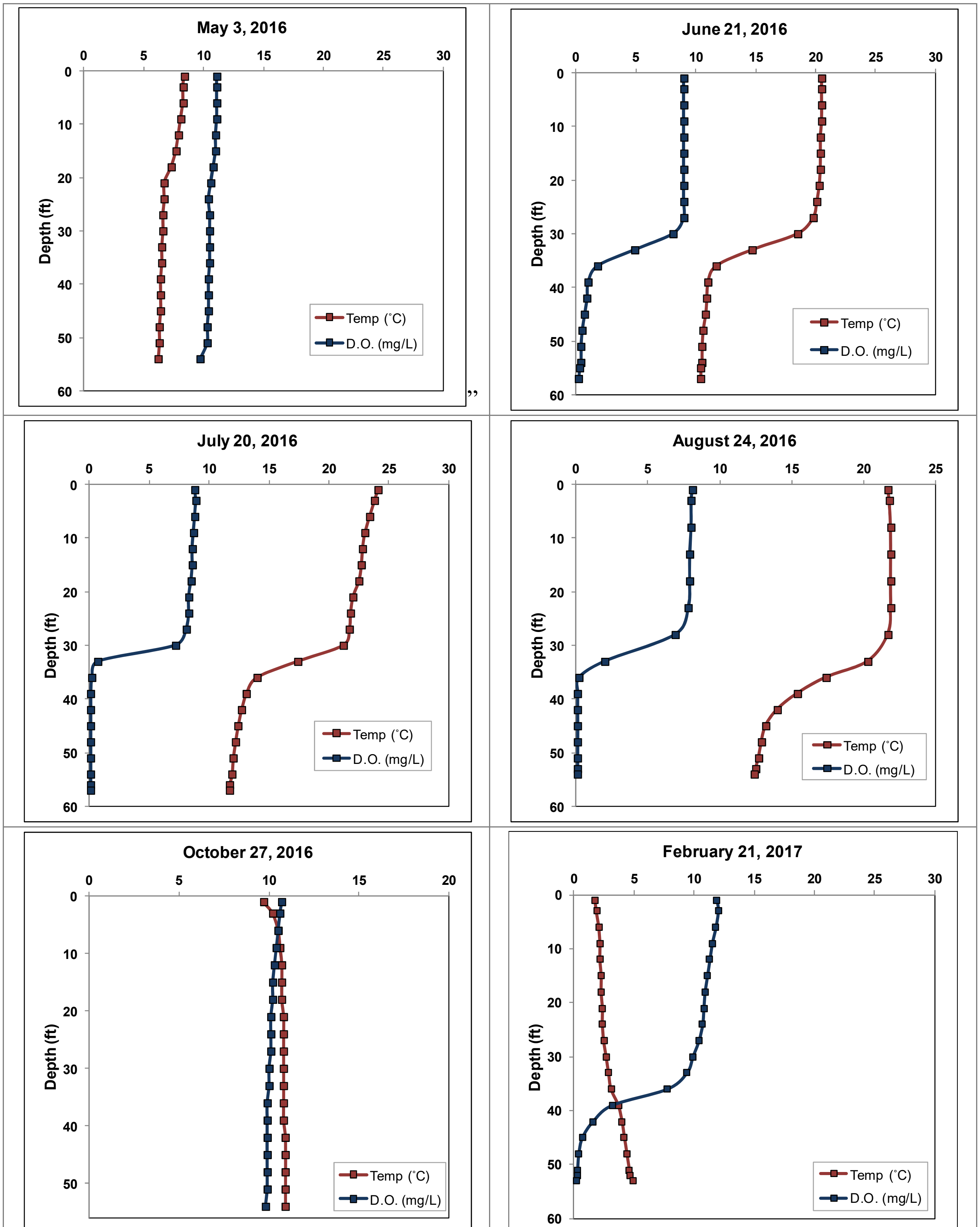


Figure 3.1-8. North Twin Lake dissolved oxygen and temperature profiles.

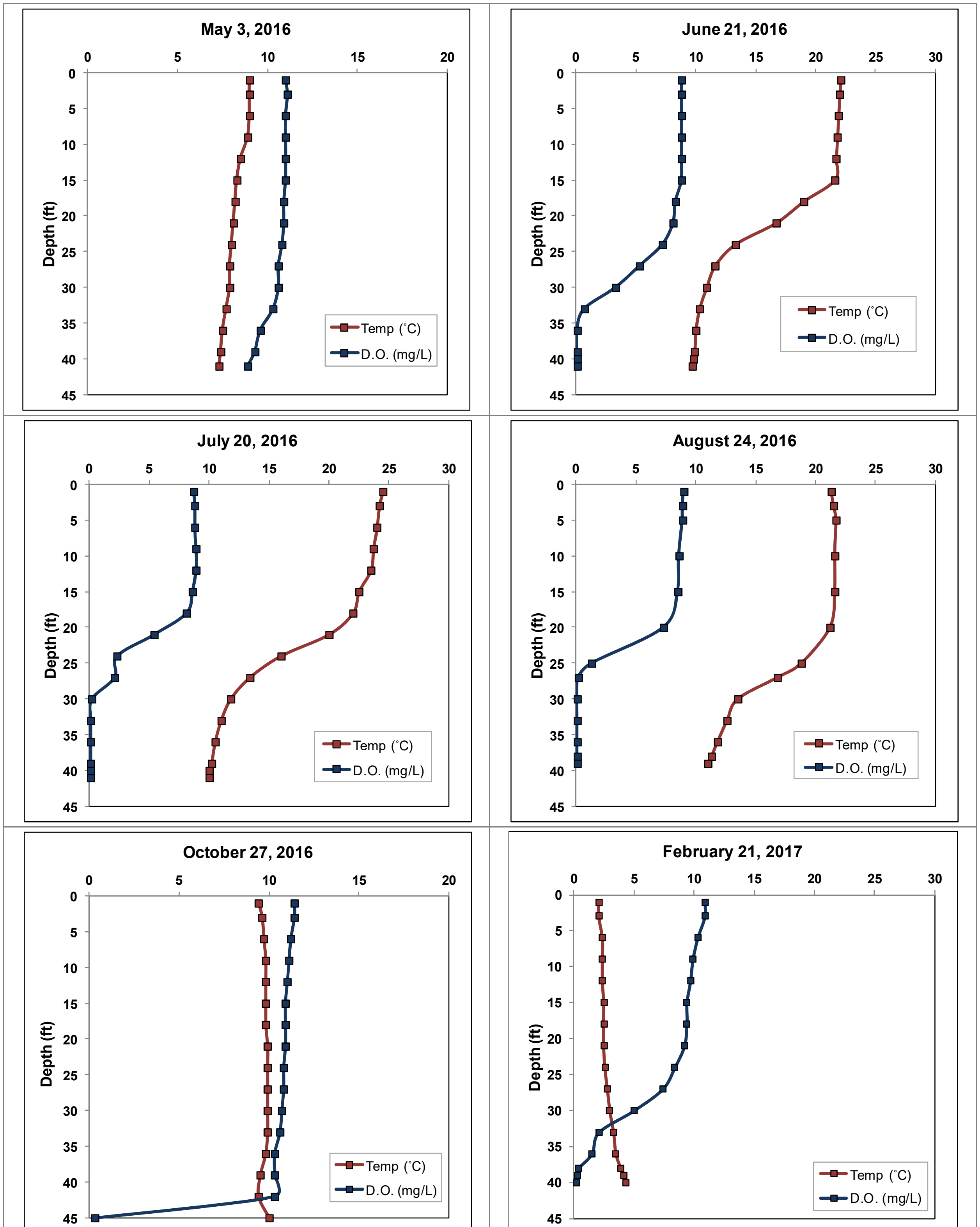


Figure 3.1-9. South Twin Lake dissolved oxygen and temperature profiles.

North Twin Lake 303(d) List Impairment Listing

The State of Wisconsin is required by law under the Clean Water Act to submit a list of lakes that do not meet specific water quality standards based upon lake type. The list of impaired waters, also known as the 303(d) list, is updated every two years. Each state is required to document the methodology used to assess the waterbodies. The WDNR developed and uses the Wisconsin Consolidated Assessment and Listing Methodology (WisCALM) to set water quality standards and assess the state's waterbodies. The WDNR is currently using WisCALM 2016; however, a draft document is currently being reviewed for implementation in 2018.

North Twin Lake was first placed on the 303(d) in 2016, because the lake's total phosphorus exceeds the 2016 WisCALM threshold for fish and aquatic life use in a two-story lake. The total phosphorus threshold is 15 µg/L, normally an amount that would be considered *excellent* for this lake type (deep lowland drainage lakes). But in order for a two-story lake to maintain oxygen in the hypolimnion for cold water fish species, even low total phosphorus concentrations can stimulate production that would lead to reduced oxygen levels.

As an example, during July and August of 2016, the hypolimnion in North Twin Lake was depleted of oxygen and the cisco population would have needed to move into the metalimnion (thermocline) to survive. In the 2018 WisCALM draft, the WDNR has proposed to examine two-story lakes by not only total phosphorus concentrations, but also by the quantity of cold water habitat available during the growing season for coldwater fish species (WDNR, in preparation). At this time, no habitat quantity has been listed as being sufficient for a healthy two-story lake. Cisco require dissolved oxygen of 3 mg/L or higher and prefer temperatures ranging from approximately 4-17°C (39.2-62.6°F), but can survive temperatures up to 22.8°C (73°F). In North Twin Lake, its entire volume was suitable cisco habitat in May and October 2016 with the full water column above 3 mg/L of dissolved oxygen and within cisco's preferred temperature range. During June and August 2016, the entire epilimnion and the thermocline was available for cisco and in July 2016 the entire thermocline and the bottom portion of the epilimnion were available for cisco. While technically almost the entire epilimnion in the summer of 2016 was in a survivable range for cisco, they likely prefer to stay below the photic zone from approximately 20 to 30 feet. This range below the photic zone is approximately 28,230 acre-feet of volume, or approximately 35% of North Twin Lake's entire volume.

As mentioned above, the current 2018 draft WisCALM document does not contain a volume of cold water habitat that would be considered minimal for cisco; however, once those criteria are developed, it may be found that North Twin Lake's available habitat is sufficient to remove North Twin from the 303(d) list. The NSTLRA would like to see North Twin removed from this list as the two-story fishery is doing well and the total phosphorus values are low.

Additional Water Quality Data Collected at the Twin Lakes

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 the Twin Lakes' water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH of the water in both the Twin Lakes was found to be slightly alkaline with a value of 8.1, and falls within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). 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 North Twin Lake was measured at 44 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain. Similarly, the alkalinity in South Twin Lake was measured at 43 (mg/L as $CaCO_3$), also indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so the Twin Lakes' pH of 8.1 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of the Twin Lakes was found to be 11.6 mg/L and 11.2 mg/L, respectively, falling just below the optimal range for zebra mussels.

Zebra mussels (*Dreissena polymorpha*) are a small bottom dwelling mussel, 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.

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, the Twin Lakes were considered borderline suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in the Twin Lakes in 2016 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys.

Stakeholder Survey Responses to the Twin Lakes 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. Of the 439 surveys distributed, 171 (39%) were returned. Without a response rate of 60% or higher, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of water quality in the Twin Lakes but cannot be stated with statistical confidence.
Figure 3.1-10 displays the responses of members of North & South Twin Lakes stakeholders to questions regarding the Twin Lakes' current water quality. When asked how they would describe the current water quality of their lake, 63% of respondents indicated *good*, 17% indicated *fair*, 15% indicated *excellent*, 3% indicated *poor*, 2% indicated that they were *unsure*, and <1% indicated *very poor*.

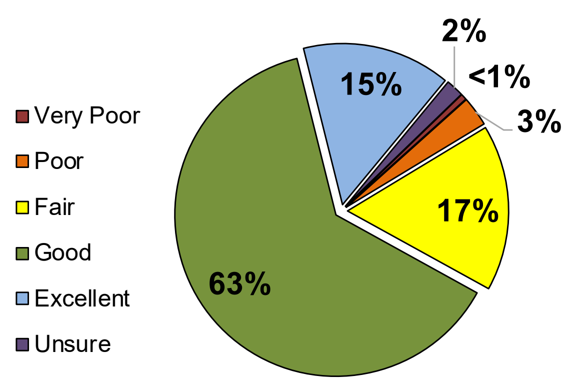


Figure 3.1-10. Stakeholder survey response Question #16. How would you describe the current water quality of your lake?

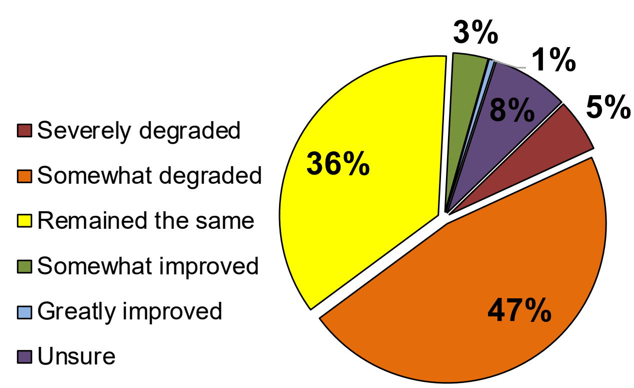


Figure 3.1-11. Stakeholder survey response Question #17. How as the water quality changed in your lake since you first visited the lake?

When asked how they believe the current water quality has changed since they first visited their lake, the largest proportion of respondents, 47%, indicated it has *somewhat degraded*, 36% indicated it has *remained the same*, 8%, indicated they were *unsure*, 5% indicated it has *severely degraded*, 3% indicated it has *somewhat improved*, and 1% indicated it has *greatly improved* (Figure 3.1-11). As discussed in the previous section, there are no statistically significant trends in total phosphorus, chlorophyll-a, or water clarity in the Twin Lakes. While the majority of stakeholders believe the water quality of the lakes is good, the proportion of stakeholders who indicated the lakes' water quality has somewhat degraded may be taking into account Eurasian watermilfoil growth in the lakes or may have concerns regarding swimmers itch, which was mentioned by stakeholders throughout the survey (Appendix B). But again, historical data indicate water quality has not been degrading over time in the Twin Lakes.

Twin Lake Water Levels

The Twin Lakes are one of 21 Wisconsin Valley Improvement Company (WVIC) water storage reservoirs used to maintain a nearly uniform flow of water as practicable in the Wisconsin River by storing surplus water in reservoirs for discharge when water supply is low to improve the usefulness of the rivers of the rivers for hydropower, flood control, and public use (Figure 3.1-12).

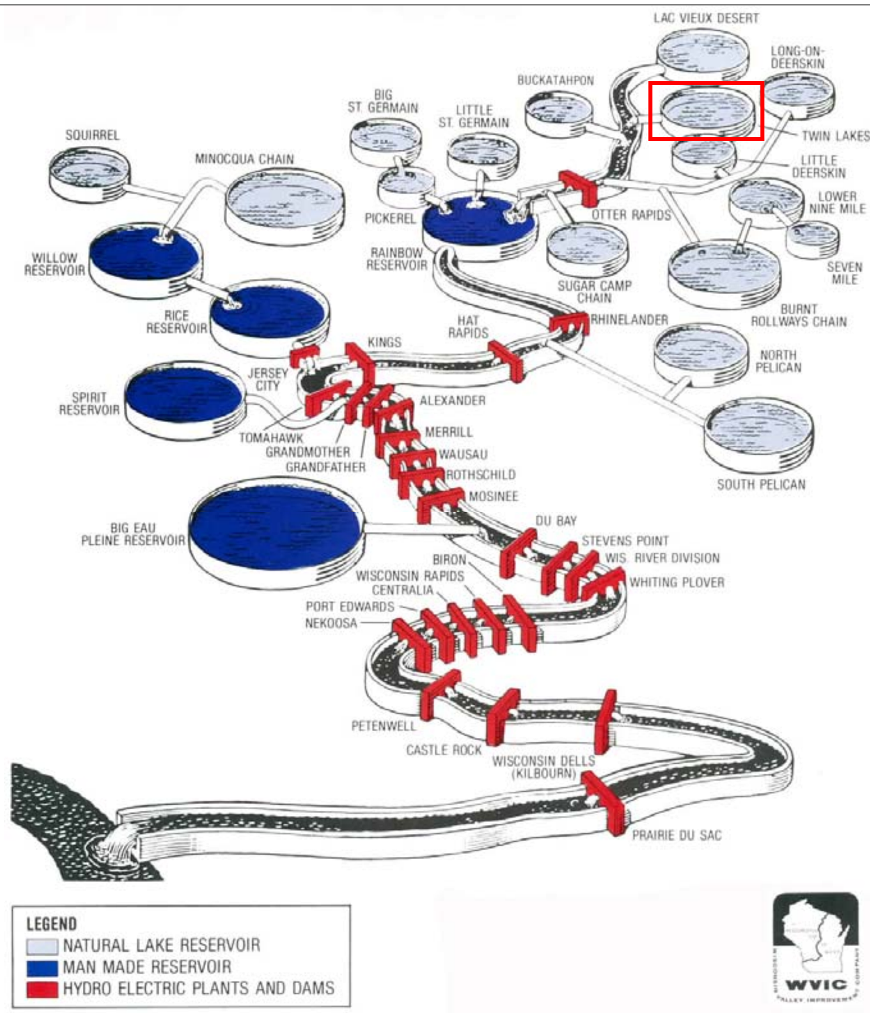


Figure 3.1-12. WVIC reservoir system. Twin Lakes are outlined in red. Adapted from WVIC website.

Hydroelectric power projects are licensed by the Federal Energy Regulatory Commission (FERC). As part of the FERC operation license, the minimum and maximum water levels are set for each waterbody. Natural lake reservoir water levels are maintained within a relatively narrow range in comparison to the five man-made reservoirs which exhibit changes of water levels that could span 10-20 feet in a single year.

The Twin Lakes are one of the natural lake reservoirs in the WVIC system, and the 1996-2026 FERC operating order grants an operational range of 1.66 feet during the summer (June 1 to

September 30) and an additional 0.34 feet can be lowered in the winter (October 1 to May 31). In addition to establishing a range of water levels, minimum outflows are also set by FERC to make sure the downstream riverine systems are not negatively impacted by abnormally low flows. The Twin Lakes must maintain a flow of 7.7 cubic feet per second year-round.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

In systems with high WS:LA ratios, like those 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.

North & South Twin Lake Watershed Assessment

The Twin Lakes' watershed encompasses an area of approximately 14,144 acres (22 square miles) across Vilas County, Wisconsin and Gogebic and Iron Counties in Michigan (Map 2). North Twin Lake's watershed covers approximately 12,595 acres while South Twin Lake's watershed includes North Twin Lake's watershed and an additional 1,549 acres of land which drains directly into South Twin Lake. The size of their watersheds relative to their surface area yields watershed to lake area ratios of 3:1 and 21:1 for North Twin Lake and South Twin Lake, respectively. According to WiLMS modeling, North Twin Lake's water is completely replaced once every 6.3 years while South Twin Lake's water is completely replaced on average once per year.

Approximately 51% of North Twin Lake's watershed is composed of forest, 23% of North Twin Lake's surface, 19% is composed of wetlands, 5% is composed of pasture/grass, and 2% composed of row crop agriculture (Figure 3.2-1). Using the landcover types and their acreages within North Twin Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load to North Twin Lake. WiLMS estimates that approximately 1,878 pounds of phosphorus are loaded to North Twin Lake on an annual basis (Figure 3.2-1). Of the 1,878 pounds, 41% is estimated to originate from atmospheric deposition on the lake's surface, 27% from forests, 11% from wetlands, 10% from areas of pasture/grass, 10% from row crop agriculture, and <1% from both rural residential and urban areas. Phosphorus loading from septic systems was also estimated using data obtained from the 2016 stakeholder survey of riparian property owners, and indicates that approximately 11 pounds, or roughly 1% of the annual phosphorus load is attributed to septic systems around North Twin Lake.

Using the estimated annual potential phosphorus load to North Twin Lake, WiLMS predicts that North Twin Lake should have an in-lake growing season mean total phosphorus concentration of around 15 µg/L, slightly lower than the measured average growing season of 20 µg/L. The small discrepancy between the predicted versus measured total phosphorus concentration is likely, in portion, due to internal nutrient loading in North Twin Lake.

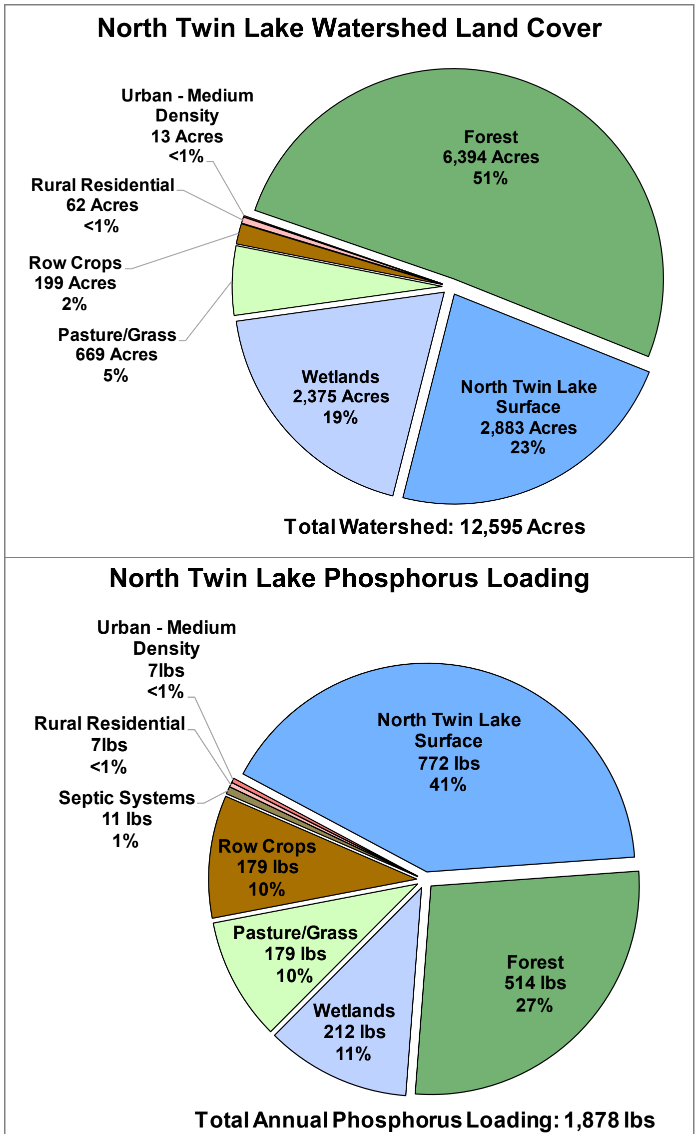


Figure 3.2-1. North Twin Lake watershed land cover types and estimated annual phosphorus loading. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Modeling of phosphorus loading to South Twin Lake was conducted by estimating the amount of phosphorus loaded from the North Twin Lake subwatershed and phosphorus from land cover within South Twin Lake's immediate, or direct watershed (Map 2). The annual phosphorus load from the North Twin Lake watershed was estimated using measured phosphorus concentrations from North Twin Lake and the annual outflow of water estimated from WiLMS. Approximately 89% of South Twin Lake's watershed is comprised of the North Twin Lake subwatershed while 11% is comprised of the lake's direct watershed (Figure 3.2-2). Approximately 51% of South Twin Lake's direct watershed is comprised of forests, 23% is comprised of the lake's surface, 19% is comprised of wetlands, 5% is comprised of areas of pasture/grass, 2% is comprised of row crop agriculture, and <1% is comprised of both rural residential and urban areas (Figure 3.2-2).

WiLMS estimates that approximately 950 pounds of phosphorus are loaded to South Twin Lake annually (Figure 3.2-2). Of the 950 pounds, 70% is estimated to come from upstream North Twin Lake, 18% from atmospheric deposition on the lake's surface, 5% from forests within the direct watershed, 3% from areas of pasture/grass within the direct watershed, 2% from row crop agriculture within the direct watershed, and 1% from wetlands within the direct watershed. Using the data from the 2016 stakeholder survey, less than 1% of the annual phosphorus load to South Twin Lake is estimated to originate from riparian septic systems.

While it is estimated that approximately 1,878 pounds of phosphorus are loaded to North Twin

Lake annually, it is estimated that 661 pounds are loaded from North Twin Lake to downstream South Twin Lake. In other words, North Twin Lake sequesters on average 65% of its annual phosphorus load and exports less phosphorus downstream than what is loaded from its watershed. This is typical of most lakes which act as phosphorus sinks, or accumulate phosphorus over time. Through chemical, physical, and biological processes, phosphorus settles to the lake bottom accumulates within bottom sediments. In essence, North Twin Lake acts as a large sedimentation basin for South Twin Lake, sequestering the majority of the phosphorus before it flows downstream. It is for this reason that phosphorus concentrations are slightly lower in South Twin Lake when compared to North Twin Lake. Using the estimated annual potential phosphorus load of 950 pounds to South Twin Lake, WiLMS predicts that the lake should have an in-lake growing season mean total phosphorus concentration of around 15 µg/L, very similar to the measured growing season mean concentration of 16.9 µg/L.

Using the WiLMs model for the Twin Lakes watershed, scenarios can be developed to determine how the lakes' water quality would change given alterations to their watershed. For example, if 25% of the forests within North Twin Lake's watershed were converted to row crop agriculture, phosphorus levls would be predicted to increase from the current growing season concentration of 20.1 µg/L to approximately 29.5 µg/L. This increase in total phosphorus would

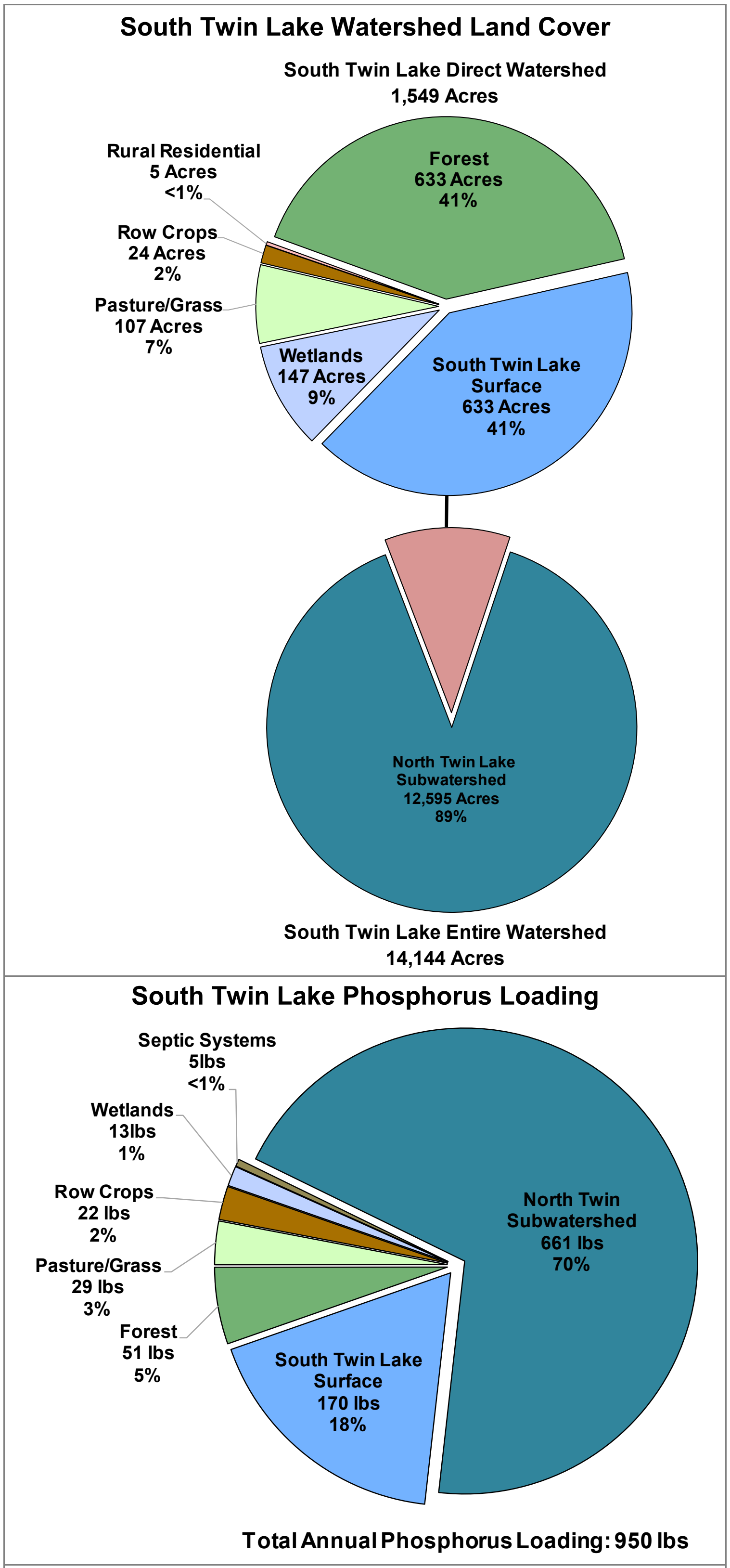


Figure 3.2-2. South Twin Lake watershed land cover types and estimated annual phosphorus loading. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

result in chlorophyll-*a* concentrations increasing from the current growing season average of 4.7 µg/L to approximately 11.7 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 11.9 feet to approximately 5.7 feet. As a result, the phosphorus load from North Twin Lake to downstream South Twin Lake is predicted to increase from 661 pounds annually to approximately 970 pounds. This increase would result in South Twin Lake's chlorophyll-*a* concentrations increasing from the current growing season average of 4.0 µg/L to approximately 6.2 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 12.0 feet to approximately 8.8 feet. This modeling illustrates the importance of the natural land cover types within the Twin Lakes' watershed in maintaining the lakes' excellent water quality.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) effects on the lake is important in maintaining the quality of the lake's water and habitat.

The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development 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. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. 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. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- 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: 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.

- 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 with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

- 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.

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 led to passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale, and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

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

Photograph 3.3-1. 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 important for aquatic macroinvertebrates (Sass 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

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

National Lakes Assessment

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

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

Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" 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 3.3-2. 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.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

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

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

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

The Twin Lakes Shoreland Zone Condition

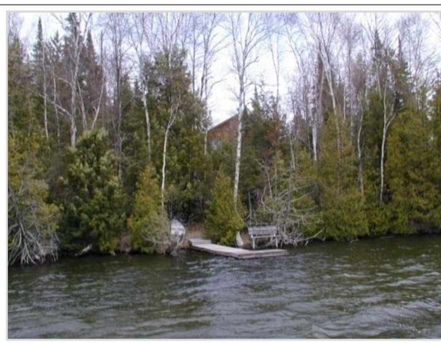
Shoreland Development

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

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

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

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



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

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

Figure 3.3-1. Shoreland assessment category descriptions.

On the Twin Lakes, the development stage of the entire shoreland was surveyed during the fall of 2016, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

The Twin Lakes have stretches of shoreland that fit all of the five shoreland assessment categories. In all, 7.4 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 3.5 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Twin Lakes' shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Maps 3-4 displays the location of these shoreland lengths around the entire lake.

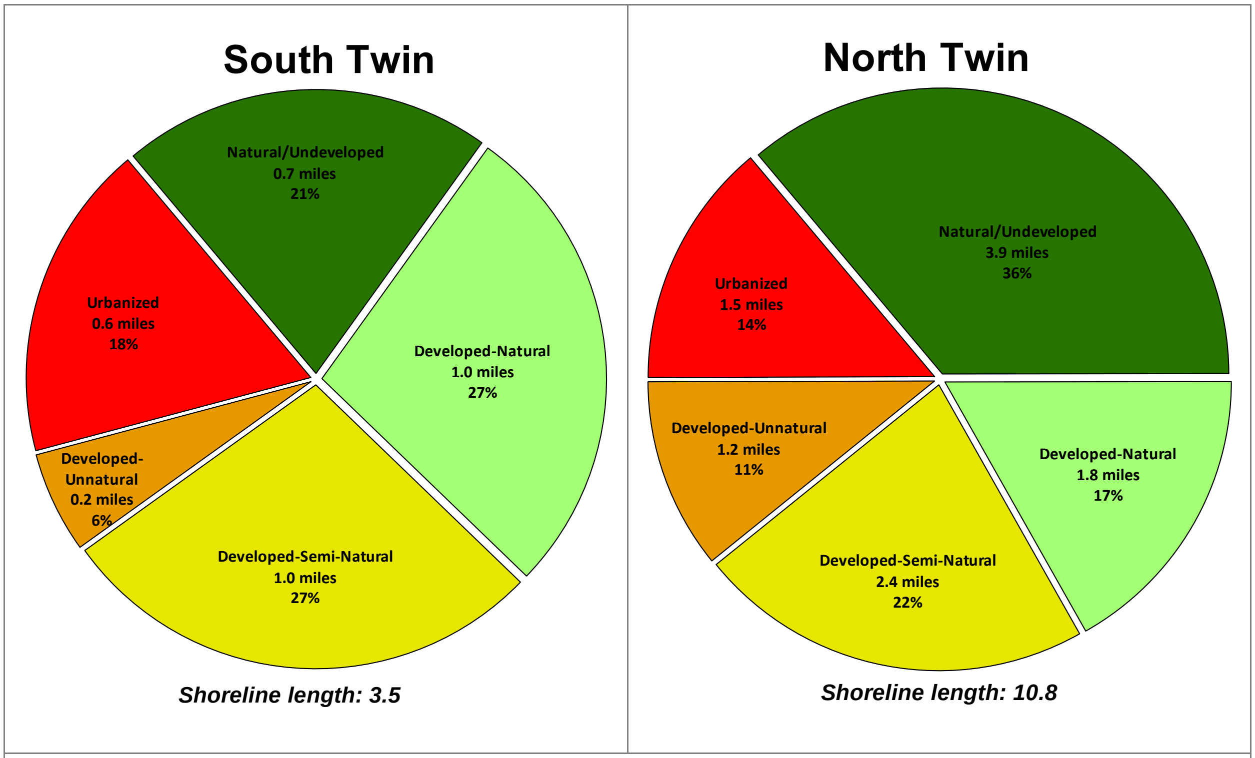


Figure 3.3-2. The Twin Lakes shoreland categories and total lengths. Based upon a Fall 2016 survey. Locations of these categorized shorelands can be found on Maps 3-4.

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

Coarse Woody Habitat

The Twin Lakes were surveyed in 2016 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

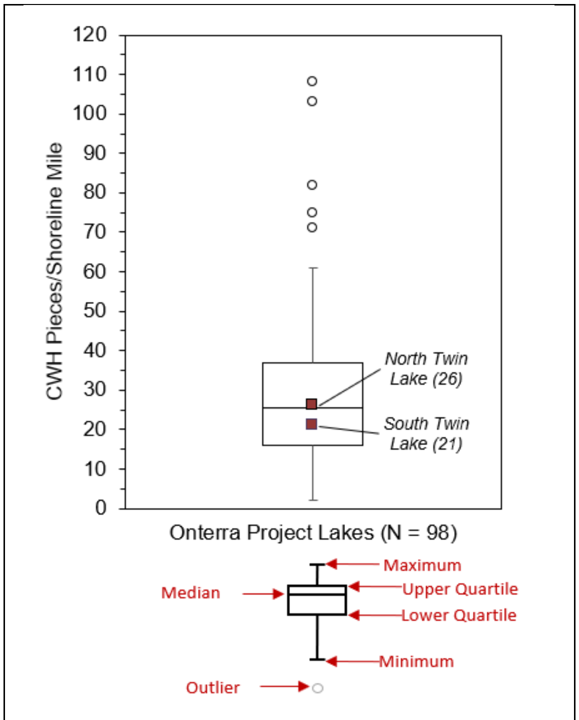
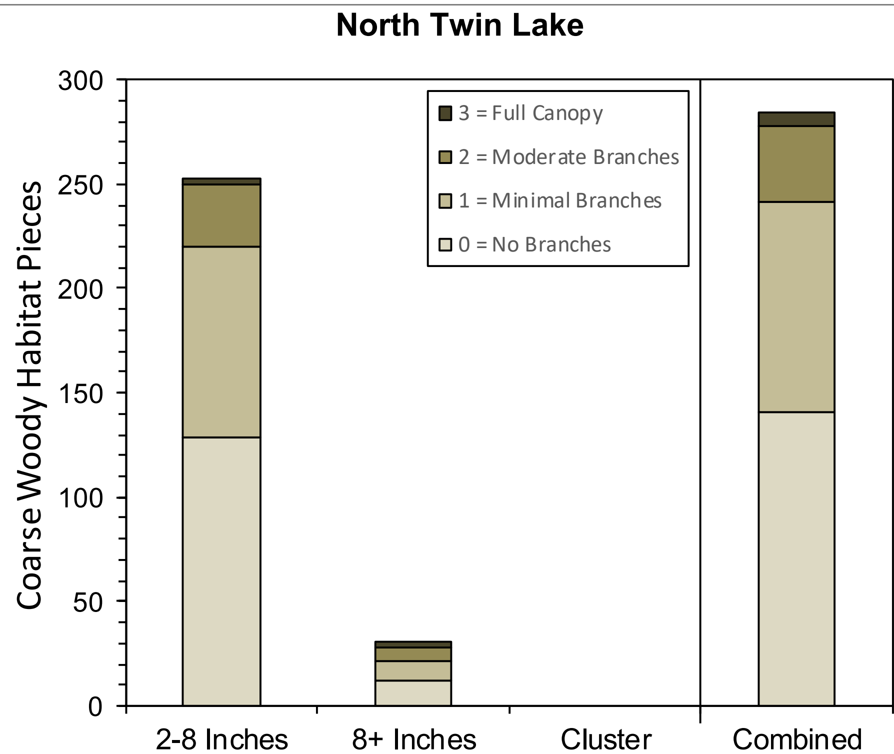


Figure 3.3-3. The Twin Lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. Comparative data available from 98 lakes surveyed by Onterra since 2012.

During this survey, 357 total pieces of coarse woody habitat were observed along 14.3 miles of shoreline (Maps 5 and 6), which gives the Twin Lakes a coarse woody habitat to shoreline mile ratio of approximately 25 per mile. Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. During the survey on North Twin Lake, 284 total pieces of coarse woody habitat were observed along 10.8 miles of shoreline, which gives the lake a coarse woody habitat to shoreline mile ratio of 26:1 (Figure 3.3-3). On South Twin Lake, a total of 73 pieces of coarse woody habitat were observed along 3.5 miles of shoreline, which gives the lake a coarse woody habitat to shoreline mile ratio of 21:1. The number of coarse woody habitat pieces per shoreline mile in North Twin Lake is slightly above the median for these 98 lakes (50^{th} percentile) and the number of coarse woody habitat pieces per shoreline mile in South Twin Lake fell just below the median for these 98 lakes (38^{th} percentile).

The overall size of the woody material on the Twin Lakes is relatively small, with almost 90% being below 8 inches (Figure 3.3-4). The complexity of the woody material is also low, with 85% of the pieces having *no branches* or *minimal branches*. As discussed in Newbrey et al. 2005, not all wood is equal in terms of potential habitat. While the quantity of woody material on the Twin Lakes is approximately similar to other waterbodies in Onterra's dataset, the woody material present does not have the highest value.



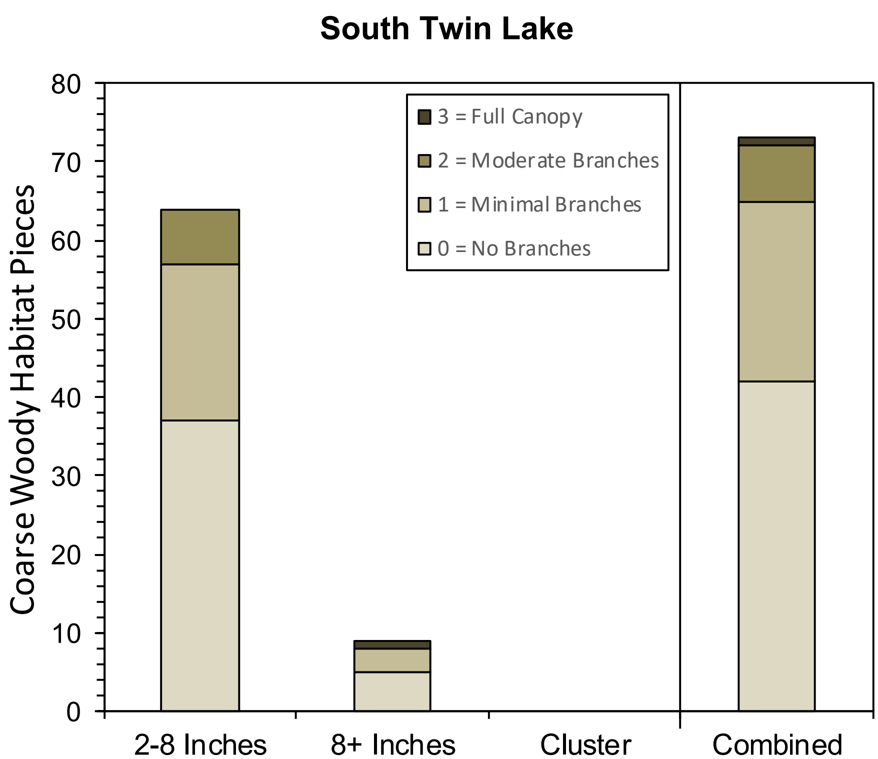


Figure 3.3-4. The Twin Lakes coarse woody habitat survey results. Based upon a Fall 2016 survey. Locations of the Twin Lakes coarse woody habitat can be found on Maps 5-6.

3.4 Aquatic Plants

Introduction

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

Photograph 3.4-1. Example of emergent and floating-leaf 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 water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These 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 North and South Twin 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 North and South Twin 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 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. 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. Removal of non-native plant species anywhere in the lake does not require a permit as long as a mechanical harvesting device is not used in the extraction process.

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

Manual Removal (Hand-Harvesting & DASH)

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however, Wisconsin law states that all plant fragments must be removed.

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

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

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 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 large-scale efforts are conducted after June 15th.to correspond with fish spawning • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area. • Plant biomass is removed from waterbody.	• Labor intensive. • Impractical for larger areas or dense plant beds. • Subsequent treatments may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

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

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

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

Water Level Drawdown

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

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

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

Mechanical Harvesting

Photograph 3.4-3. 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 3.4-4. Granular 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 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

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

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

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

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

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

<table>
<tr><th colspan="2">General Mode of Action</th><th>Compound</th><th>Specific Mode of Action</th><th>Most Common Target Species in Wisconsin</th></tr>
<tr><td rowspan="3">Contact</td><td rowspan="3"></td><td>Copper</td><td>plant cell toxicant</td><td>Algae, including macro-algae (i.e. muskgrasses & stoneworts)</td></tr>
<tr><td>Endothall</td><td>Inhibits respiration & protein synthesis</td><td>Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides</td></tr>
<tr><td>Diquat</td><td>Inhibits photosynthesis & destroys cell membranes</td><td>Nusiance natives species including duckweeds, targeted AIS control when exposure times are low</td></tr>
<tr><td rowspan="7">Systemic</td><td rowspan="2">Auxin Mimics</td><td>2,4-D</td><td>auxin mimic, plant growth regulator</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td>Triclopyr</td><td>auxin mimic, plant growth regulator</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td>In Water Use Only</td><td>Fluridone</td><td>Inhibits plant specific enzyme, new growth bleached</td><td>Submersed species, largely for Eurasian water milfoil</td></tr>
<tr><td rowspan="2">Enzyme Specific (ALS)</td><td>Penoxsulam</td><td>Inhibits plant-specific enzyme (ALS), new growth stunted</td><td>New to WI, potential for submergent and floating-leaf species</td></tr>
<tr><td>Imazamox</td><td>Inhibits plant-specific enzyme (ALS), new growth stunted</td><td>New to WI, potential for submergent and floating-leaf species</td></tr>
<tr><td rowspan="2">Enzyme Specific (foliar use only)</td><td>Glyphosate</td><td>Inhibits plant-specific enzyme (ALS)</td><td>Emergent species, including purple loosestrife</td></tr>
<tr><td>Imazapyr</td><td>Inhibits plant-specific enzyme (EPSP)</td><td>Hardy emergent species, including common reed</td></tr>
</table>

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

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

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

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

Cost

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

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause 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 water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Preliminary results indicate that the background population level of native weevils in a given waterbody cannot be greatly increased through stocking efforts. 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 water-milfoil density.

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as 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 the Twin Lakes; 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 on the Twin Lakes 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 the Twin Lakes, 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 the Twin Lakes to be compared to other lakes within the region and state.

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species.

The Simpson's Diversity Index value from the Twin Lakes is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests (lakes only, does not include flowages) 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 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.

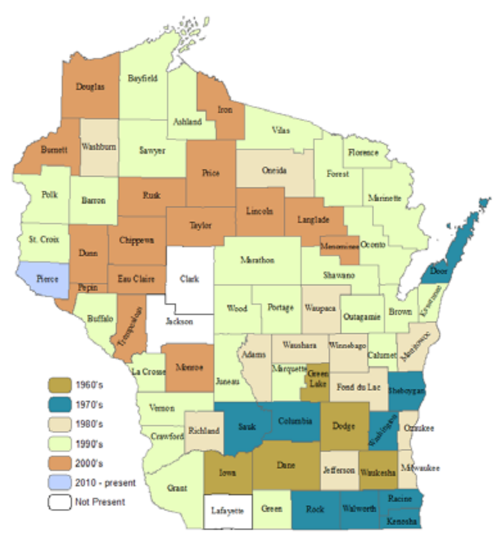


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

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

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

Aquatic Plant Survey Results

In 2016, a comprehensive set of aquatic plant surveys were conducted on the Twin Lakes and will be used in the subsequent analysis of the aquatic plant community. Additional surveys were conducted on the lakes in 2017 as part of Eurasian watermilfoil monitoring and will be discusses as appropriate.

During the aquatic plant surveys completed on the Twin Lakes in 2016, a combined total of 38 species of plants were located in the lakes, one of which is considered a non-native, invasive species, Eurasian watermilfoil (Table 3.4-1). On June 30 and July 7, 2016, an Early-Season AIS Survey was completed on the lakes that focused on locating and mapping potential occurrences of curly-leaf pondweed. This meander-based survey did not locate any occurrences of curly-leaf pondweed. At present, curly-leaf pondweed either does not occur in the Twin Lakes or exists at an undetectable level.

The whole-lake aquatic plant point-intercept survey was conducted on the Twin Lakes on July 28 and August 17-18, 2016 by Onterra. The emergent and floating-leaf aquatic plant community mapping survey was completed by Onterra on August 18, 2016. A whole-lake aquatic plant point-intercept survey was also conducted on North Twin Lake in 2011 by Onterra and a point intercept survey has been completed on South Twin Lake nearly every summer since 2008 by either WDNR or Onterra, including in 2017. Changes across these surveys will be discussed later within this section. Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. Because the non-native plant, Eurasian watermilfoil (EWM) has the ability to negatively impact lake ecology, recreation, and aesthetics, its population is discussed in detail within the Non-Native Aquatic Plants in the Twin Lakes subsection.

Table 3.4-1. Aquatic plant species located on the Twin Lakes during August 2016 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	North Twin 2016 (Onterra)	South Twin 2016 (Onterra)
Emergent	*Carex lacustris*	Lake sedge	6		I
	Eleocharis palustris	Creeping spikerush	6	X	
	Phragmites australis subsp. americanus	Common reed	5	I	
	Sagittaria rigida	Stiff arrowhead	8	I	I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	
	Typha spp.	Cattail spp.	1	I	I
FL	*Nuphar variegata*	Spatterdock	6	I	
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I	I
	Bidens beckii	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes *spp.*	Quillwort spp.	8	X	X
	Myriophyllum alterniflorum	Alternate-flowered watermilfoil	10	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton berchtoldii	Slender pondweed	7	X	
	Potamogeton friesii	Fries' pondweed	8	X	
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X
	Potamogeton illinoensis	Illinois pondweed	6		X
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7		X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	8	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus aquatilis	White water crowfoot	8	X	
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X	
	Stuckenia pectinata	Sago pondweed	3	X	
	Utricularia vulgaris	Common bladderwort	7	X	
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X
	Juncus pelocarpus	Brown-fruited rush	8		X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species

The sediment within littoral areas of the Twin Lakes is conducive for supporting diverse aquatic plant growth. Data from the North Twin Lake point-intercept survey indicate that approximately 85% of the sampling locations located within the littoral zone contained sand, 14% contained rock, and 1% contained fine organic sediment (muck) (Figure 3.4-2, Maps 7). Data from South Twin Lake in 2016 indicates that approximately 80% of the sampling locations within the littoral zone contained sand, 17% contained fine organic sediment (muck), and 3% contained rock (Map 8)

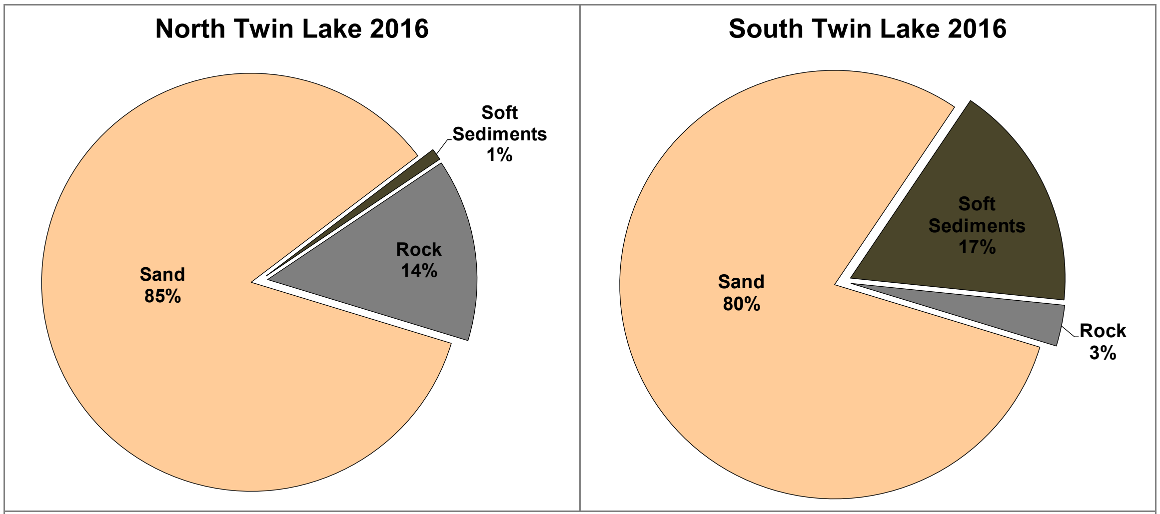


Figure 3.4-2. The Twin Lakes proportion of substrate types within littoral areas. Created using data from the 2016 aquatic plant point-intercept survey.

Approximately 80% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (17 feet), or the littoral zone, contained aquatic vegetation. Maps 9-10 show that the majority of the aquatic vegetation in the Twin Lakes is located in near-shore areas. Figure 3.4-3 shows that the majority of the aquatic vegetation in the lakes grows between 1 and 10 feet with plants growing regularly to 15 feet.

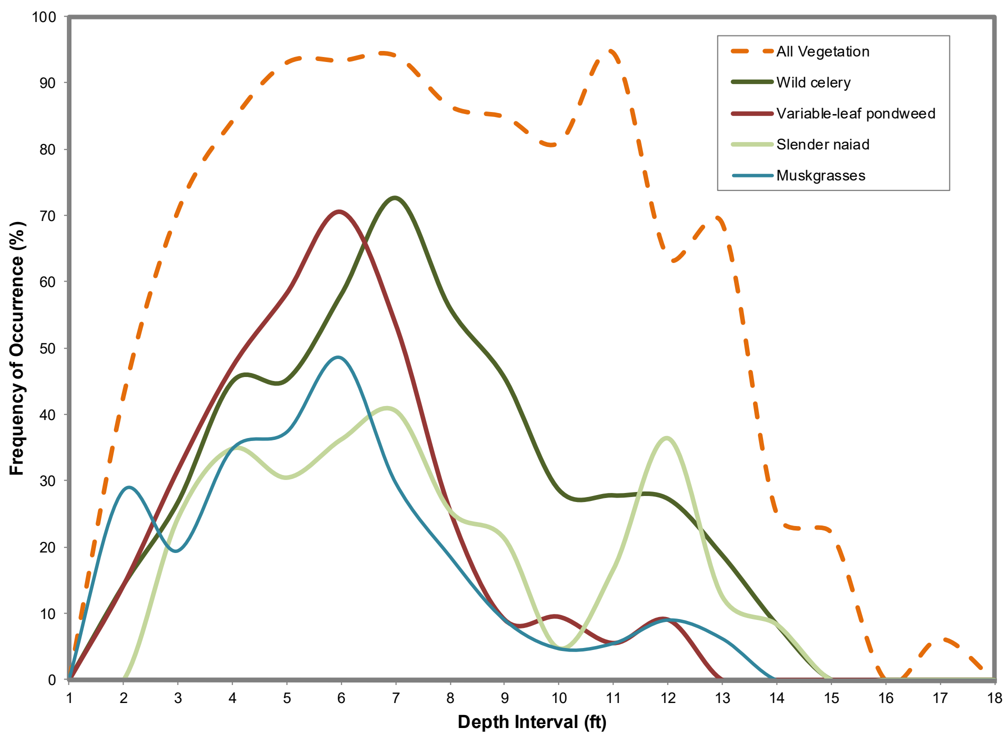


Figure 3.4-3. Frequency of occurrence at littoral depths for several of the Twin Lakes plant species. Created using data from the 2016 aquatic plant point-intercept survey.

Aquatic plants can be placed in one of two general groups, based upon their form of growth and habitat preferences. These groups include the isoetid growth form and the elodeid growth form.

The Twin Lakes has both isoetid and elodeid species within its waters. Plants of the isoetid growth form are small, slow growing, and inconspicuous submerged plants. 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 the Twin Lakes include brown-fruited rush and needle spikerush. Submersed species of the elodeid growth form have leaves on tall, erect stems which grow upwards into the water column. Examples of the Twin Lakes elodeid species include variable-leaf pondweed, northern watermilfoil 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. Isoetids are common within North and South Twin due to the large areas of sandy sediment and high alkalinity but elodeids are the dominant growth form.

Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. In North Twin Lake, of the 352 sampling locations that fell at or shallower than the maximum depth of plants (the littoral zone) in 2016, approximately 72% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 45% of the 352 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 19% had a TRF rating of 2, and 8% had a TRF rating of 3 (Map 9, Figure 3.4-4).

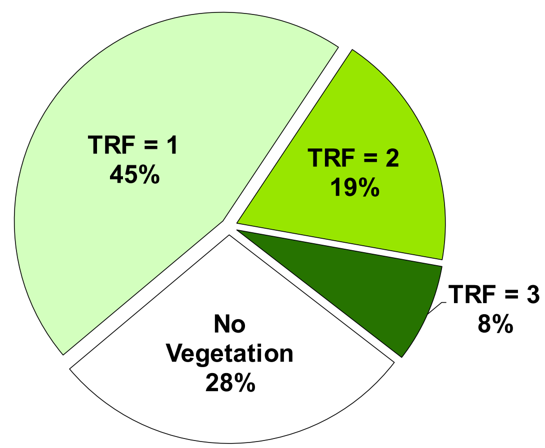


Figure 3.4-4. North Twin Lake 2016 aquatic vegetation total rake fulness (TRF) ratings within littoral areas. Created using data from the 2016 aquatic plant point-intercept survey.

In South Twin Lake, of the 295 sampling locations that fell at or shallower than the maximum depth of plants (the littoral zone) in 2016, approximately 94% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 52% of the 295 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 22% had a TRF rating of 2, and 19% had a TRF rating of 3 (Map 10, Figure 3.4-5).

As discussed in the 2016 North and South Twin AIS Control & Monitoring Report, the overall frequency of point-intercept locations containing vegetation, in South Twin Lake, has varied from 90% to 97% over the time period these surveys have been conducted. In 2015, 54% of the point-intercept sampling locations had total rake fulness ratings or 2 or 3. In 2016, immediately following the large-scale 2,4-D herbicide treatment, only 42% of sampling locations contained rake fulness ratings of 2 or 3. It is important to note that the aquatic plant density in 2016 is almost completely comprised of native plant species, whereas EWM was a major contributor to the aquatic plant biomass in 2015. Eurasian watermilfoil rebound in 2017 partially contributed to increased plant densities on South Twin Lake.

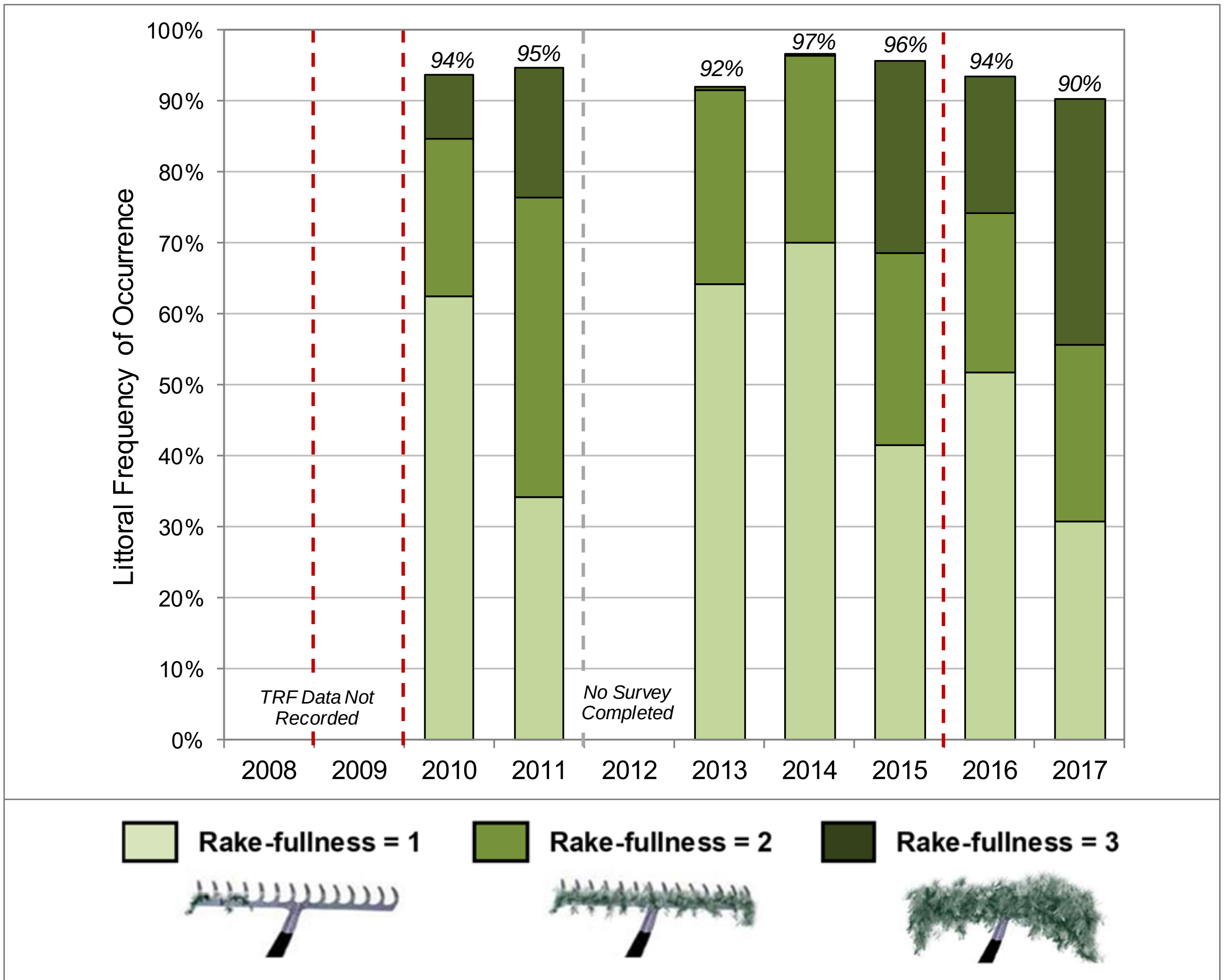


Figure 3.4-5. South Twin Lake total rake fullness ratings from 2008 – 2017. Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatment.

Of the 38 aquatic plants were located in total in the Twin Lakes in 2016, 32 species were encountered directly on the rake during the whole-lake point-intercept survey. The remaining 6 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community.

Of the species encountered in 2016, wild celery, variable-leaf pondweed, slender naiad, and muskgrasses were the most common (Figure 3.4-6). Wild celery, also known as tape or eel grass, is common in Wisconsin and can be found growing in many differing lake habitats, making it an excellent source of food for waterfowl, muskrats, and other wildlife. Often found growing particularly well in sandy substrates, wild celery's long leaves also provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Wild celery was most abundant between three and twelve feet.

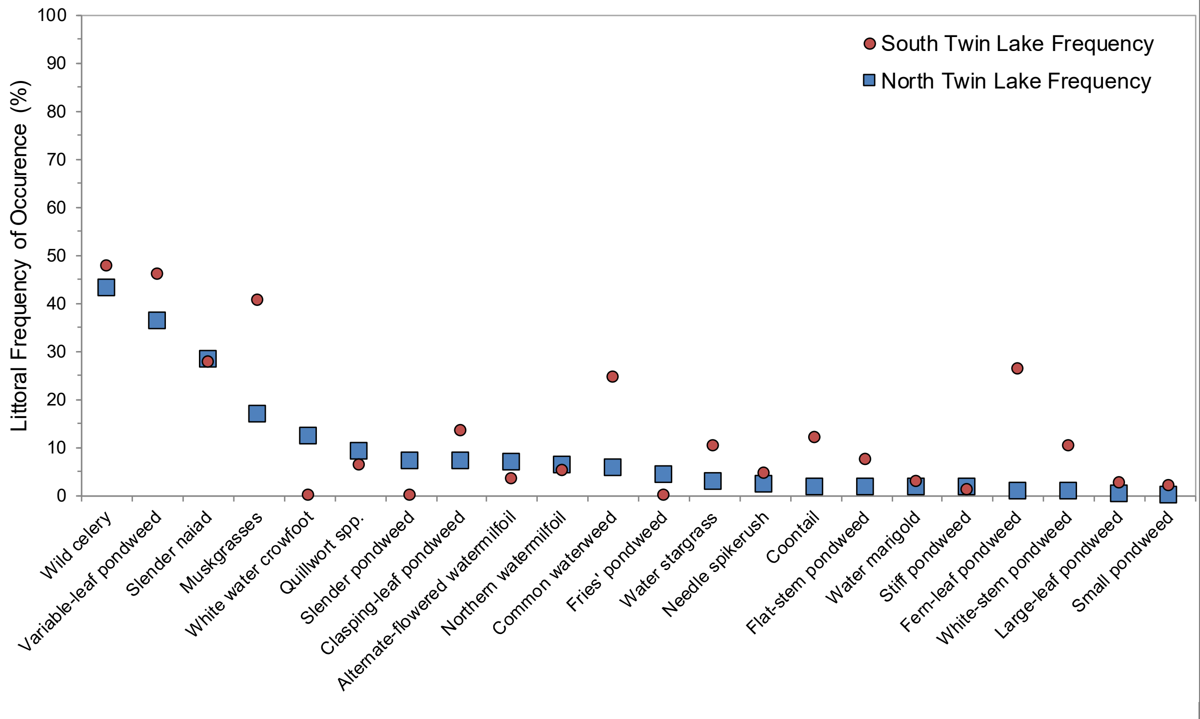


Figure 3.4-6. The Twin Lakes aquatic plant littoral frequency of occurrence. Created using data from the 2016 aquatic plant point-intercept survey.

Variable-leaf pondweed, the second-most encountered species in both lakes during 2016. This submersed plant produces a thin, cylindrical stem that has numerous branches. These branches produce linear leaves that grow anywhere from four to eleven centimeters long, and may produce three to seven veins per leaf. This plant also hybridizes easily with other pondweed (*Potamogeton*) species; thus, this plant can appear quite variable in size and shape and is named appropriately. Variable-leaf pondweed was abundant between two and nine feet.

Slender naiad, the third-most encountered species in North Twin and the forth-most common species in South Twin, is a submersed, annual plant that may reach lengths of 2.5 meters (Figure 3.4-6). It is sometimes called bushy pondweed because its small leaves branch out in numerous directions and become stiff and recurved as it ages. Slender naiad can reproduce through fragmentation; however, its primary means of reproduction is by seed. The seeds form a dual purpose, as they are a valuable food source for waterfowl. Slender naiad was abundant across all depths.

Muskgrasses, a species within the genus *Chara*, are actually a form of macroalgae, not true aquatic plant. They were the fourth-most encountered species within North Twin Lake and the third-most encountered in South Twin Lake (Figure 3.4-6). They are grey to green colored and grow in large clumps in shallow to deep water. When growing in hard, mineral rich water, muskgrasses sometimes become coated with calcium carbonate, giving them a rough, gritty feel. They are easily identified by their strong skunk-like or garlic odor. As well as providing a food source for waterfowl, muskgrasses often serves as a sanctuary for small fish and other aquatic organisms. Muskgrasses were most abundant between four and eight feet.

North Twin Lake Changes in Plant Frequency

Figure 3.4-7 displays the littoral frequency of occurrence of aquatic plant species from the 2011 and 2016 point-intercept surveys in North Twin Lake. Only the submergent species that had a littoral frequency of occurrence of at least 4% in one of the surveys are displayed. In total, five aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2011 and 2016. Wild celery, variable-leaf pondweed, and muskgrasses all increased in their littoral occurrence from 2011 to 2016. The occurrences of northern watermilfoil, water stargrass, and flat-stem pondweed all decreased in their littoral frequency of occurrence from 2011 to 2016. The occurrences of EWM, white water crowfoot, alternate-flowered watermilfoil, slender naiad, clasping-leaf pondweed, quillwort species, common waterweed, and fries' pondweed were not statistically different over the time period.

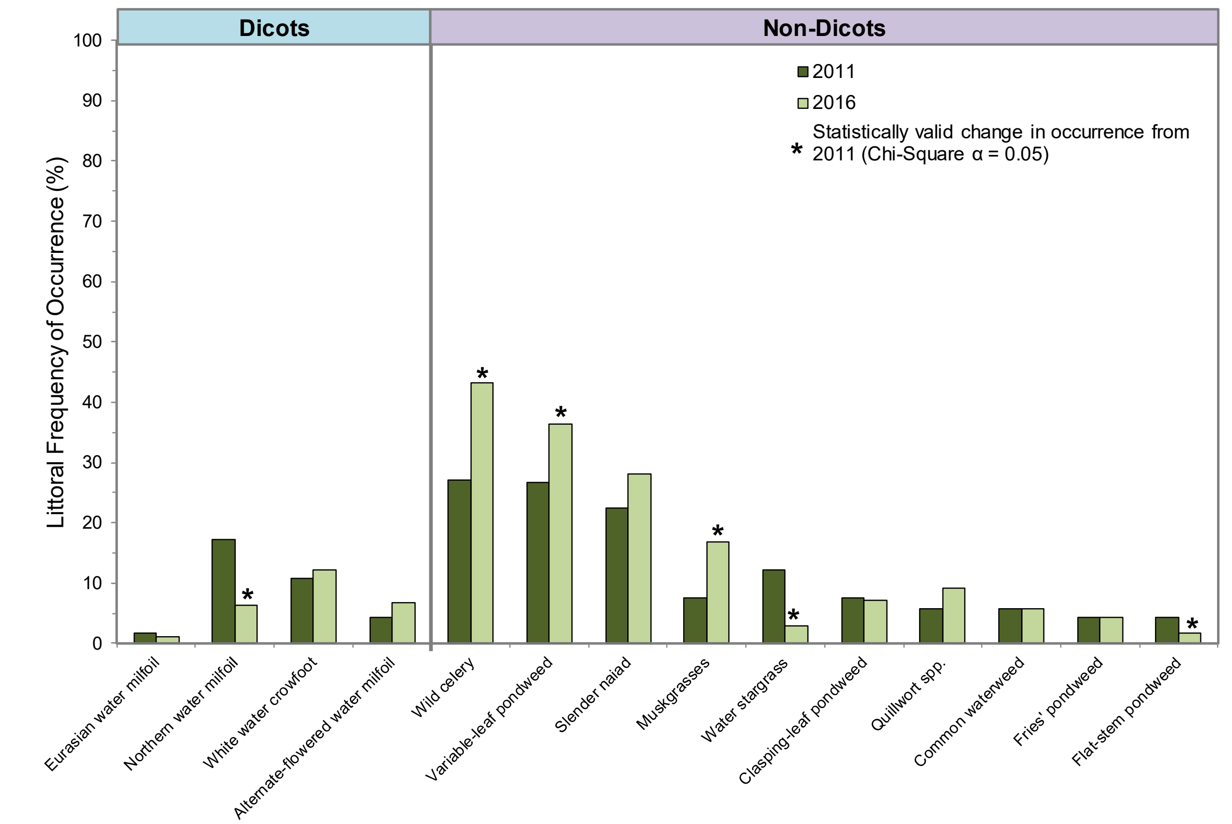


Figure 3.4-7. North Twin Lake 2011 and 2016 aquatic plant littoral frequency of occurrence. Created using data from Onterra 2011 and 2016 aquatic plant point-intercept survey.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants like EWM. These observed reductions and increases in occurrence of certain species are believed to be due to varying interannual environmental conditions in North Twin Lake since no large-scale herbicide treatments have occurred.

South Twin Lake Changes in Plant Frequency

Figure 3.4-8 displays the average littoral frequency (and range) of select aquatic plants within South Twin Lake from 2008-2017 compared to the 2017 whole-lake point-intercept survey following a whole-lake herbicide treatment. These data indicate that some aquatic plant populations, northern watermilfoil, water marigold, flat-stem pondweed, and small pondweed were at lower than average levels since monitoring began in 2008. Oher plant species, alternate-flowered watermilfoil, slender naiad, muskgrasses, common waterweed, clasping-leaf pondweed, and quillworts were at higher than average levels. These data will be explored further as they relate to the ongoing EWM control program that is occurring on South Twin Lake (Figures 3.4-17 to 3.4-20).

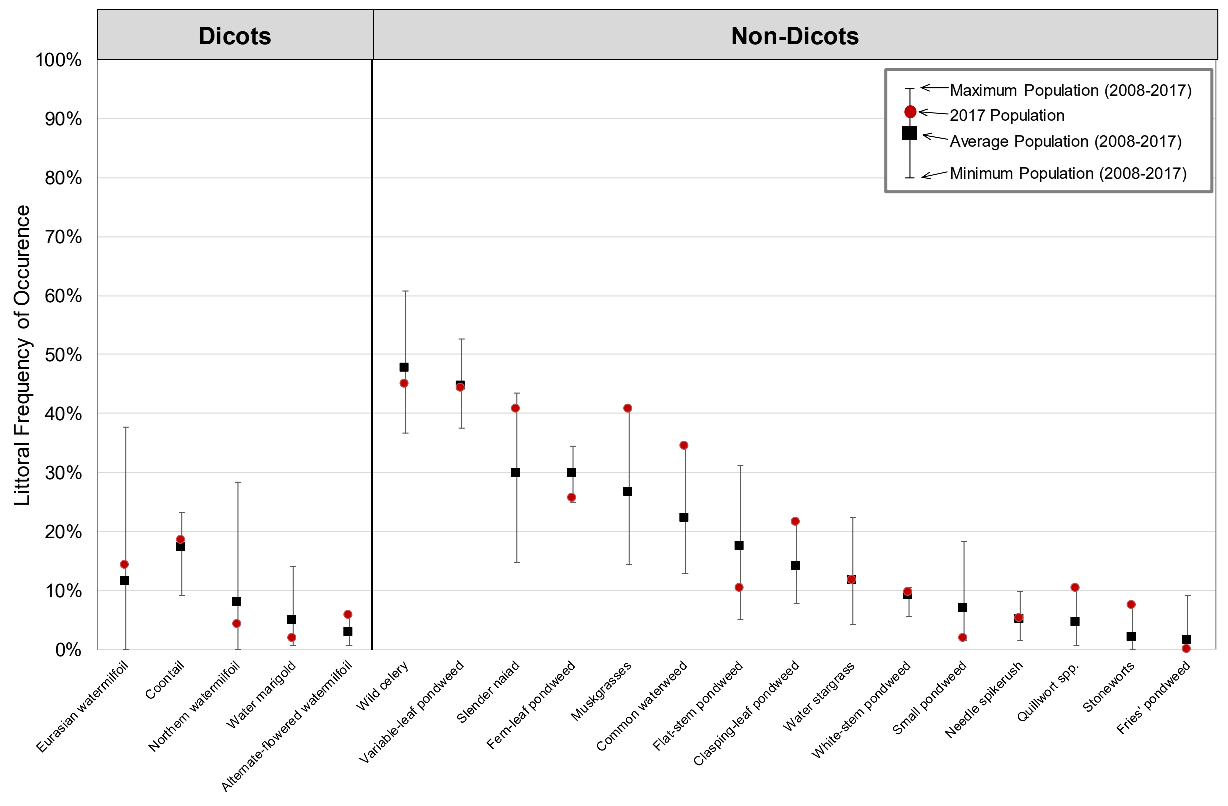


Figure 3.4-8. South Twin Lake aquatic plant littoral frequency of occurrence from 2008-2017. Square symbol represents mean frequency of occurrence pooled from all point-intercept surveys, error bars represent range of annual frequencies, red circle represents 2016 littoral frequency of occurrence.

Twin Lakes Vegetation Metrices

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 37 native aquatic plant species were located in the Twin Lakes during the 2016 surveys, 31 were directly encountered on the rake during the point-intercept survey.

North Twin Lake's native aquatic plant species richness in both 2011 and 2016 exceeds the median value for lakes within the Northern Lakes and Forests (NLFL) ecoregion and for lakes throughout Wisconsin (Figure 3.4-10). In 2008, South Twin Lake's native aquatic plant species richness exceeded the median value for lakes within the NLFL ecoregion; however, in recent years South Twin Lake was surveyed, the species richness is relatively similar to the median value for lakes within the NLFL ecoregion (Figure 3.4-9). The species richness recorded in 2016 in South Twin Lake was higher than recorded during the previous point-intercept survey in 2015.

The average conservatism of the native aquatic plants recorded on the rake in North Twin Lake in 2016 was 6.5, falling just below the median value (6.7) for lakes within the NLFL ecoregion and just above the median value (6.3) for lakes throughout Wisconsin (Figure 3.4-9). Similarly, the average conservatism of native aquatic plants recorded on the rake in South Twin Lake in 2017 was 6.6, also falling just below the median value for lakes within the NLFL ecoregion and above the median value for lakes throughout Wisconsin (Figure 3.4-12).

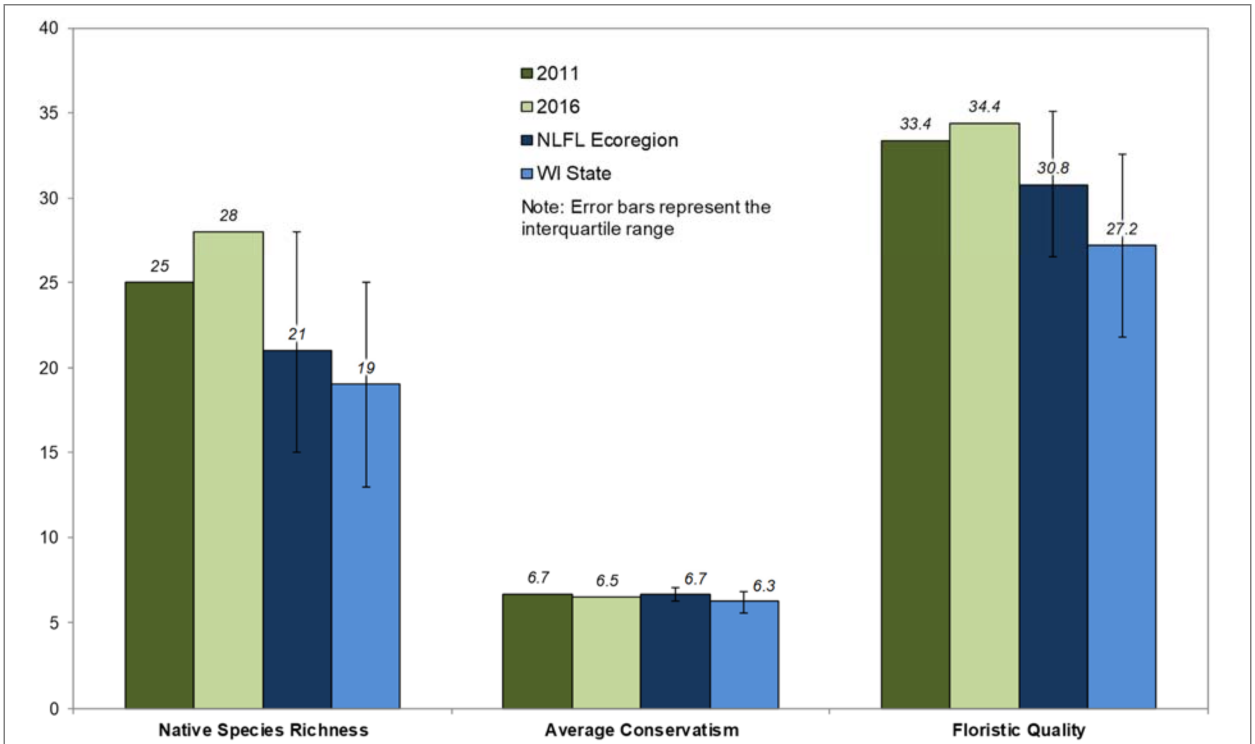


Figure 3.4-9. North Twin Lake Floristic Quality Analysis. Created using data from Onterra 2011 and 2016 surveys.

Using North Twin Lake's 2016 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 34.4, exceeding the average for lakes within the NLFL ecoregion and the average for the state (Figure 3.1-10). This indicates that North Twin Lake's aquatic plant community is above average quality in terms of species richness and community composition compared to other lakes within the ecoregion and the state. Given that native species richness was higher in 2016 when compared to 2011, the 2016 Floristic Quality Index value was also higher than calculated for 2011.

Using South Twin Lake's 2017 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 31.6, just above the average for lakes within the NLFL ecoregion and exceeding the average for the state (Figure 3.1-12). This indicates that South Twin Lake's aquatic plant community is of average quality in terms of species richness and community composition compared to other lakes within the ecoregion above average quality when compared to all other lakes in the state.

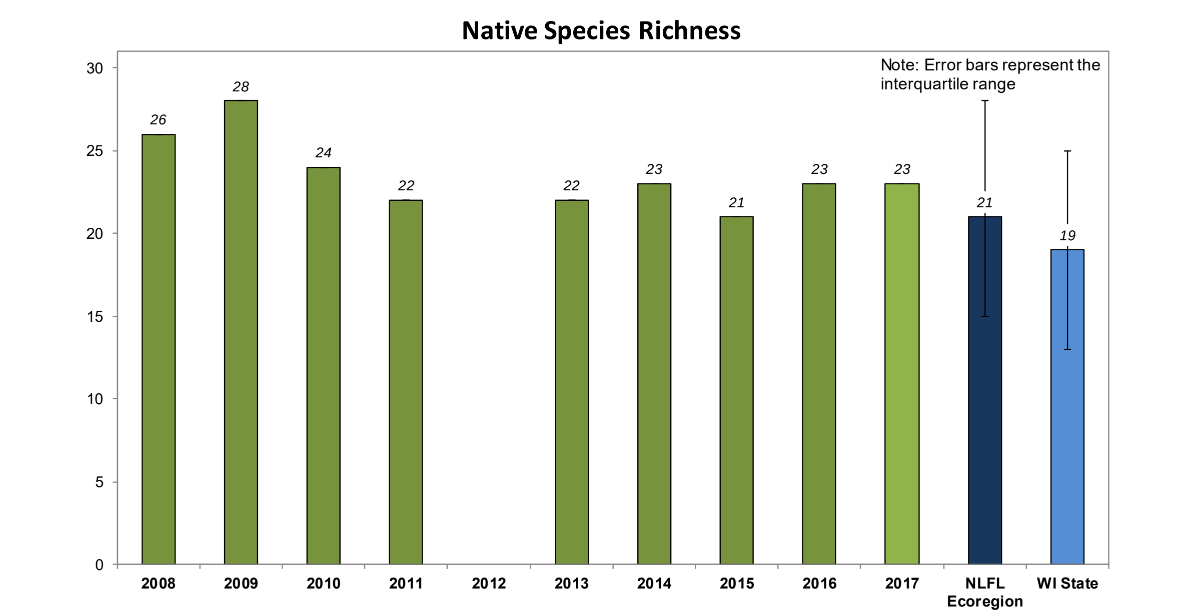


Figure 3.4-10. South Twin Lake Native Species Richness. Created using data from WDNR and Onterra 2008-2017 surveys.

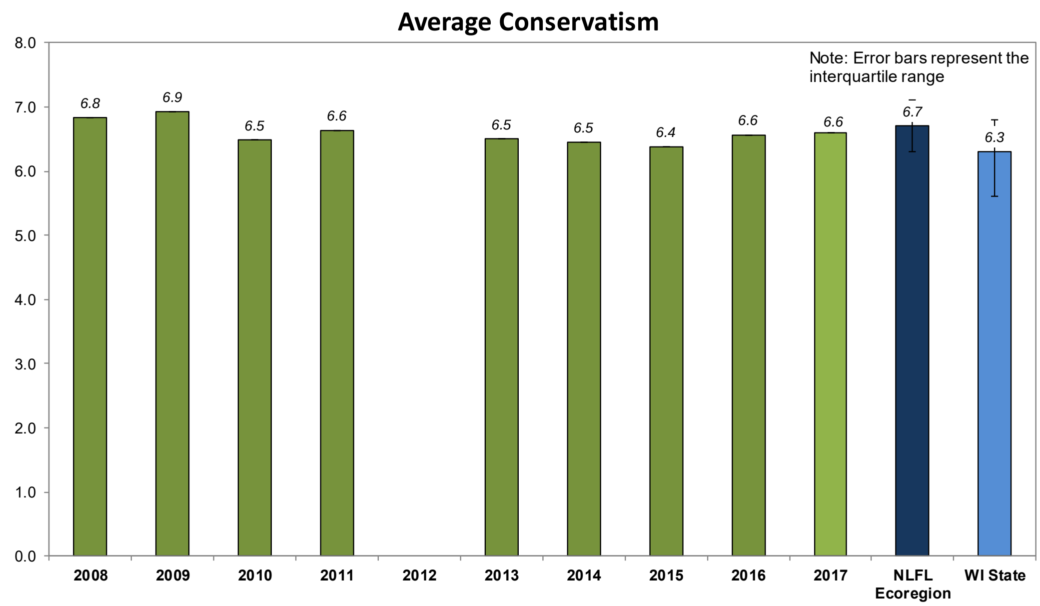


Figure 3.4-11. South Twin Lake Average Conservatism. Created using data from WDNR and Onterra 2008-2017 surveys.

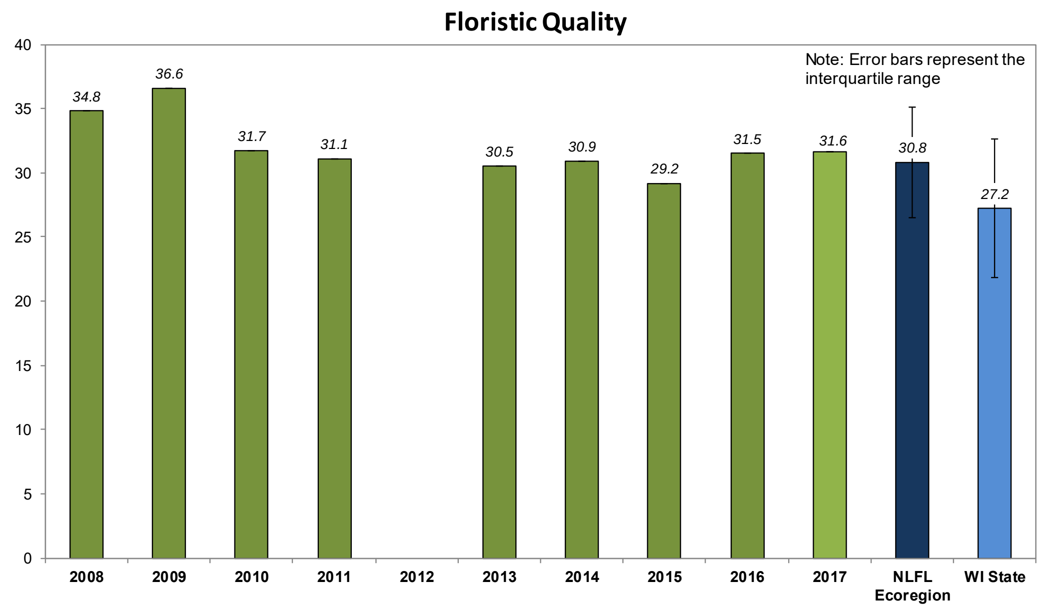


Figure 3.4-12. South Twin Lake Floristic Quality Index. Created using data from WDNR and Onterra 2008-2017 surveys.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Twin Lakes' diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 3.4-13). Using the data collected from the point-intercept surveys, North Twin Lake's diversity is currently at the median value for the NLFL ecoregion and South Twin Lake is well above the 75th percentile for the ecoregion.

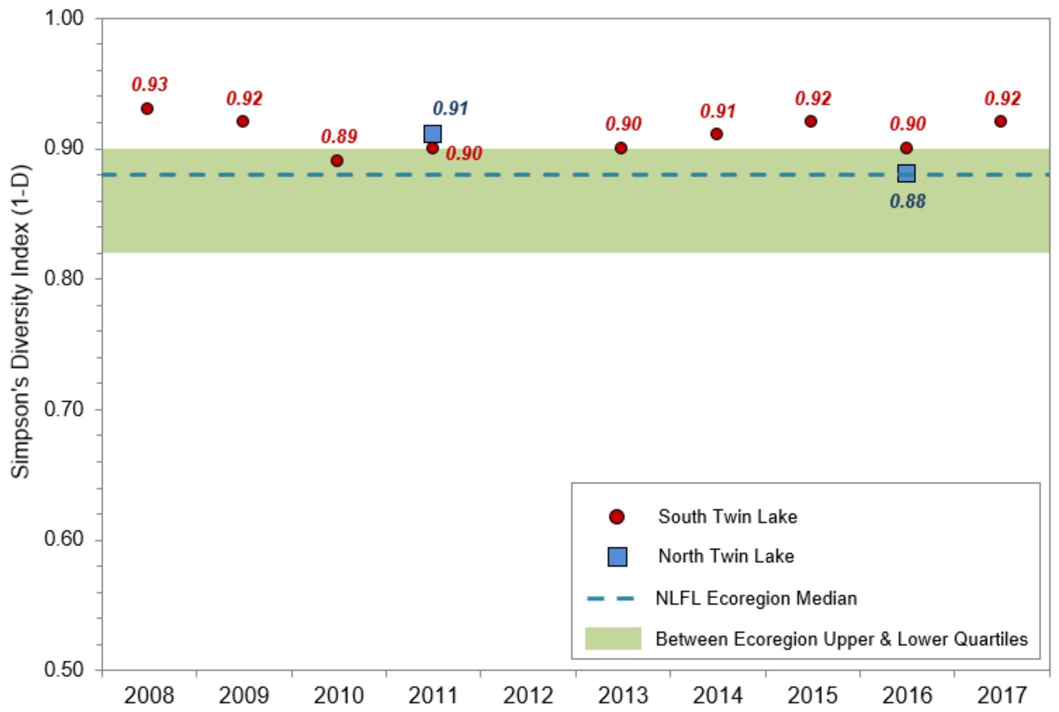


Figure 3.4-13. The Twin Lakes species diversity index. Created using data from WDNR and Onterra 2008-2017 surveys. Ecoregion data from 212 NLFL lakes collected by WDNR Science Services and Onterra.

While North Twin Lake contains a high number of aquatic plant species, the majority, 53%, of the plant community was comprised of just three species in 2016 (Figure 3.4-14). Similarly, 53% of the plant community in South Twin Lake is comprised of just four species. One way to visualize the lakes' species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.4-15 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey and illustrates the relatively uneven distribution of aquatic plant species within the communities. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population).

For instance, while wild celery had a littoral frequency of occurrence of 43% and 48% in the Twin Lakes, respectively, the relative frequency of occurrence was 21% and 16%, respectively. Explained another way, if 100 plants were sampled from North Twin Lake, 21 would be wild celery. Despite North Twin Lake having a high number of aquatic plant species (species richness), the dominance of the plant community by a few number of species results in moderate species diversity.

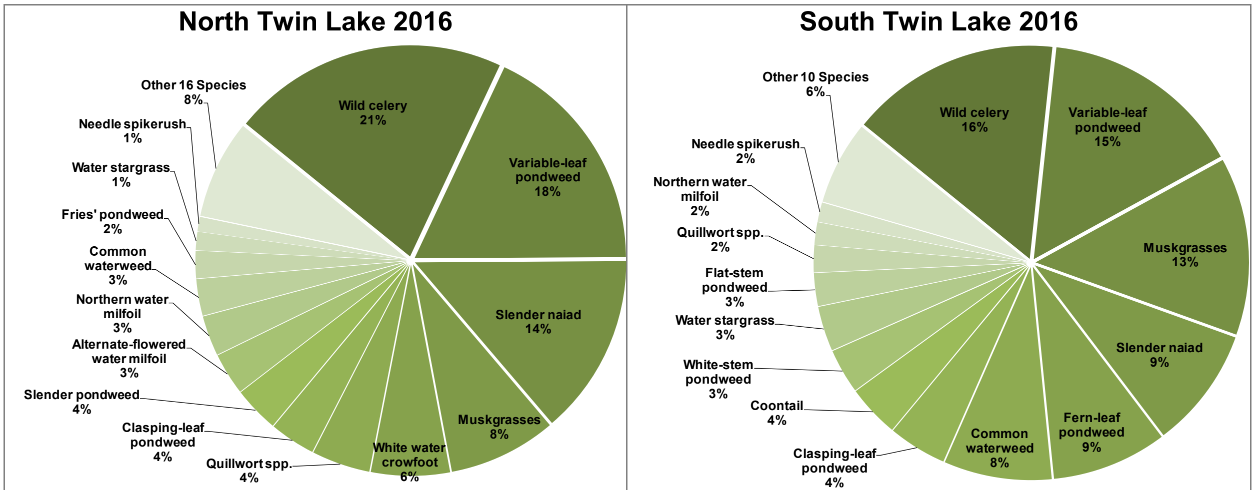


Figure 3.4-14. 2016 relative frequency of occurrence of aquatic plants in the Twin Lakes. Created using data from 2016 point-intercept survey.

Twin Lakes Emergent & Floating-Leaf Communities

The quality of the Twin Lakes' plant community is also indicated by the number of native emergent and floating-leaf aquatic plant species located in 2016. The 2016 community mapping survey found that approximately 96.2 acres (2.7%) of the combined 3,516 acre-lakes contain these types of plant communities (Table 3.4-2 and Maps 11-12). This is one acre more than was mapped in 2011 (95.2 acres). Nine floating-leaf and emergent species were located on the Twin Lakes, 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.

Table 3.4-2. The Twin Lakes acres of plant community types. Created from August 2016 community mapping survey.

Plant Community	North Twin	South Twin	Total
Emergent	74.8	13.7	88.5
Floating-leaf	3.5	0.7	4.2
Mixed Emergent & Floating-leaf	3.6	-	3.6
Total	**81.9**	**14.4**	**96.2**

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the Twin Lakes. 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.

Figure 3.4-15 shows how the main bulrush locations in each lake have changed since from 2007 to 2016. In South Twin Lake, there was a small expansion noted, especially in the northern-most colony. The bulrush communities in North Twin have roughly stayed the same, although the man-made navigation corridors are more defined in the latest survey. The bulrush communities in South Twin Lake are less dense than in North Twin Lake, potentially due to the fact that they are located in deeper waters, roughly 4-5 feet versus 2-3 feet.

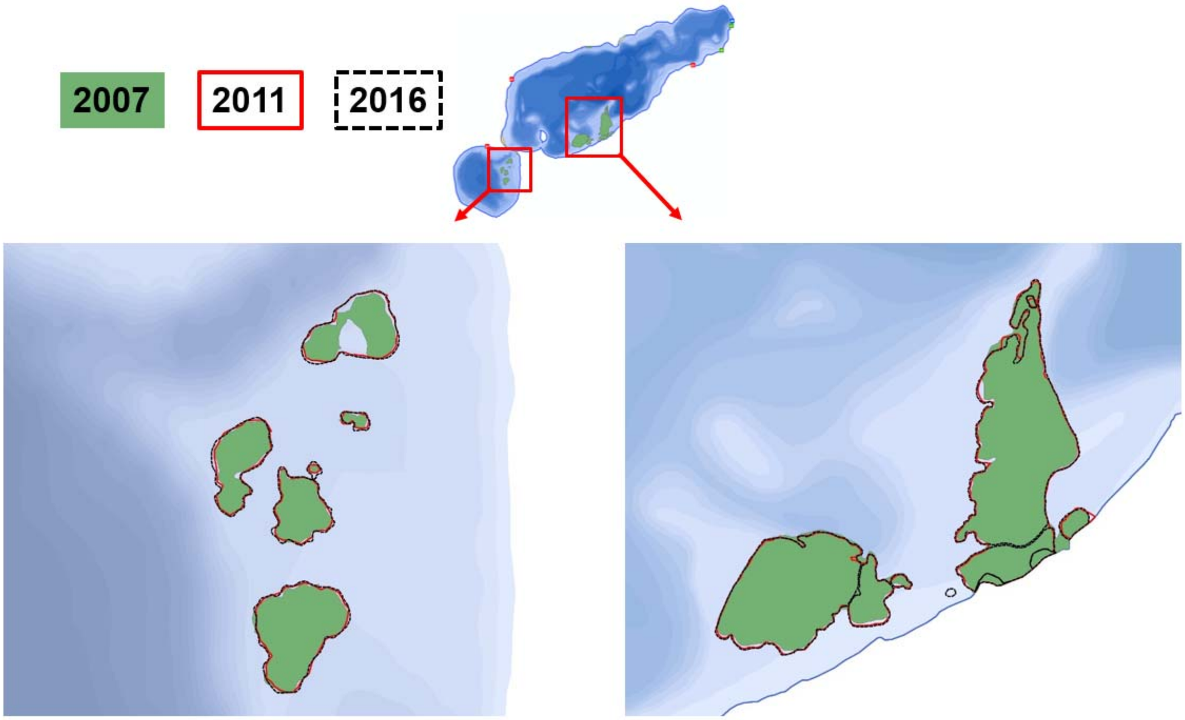


Figure 3.4-15. Bulrush community dynamics. Mapping conducted with sub-meter GPS technology in 2007 (solid green), 2011 (red outline), and 2016 (black hashed outline).

Non-native Plants in the Twin Lakes

Eurasian watermilfoil

Eurasian watermilfoil (EWM; Photograph 3.4-5) is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. EWM 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 oftentimes does not stop growing like most native plants,

Photograph 3.4-5. Eurasian watermilfoil, a non-native, invasive aquatic plant. Photo credit Onterra.

instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. EWM 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. It is important to note that on many lakes, perhaps more often in northern Wisconsin, the EWM population remains low and may only cause localized nuisance conditions and not cause lake-wide ecological changes. A WDNR study of 397 lakes that had confirmed EWM populations, approximately 65% contained populations of 10% or less (Nault 2016).

EWM reaches its peak growth in mid- to late-summer, and assessments are usually completed in July through September to capture populations at their peak. Because EWM should be at its maximum density, the results of this survey provide an accurate assessment of where EWM is in the lake. As a result, this data is useful in determining the efficacy of control actions used during the summer months as well as being heavily relied upon for next year's planning.

Many lake managers believe that there are benefits in early intervention of an invasive species. As part of a 28-lake study in Wisconsin, Kujawa et al (2017) indicate that management "appears to be particularly effective in recently invaded lakes, where it can be used with lower frequency and overall magnitude to maintain low [EWM] abundance." That being said, this study looks at the findings over a broad-scale, whereas, "the specific effects of individual treatments can be unpredictable." And some of the case studies of early intervention contained relatively high EWM populations (18-49% LFOO), above what some would consider an early intervention.

Particularly in regards to an established EWM population, some lake groups have adopted a strategy where they postpone active management until an EWM population reaches a certain threshold and then implement a large-scale (aka whole-lake) treatment. This threshold may be set at a level where the EWM population is 1) suspected to cause change in the lake's historic ecologic function and/or 2) a level that reduced the lake's ability to be enjoyed by riparians prior to the EWM population. Within strategic planning meetings, the NSTLRA Planning Committee discussed these two concepts and some of the information that surrounds them.

Impact Riparian Use

While riparians would claim they know it when they see it, it is subjective to define the population level when navigation, recreation, aesthetics, property values, etc. are impacted by EWM populations. The Twin Lakes are utilized by recreationalists for varying uses. They are an exceptional water resource for water skiing, fishing, swimming, nature viewing, and more. While almost impossible to quantitatively document, most riparians agree that navigation, recreation, and aesthetic impairment has occurred in specific areas on Twin Lakes in recent years. As EWM populations fluctuate in the future, these impairments may be reduced or exacerbated. Studies have documented decreases in lakefront property values when EWM inhibits water-based recreational activities on lakes (Eiswerth et al. 2000, Horsch and Lewis 2009, Zhang and Boyle 2010).

Impact Historic Ecosystem Function

The scientific literature has a number of single-lake scale examples of declining native vegetation on communities dominated by EWM (Madsen et al. 1991; Boylen et al. 1999, Madsen 1999). More recent multi-lake studies suggest that "[EWM] invasion does not correlate with decreased native macrophyte abundance at a landscape scale" (A. Mikulyuk et al, unpublished manuscript). This could be interpreted as suggesting that EWM populations may not be outcompeting native plants as often as traditionally thought; displacement of native species by EWM is likely occurring in localized areas and the impact may be undetectable at a lake-wide scale or across the landscape.

If the native plant communities stay at relatively the same population levels in a lake, but the increased EWM adds a large amount of additional biomass to the lake, one may contend that lake now has a different habitat architecture (i.e. lakescape). Depending on the perspective, this may be negative or positive. EWM has a concentration of biomass in the top of the water column, which may be different from existing habitat structure of the lake. While not only exacerbating human use, this increase of biomass in the upper part of the water column can impact refugia for zooplankton and fish species. This is especially important for shallow and heavily vegetated lakes that are dominated by panfish and other planktivores and insectivores. It is less clear how the addition of large amounts of plant biomass impact systems like the Twin Lakes that have fisheries driven by predator fish (piscivores).

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. As outlined in *The Science Behind the "So-Called" Super Weed* (Nault 2016), EWM population dynamics on lakes are not that simplistic.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.4-16). The upper frame of Figure 3.4-16 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected "unmanaged lakes" were moved into the "managed" category as the EWM populations were targeted for control by the local lake organization.

Some lakes, such as Hancock Lake, maintained low EWM populations over the study averaging a littoral occurrence of 2.3% between 2008 and 2015. At these low levels, there are likely no observable ecological impacts to the lake and are no reductions in ecosystem services to lake users. The EWM population of Hancock Lake has increased in recent years to almost 32% in 2017, which corresponds to 11 years after its initial detection.

Eurasian watermilfoil populations in other lakes, such as Bear Paw Lake and Little Bearskin Lake trended to almost 25% only three years following initial detection. The EWM population of Bear Paw Lake declined to below 2% by six years after detection and has increased to approximately 6% in 2017 (10 years after initial detection). The EWM population on Little Bearskin Lake followed a similar trend, but the magnitude of the decline was less and was just below 10% in 2017 (9 years after initial detection).

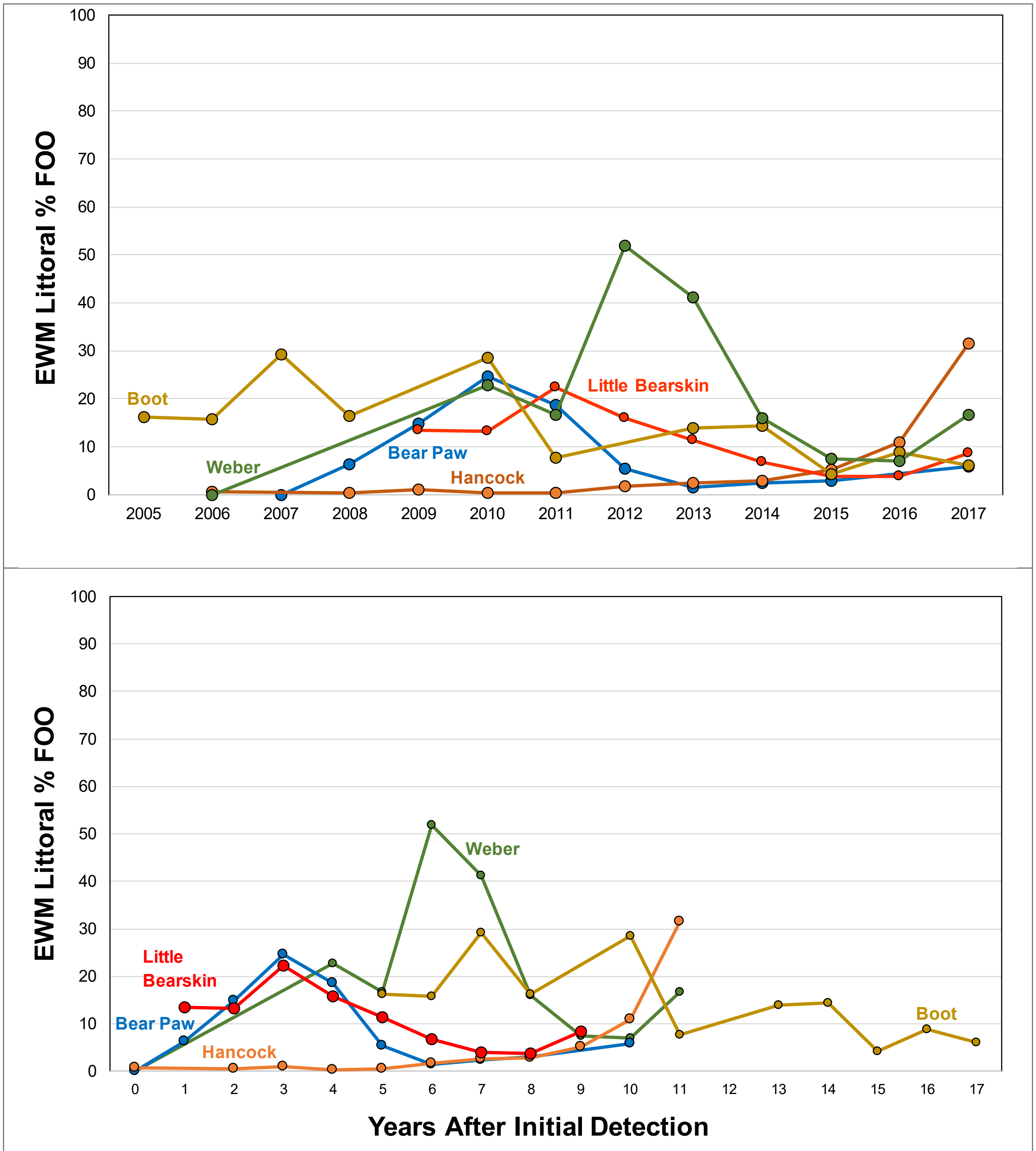


Figure 3.4-16. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from WDNR.

Boot Lake is a eutrophic system with low water clarity (approx. 3-ft Secchi depth) due to naturally-high phosphorus concentrations. It is hypothesized that water clarity conditions in some years may favor EWM growth whereas changes in these conditions may keep the population suppressed in other years. Since 2011, the EWM population of Boot Lake has stabilized around 10%, corresponding to 11-17 years following initial detection.

Rapid and large fluctuations in the occurrence of EWM like those observed on Weber Lake have also been documented. The EWM population in 2010-2011 was approximately 20% before rapidly increasing above 50% in 2012, corresponding with six years after being initially detected in the lake. Then the population declined to under 10% in 2015 and 2016, and has rebounded to approximately 17% in 2017.

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

Within this same study, eight lakes were in the managed category. As discussed above, the list of lakes in this category was initially shorter, but some lakes that were originally in the unmanaged category had lake groups that opted to conduct herbicide treatment strategies to reduce the EWM population within the lake.

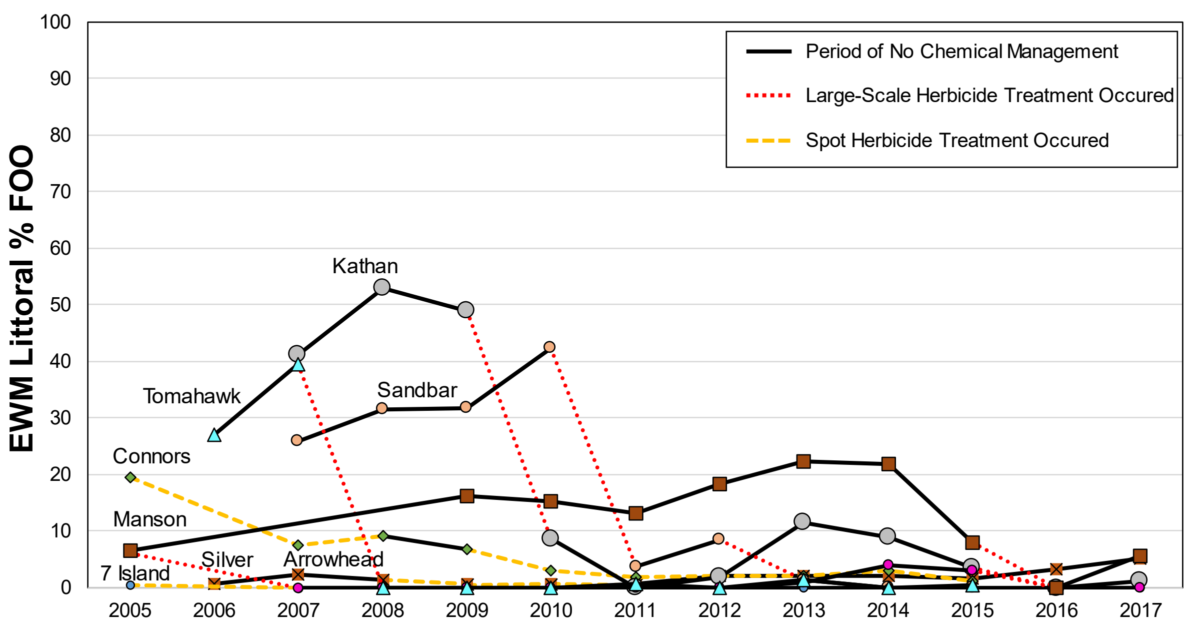


Figure 3.4-17. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion with management. Data provided by and used with permission from the WDNR Bureau of Science Services.

Some of the lakes within the study conducted large-scale (whole-lake) herbicide treatments and had large reductions of EWM. Sandbar Lake conducted follow up large-scale treatments two years following the first large-scale treatment and again four years later. Tomahawk Lake, Silver Lake, and Kathan Lake conducted second large-scale treatments after 10, 9, and 6 years following the first, respectively.

Other lakes conducted more frequent spot treatments to reduce or maintain a low EWM population within the lake. The 2005 spot treatment on Connors Lake may have been close to approaching a large-scale treatment, as almost 8% of the lake was targeted for control. Seven Island Lake conducted a large spot treatment in a bay of the lake in 2005 and has not conducted additional herbicide management to date. After a few largely unsuccessful herbicide treatments from 2008 to 2010 on Arrowhead Lake, herbicide management was abandoned and the population has slowly increased to just over 5% after 6 years.

The study results clearly show that management can be effective to reduce and maintain lowered EWM populations.

South Twin Lake EWM Population Progression and Management History

The EWM population of the Twin Lakes was first noted near the bulrushes in South Twin Lake and near the island in North Twin Lake. The population progression of EWM in South Twin Lake is better documented than for North Twin Lake. The first formal EWM mapping survey occurred during 2004 on South Twin Lake. Colonized EWM was located within the bulrush beds. In a clockwise fashion starting at the bulrush beds, it appeared at the time that the occurrence of single EWM plants diminished with distance (Figure 3.4-18). As the years progressed, the foot print of EWM within South Twin Lake was found to increase and circle the entire littoral zone of the lake. In 2007, large and dense colonies were documented near the bulrush colonies.

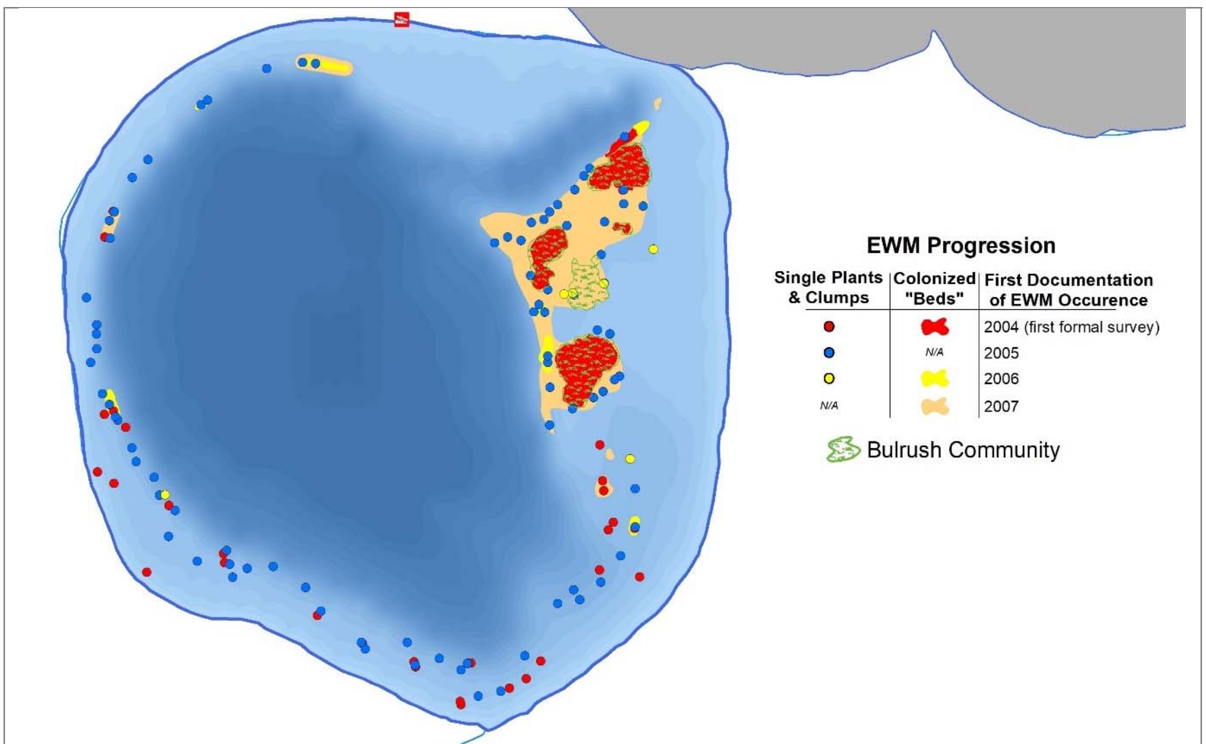


Figure 3.4-18. South Twin EWM population progression during early detection and response management (2004-2007).

The North and South Twin Lakes Riparian Association (NSTLRA) took a rapid and proactive approach to management during the years following initial infestation by implementing strategic hand-harvesting (2001, 2002) and herbicide spot treatments through 2008 (Figure 3.4-19) on South Twin Lake.

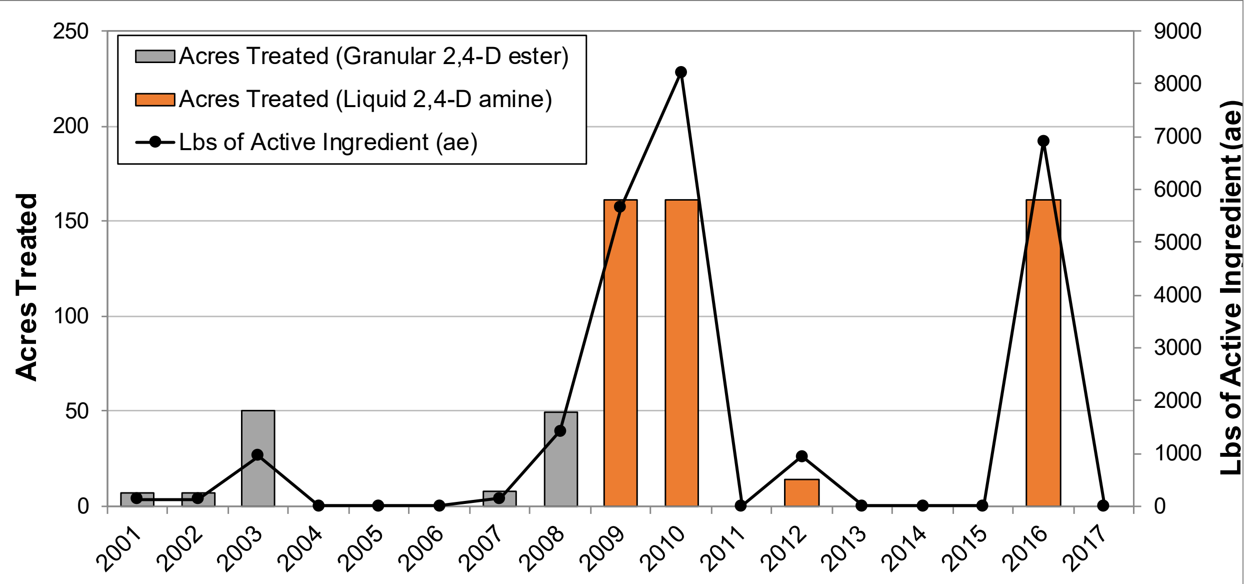


Figure 3.4-19. South Twin herbicide use history.

The 2008 spot treatment of South Twin targeted approximately 50 acres of South Twin Lake with a granular ester formulation of 2,4-D (Navigate ®) at 150 lbs/acre. Applying the current understanding of herbicide mixing, this would have resulted in 0.07 ppm acid equivalent (ae) lake-wide if the lake was stratified at the time of the treatment, below large-scale thresholds (0.1 ppm ae) currently embraced by Onterra and have root in the scientific literature (Glomski and Netherland 2010).

A similar but expanded approach took place in 2009 with a liquid 2,4-D amine herbicide formulation (Weedestroy®). Only a rudimentary understanding of large-scale (aka whole-lake) treatments was available at that time, but enough of an understanding that water samples testing for herbicide concentrations accompanied this treatment. The results of the sampling indicated a lake-wide mean 1-7 day after treatment (DAT) concentration of 0.12 ppm ae. While this concentration likely had lake-wide impacts to the native vegetation of South Twin Lake, it was insufficient to cause complete EWM mortality with numerous EWM occurrences being located within the lake during the late-summer following the treatment (Figure 3.4-20).

The strategy was repeated in 2010, but with slightly more herbicide being applied (application area targeting 2.5 ppm ae vs 1.75 ppm ae in 2009). The increased amount of herbicide resulted in a disproportionate increase (almost five-fold) in the measured lake-wide concentration within the lake (0.58 ppm ae.). It is now understood that when a lake is thermally stratified, the herbicide will only mix within the top water column (epilimnion) and not the entire volume of the lake. Therefore, current dosing practices rely on understanding the depth to which thermal stratification is occurring. It is likely that South Twin Lake was likely thermally stratified in 2010 and was not in 2009. Only a few large-scale 2,4-D treatments in Wisconsin have resulted in higher lake-wide concentrations than the 2010 treatment of South Twin Lake. The level of EWM control was high from this treatment, with no EWM being located from the lake during the late-summer following the treatment (Figure 3.4-20).

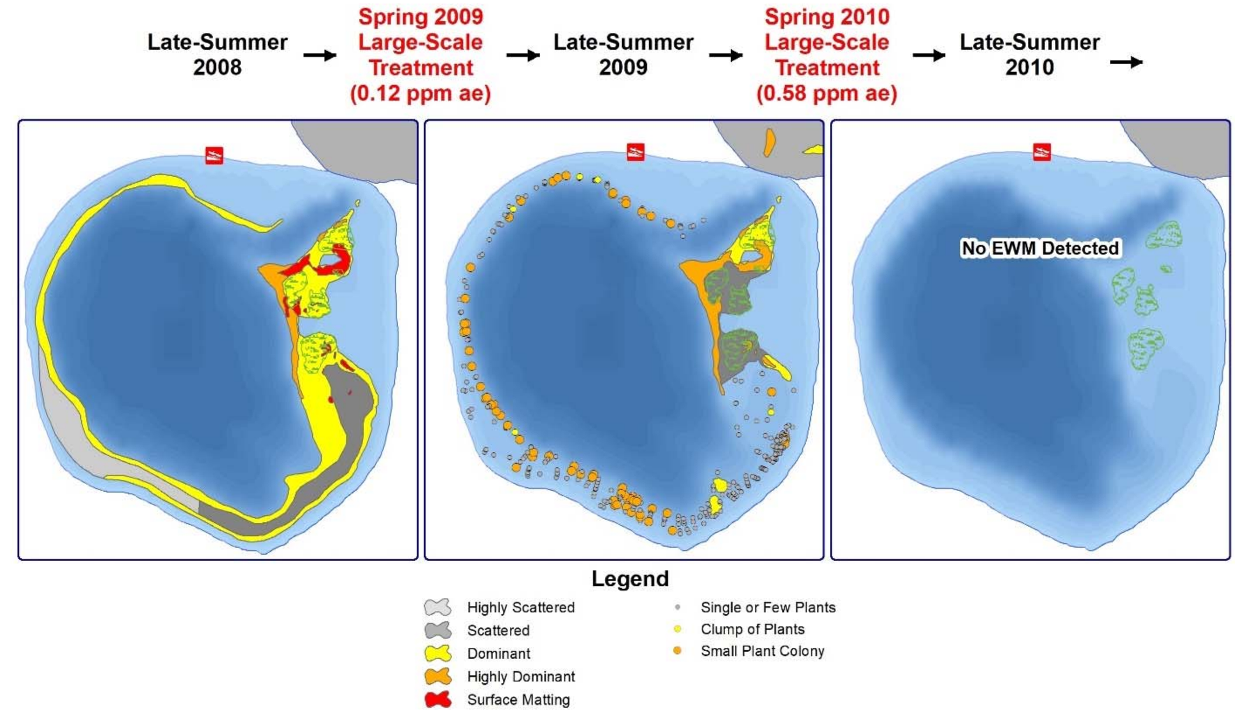


Figure 3.4-20. South Twin EWM population progression during large-scale management (2008-2010). 1-7 DAT average 2,4-D concentrations reported.

The WDNR conducted the first point-intercept survey on South Twin Lake in 2008, locating EWM within 20.7% of the littoral sampling locations (Figure 3.4-21). The 2009 large-scale treatment resulted in an EWM population reduction down to 10.8% and the 2010 large-scale treatment reduced the EWM population below detectable levels within the lake. Numerous native plant species were impacted from this treatment. Recovery of some plant species has occurred whereas others continue to be below frequencies measured in 2008. The native plant community response to the treatment program on South Twin will be subsequently explored.

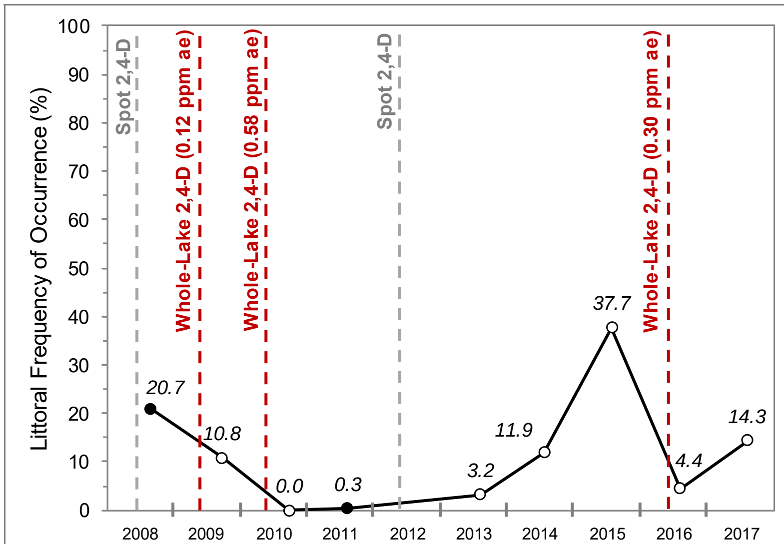


Figure 3.4-21. Littoral occurrence of EWM from South Twin Lake from 2008-2017. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments with 1-7 DAT average 2,4-D concentrations reported, gray-dashed line indicates spot treatment.

Following the 2009 and 2010 large-scale treatments, the NSTLRA switched from a population control strategy to a maintenance strategy. The goal was now to maintain the EWM reductions and allow the native plant population the opportunity to recover from the control strategy, particularly the higher-than-anticipated concentrations achieved during the 2010 large-scale treatment.

An approximately 14-acre spot treatment over two sites took place on South Twin Lake during the spring of 2012 in response to the earliest documentation of EWM within the system since the large-scale treatments in 2009-2010. The treatments were largely ineffective so a professional-based hand-harvesting strategy was enacted during the summer of 2013 and 2014 at a cost of over $10,000 each year. These efforts resulted in large piles of EWM being removed from the lake but did not slow the population progression.

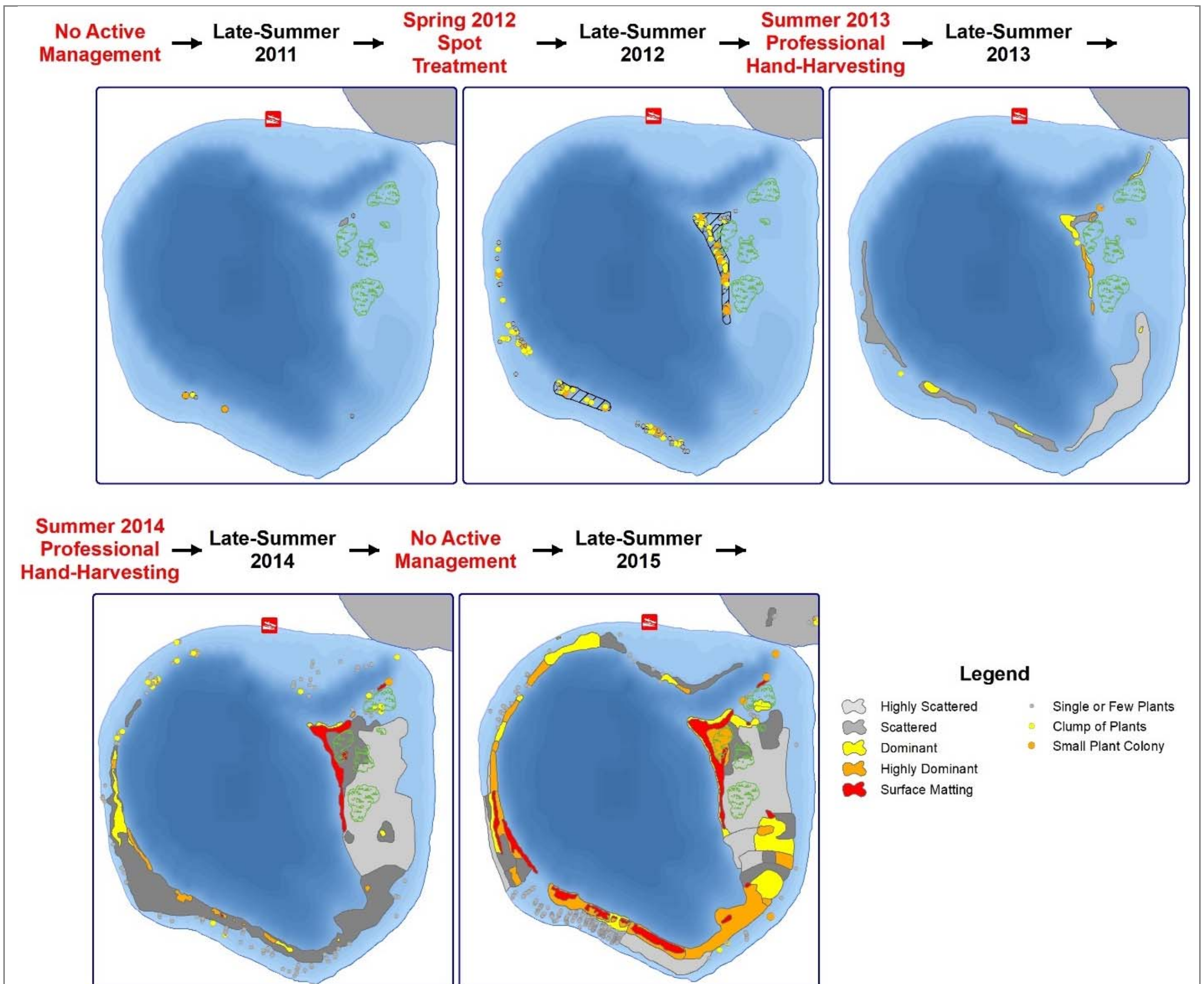


Figure 3.4-22. South Twin EWM population progression during maintenance strategy 2011-2015.

In 2014, the EWM population of South Twin Lake was 11.9% of the littoral zone (Figure 3.4-21) and *surface matted* EWM was documented lakeward from the bulrushes (Figure 3.4-22). Onterra presented the most current version of the ongoing WDNR EWM Long-Term Trends Monitoring dataset to the NSTLRA so they understood that some EWM populations do not necessarily simply continue to increase each year; some may stabilize and some may actually decline. The NSTLRA considered the WDNR EWM Long-Term Trends Monitoring dataset, the fact that many of the native plant species had not recovered from the 2009-2010 large-scale treatments, and the uncertainty that a subsequent 2,4-D treatment would be effective. The NSTLRA followed Onterra's recommendation to postpone a large-scale (aka whole-lake) treatment on South Twin Lake at least until 2015 to see how the population may progress.

A significant increase in EWM acreage and density was observed throughout South Twin Lake in 2015, exceeding levels from prior to the 2009-2010 whole-lake herbicide treatments (littoral frequency of occurrence of 37.7%, Figure 3.4-21). The dense and noticeable EWM population in South Twin Lake raised concerns from NSTLRA members (Figure 3.4-23, Figure 3.4-24, Photograph 3.4-6), spurring a meeting between Eddie Heath of Onterra and board members of the NSTLRA in early summer of 2015. At that time, a discussion about conducting another large-scale herbicide treatment on the lake occurred. Later that summer, the NSTLRA held another meeting, this time also inviting Kevin Gauthier, Local WDNR Lakes Coordinator to the meeting. A healthy discussion of control strategies, EWM population dynamics, and lake management planning took place.

Figure 3.4-23. Spring 2015 National Agriculture Imagery Program (NAIP) Orthophoto of South Twin Lake. Arrow point to EWM observed on photo.

Photograph 3.4-6. Matted EWM on South Twin Lake. August 2015.

To have more certainty whether South Twin's invasive milfoil population consists of herbicide-tolerant strains, NSTLRA partnered with SePRO to conduct laboratory studies termed "challenge testing" on a subset of plants from the lake. As a company that produces aquatic and terrestrial herbicides, SePRO has developed baseline challenge testing procedures (PlanTEST®) using the herbicide products they manufacture (2,4-D – Sculpin®, triclopyr – Renovate®, and fluridone – Sonar®). In the late summer of 2015, Onterra staff collected over 150 EWM plant meristems from three locations and sent them to the SePRO Research and Technology Campus for herbicide challenge testing within indoor small-scale aquaria.

The herbicide challenge testing concluded that the EWM population in South Twin Lake had a slightly reduced susceptibility to 2,4-D whereas a classically susceptible response to triclopyr treatment. The fluridone results were less conclusive. A slightly elevated 2,4-D dose (0.35 ppm ae) was used justified for use during the spring of 2016 in an attempt to offset the slight tolerance that was observed in the laboratory screened plants from South Twin Lake. The achieved 1-7 day after treatment average 2,4-D concentration was 0.304 ppm ae, as this metric also includes one week of herbicide degradation from original concentrations.

The spring 2016 large-scale 2,4-D treatment appeared successful at first. No EWM could be located from the surface during the late-summer 2015 EWM mapping survey (Figure 3.4-24) and only 4.4% of littoral point-intercept sampling locations contained EWM (Figure 3.4-21). Unfortunately, the EWM reduction from the spring 2016 treatment did not last as long as the NSTLRA would have liked, with a significant EWM population rebounding by 1 year after treatment (2017) back to 14.3% of littoral point-intercept sampling locations and numerous EWM occurrences being mapped around the lake (Figure 3.4-24).

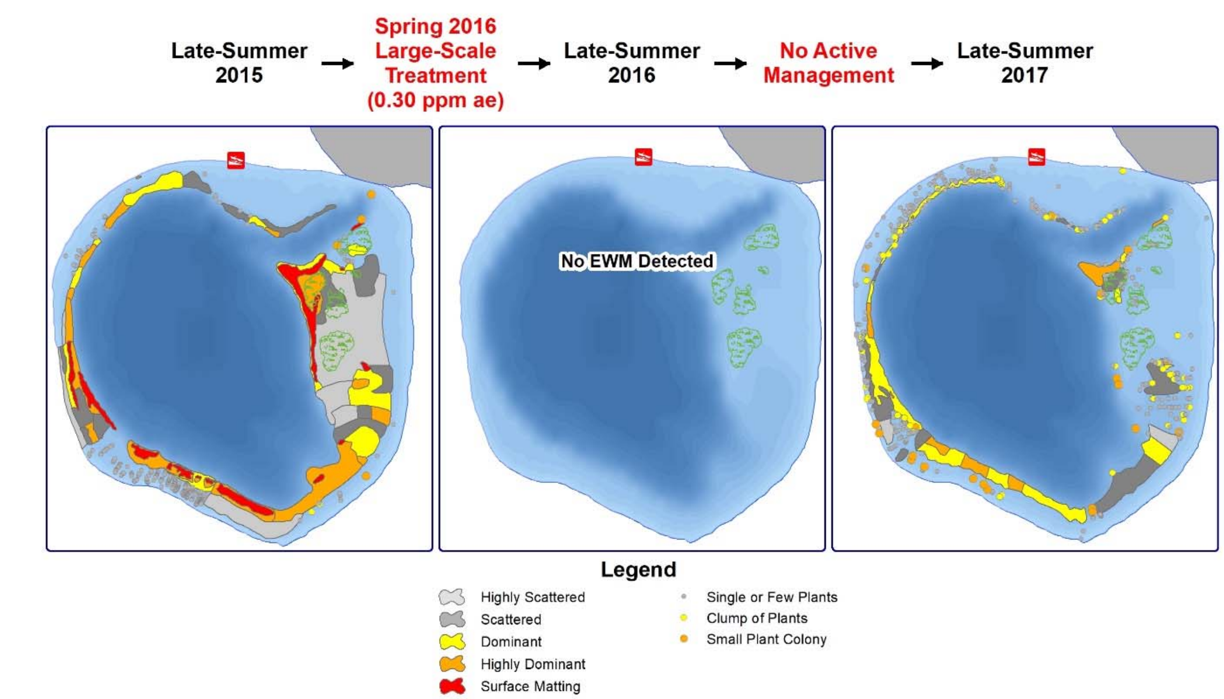


Figure 3.4-24. South Twin EWM population progression during second round of large-scale management (2008-2010). 1-7 DAT average 2,4-D concentrations reported.

In summary, the NSLTRA enacted four phases of management: 1) early response after detection (2001-2007), 2) more aggressive management to reduce the EWM population (2008-2010), 3) maintenance strategy to retain reductions made (2011-2015), and then a 4) second round of aggressive management (2016) once the EWM population had rebounded from the first round.

South Twin Lake Point-Intercept Data Trends

Many aquatic plant management activities are evaluated by comparing the *year before treatment* data to the *year of treatment* data and the *year after treatment* data. In order to confirm that the population is different from one year to the next, a statistical analysis (chi-square) is conducted that incorporates the magnitude of the change and the sampling intensity. Understanding if the statistically valid change that has occurred is caused by the aquatic plant management action can be difficult to determine.

In addition to aquatic plant management activities (i.e herbicide treatment and hand-harvesting), natural environmental changes such as water level fluctuations, precipitation, temperature, length of the growing season, etc. can impact aquatic plant composition within a lake. The natural variability of aquatic plant populations can make it difficult to evaluate the impacts of aquatic plant management activities. Therefore, ecologists look at the longer-term data to understand context.

Linear regression analysis allows lake ecologists a way to discover if statistically valid trends (increases or decreases) are occurring. For example, if aquatic plant management activities are targeting a particular species, that species should have decreasing or stable population trend over time. Linear regression analysis generates an equation or line of best fit (regression line) that minimizes the distance between the data points. A statistical measure of how close the measured data are to the regression line is called the r-squared statistic (r^2) and ranges from 0 to 1 (0% to 100%). An r^2 value of 0 indicates that the model does not explain any of the variability in the data (0% of the data), while an r^2 value of 1 indicates that the model explains all of the variability in the data (100% of the data). In addition to r^2, linear regression analysis also generates a *p*-value, which indicates if time is a significant predictor of change in the population (i.e. is a trend occurring). A low *p*-value ($\leq$ 0.05) indicates that a statistically valid population change has occurred over time, while a larger *p*-value (> 0.05) indicates that a statistically valid change has not occurred.

For South Twin Lake, linear regression analysis was conducted on the entire dataset (2008-2017). Additionally, regression analysis was conducted for the first period of large-scale management (2008-2010) as well as the following period of potential aquatic plant recover (200-2015) up until the next large-scale treatment (spring 2016). Because there is a limited number of data points in each of these separated trend analysis, it is difficult to achieve statistically validity. That being said, the direction and magnitude of the slopes of the trend analysis during each period of management are important to understanding the impact of the EWM-targeted control actions.

The initial population management goal for EWM was to reduce its population and maintain the lowered population over time. The EWM population of South Twin Lake was 20.7% in 2008 and 14.3 % in 2017. This achieved reduction in 6.4 percentage points equates to a 30.8% reduction (Figure 3.4-25). Looking closer at the data, there is a high amount of population fluctuations, seemingly in response to the large-scale control actions (Figure 3.25, top frame). The EWM population had a statistically valid decline following the 2009 and 2010 large-scale treatments (Figure 3.25, top frame) and the linear regression analysis indicates a statistically valid downward trend during this time period (Figure 3.25, bottom right frame). The 2012 spot treatment and the 2013-2014 hand-harvesting program were unable to maintain the lowered EWM population, as a positive trendline from 2010-2015 confirms the population increase. The large-scale treatment during the spring of 2016 had a statistically valid decrease in the EWM population (Figure 3.25, top frame), but the population rebounded to 14.3% during the *year after treatment*. The 2008-2017 trendline does not fit the data well, because the reductions did not occur over time, but rather in pulses during the large-scale management activities (Figure 3.4-25, bottom right frame).

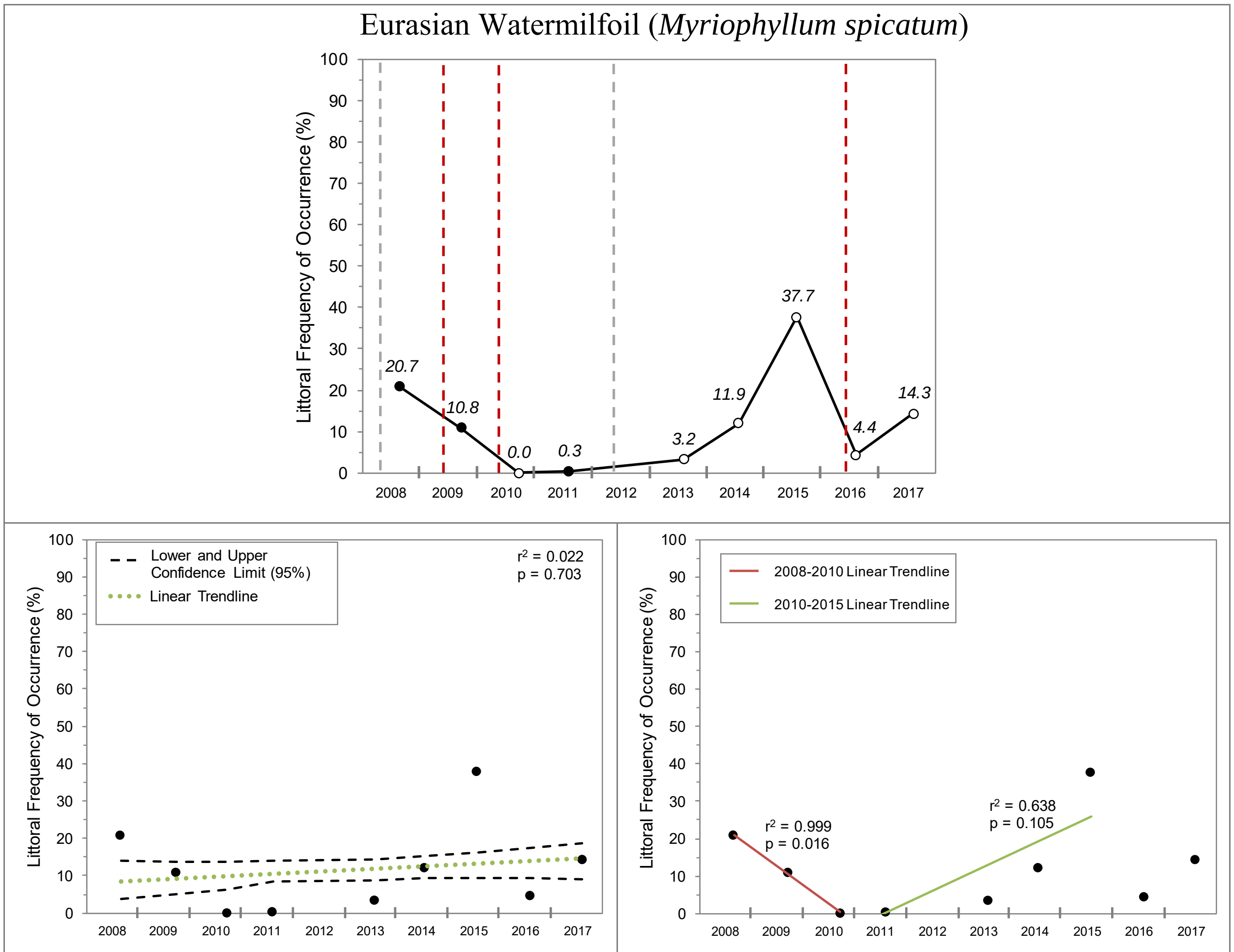


Figure 3.4-25. Littoral occurrence and trend analysis. Top figure - open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatment.

Seven native plant species had statistically lower populations in 2017 compared to 2008, whereas only 5 species had statistically valid higher populations in 2017 compared to 2008 (Figure 3.4-26). Figures 3.4-26-3.4-30- show how specific native plant occurrences have changed over time on South Twin Lake, particularly how they responded and recovered to the large-scale herbicide treatments that have occurred during this time period. The linear regression analysis methods discussed above for EWM were conducted on all native plants that had a littoral frequency of occurrence greater than 3% during one of the survey years, and is included as Appendix E. Within the subsequent analysis, it is clear that some native plants have been reduced from the large-scale herbicide treatments, especially the higher-than-anticipated concentrations that occurred during the 2010 treatment. The data also show that some of the native plant declines may not be associated with the control program, as the declines occur and/or continue during years without active management occurring.

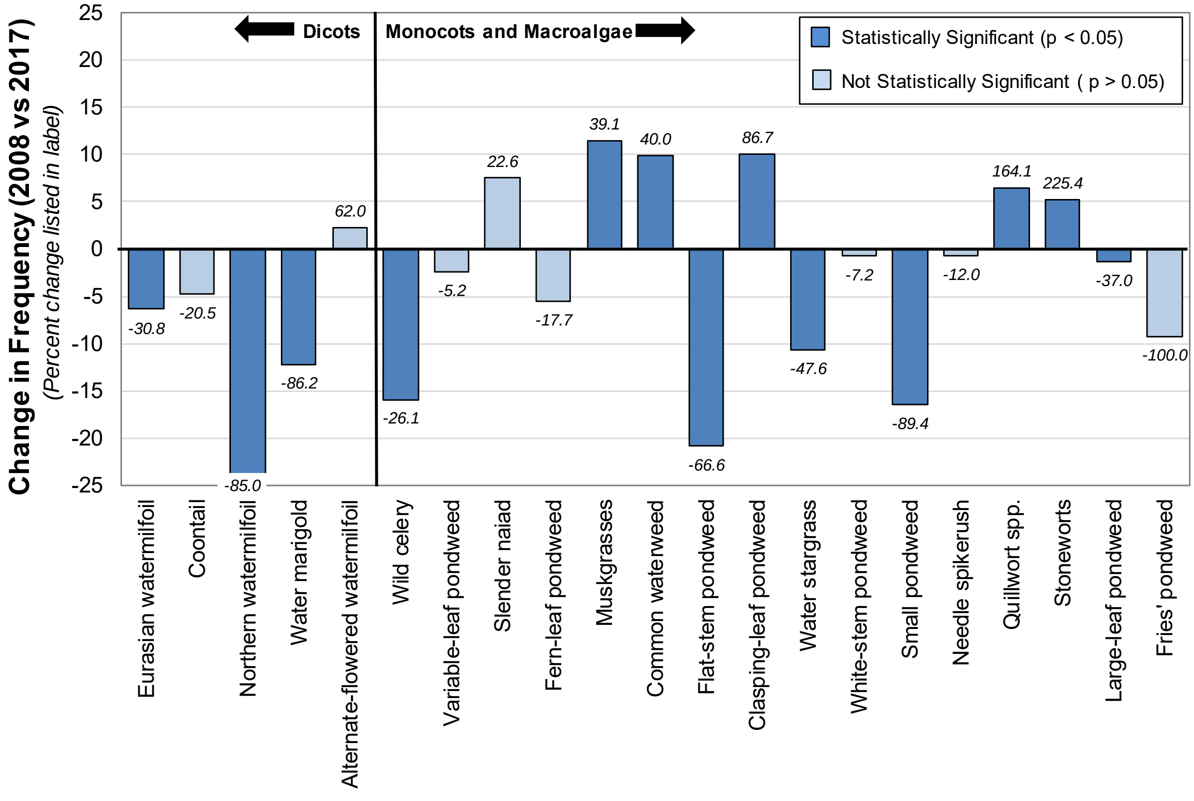


Figure 3.4-25. 2008 vs 2017 Littoral Frequency of Occurrence Analysis. Bar chart data shown on figure indicates magnitude of change, labels indicate percent change. Statistical differences based upon Chi-square (α = 0.05).

EWM is a dicot (broad-leaved plant) and the herbicides (2,4-D) which have been used in South Twin Lake in an effort to control EWM were historically believed to only have impacts to dicot species. Research conducted by the US Army Corps of Engineers, the WDNR, and private consultants have shown that certain non-dicot native plants are sensitive as well.

Figure 3.4-26 shows how the dicot species in South Twin Lake have changed over time. Coontail populations were steady at approximately 22% during and following the 2009-2010 large-scale efforts, but reduced to 9.2% during the period of small-scale management. The population of coontail has increased following the last large-scale 2,4-D treatment, although it is unknown if it is from a causative relationship. Coontail populations have had a statistically valid population reduction over time (Appendix E), although the 2017 population was not statistically different from 2008 (Figure 3.4-25).

Populations of northern water milfoil and water marigold were highest prior to the 2009 large-scale control efforts. The populations of these two species were reduced significantly following the 2009-2010 control efforts and had positive population trends from 2010-2015 but were still lower than 2008 levels (Appendix E). Both species had statistically valid reductions following the spring 2016 large-scale 2,4-D treatment with both populations being approximately 85-86% lower in 2017 than in 2008 (Figure 3.4-25). Alternate-flowered watermilfoil populations only had a statistically valid population reducing during 2010, likely following the higher-than-anticipated 2,4-D concentrations that accompanied that spring's large-scale treatment. The 2017 population of alternate-flowered watermilfoil is 2.2 percentage points higher than in 2008, representing a 62% higher population level.

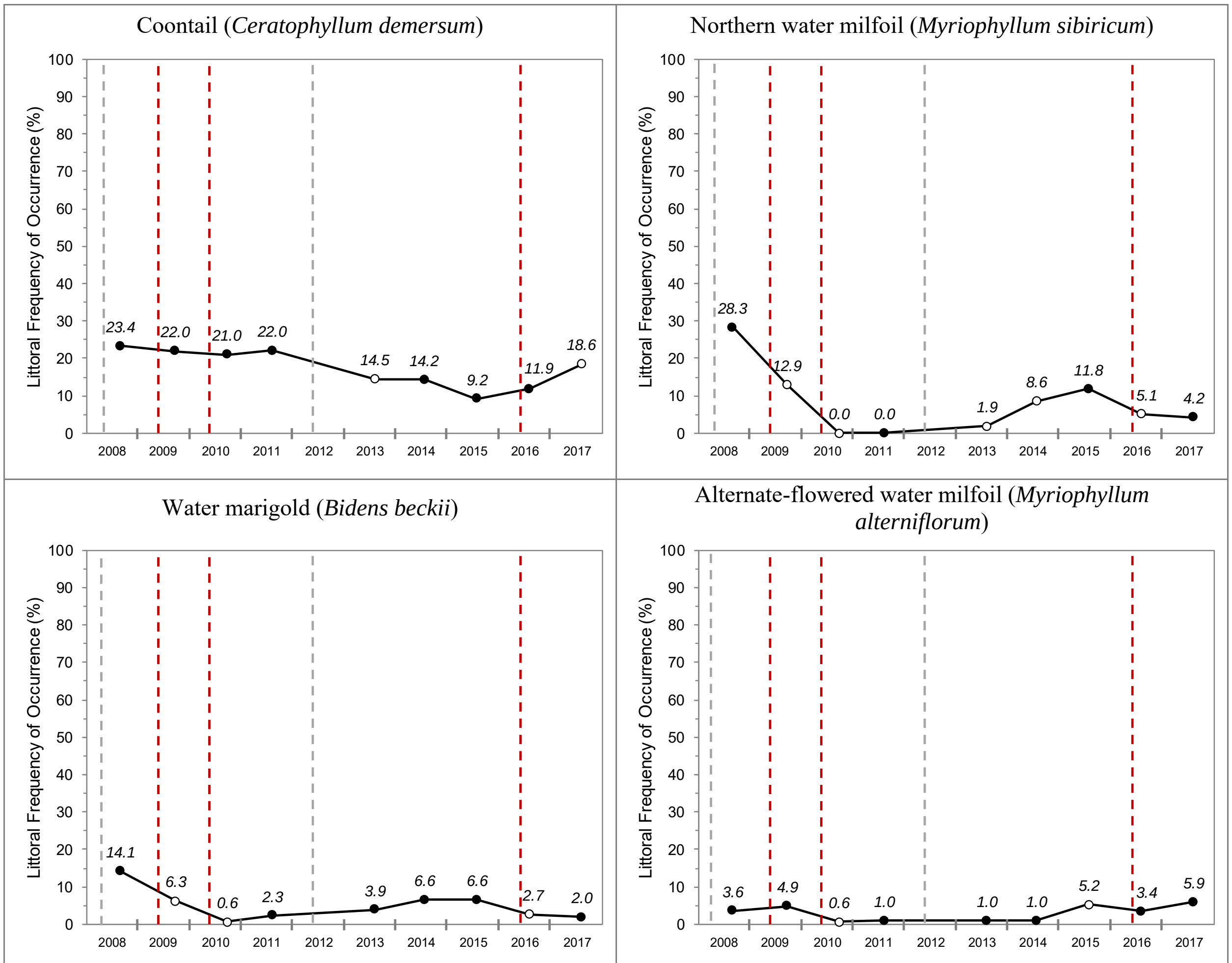


Figure 3.4-26. Littoral occurrence of dicot species. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatments.

Three monocot species had statically valid reductions from 2015 to 2016 on South Twin Lake in association with the last large-scale 2,4-D treatment (Figure 3.4-27). Onterra's experience is that flat-stemmed pondweed is sensitive to early season herbicide treatments, potentially because this plant can be observed actively growing at the time of treatment whereas some others are not. It is important to note that this species rebounded quickly following the first round of large-scale treatments, only to decline significantly in the absence of management from 2013 to 2015. Flat-stemmed pondweed populations in 2017 were almost 21 percentage points lower than in 2008 (Figure 3.4-25).

Water stargrass populations in 2017 were over 10 percentage points less than in 2008 and the regression analysis appears to confirm that population recovery was occurring from 2010-2015 (Appendix E). While needle spikerush populations were statistically lower following the last large-scale 2,4-D treatment, it is unclear if this species is this relationship is causative as the population of this species remained constant following the 2009 and 2010 large-scale treatments. The 2017 population of needle spikerush is not statistically different from the 2008 population.

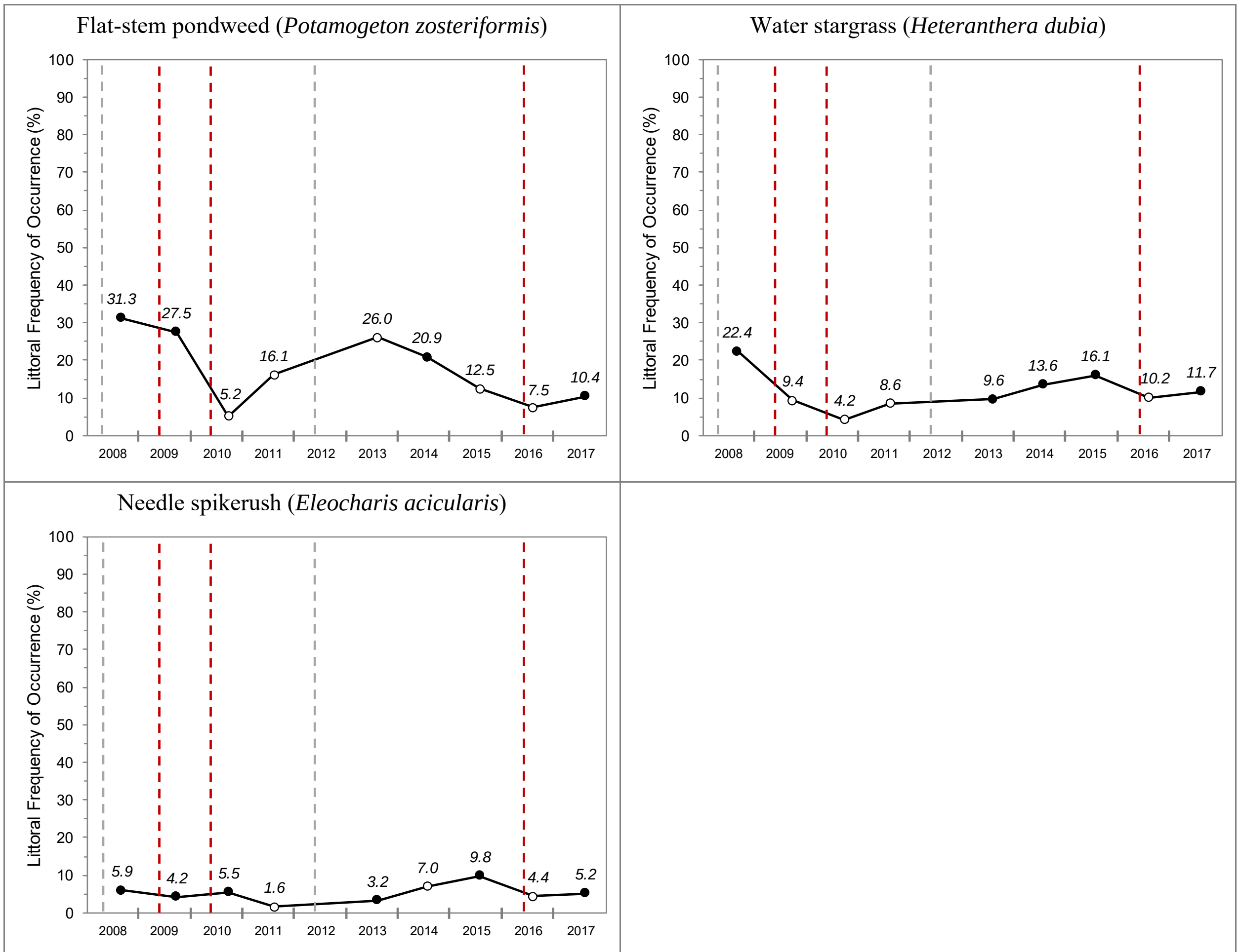


Figure 3.4-27. Littoral occurrence of monocot species that had statistically valid declines in 2016. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatment.

Four monocot species were found to have statistically valid increases following the 2016 herbicide control actions on South Twin Lake (3.4-28). While fluctuations in the occurrence of variable-leaf pondweed have been observed since 2008, potentially in response to herbicide treatment, this species has been resilient and maintained a relatively stable population over this time period. The population of variable pondweed in 2017 is not statistically different from the population in 2008 (Figure 3.4-25). Similar trends were also observed for common water weed and clasping-leaf pondweed, with both species having 2017 populations approximately 10 percentage points higher than in 2008.

Muskgrasses, a group of macro-algae, are almost universally resilient to most herbicide treatments. As an algae, herbicides are not moved through (translocated) the tissue as the "plant" is made up of colonies of cells. The populations of muskgrasses has fluctuated over time on South Twin Lake, with an increasing population trend occurring since 2014. A similar trend of increased population of muskgrasses has been observed over this same time period on Big Sand Lake, also in absence of any active management strategies being implemented.

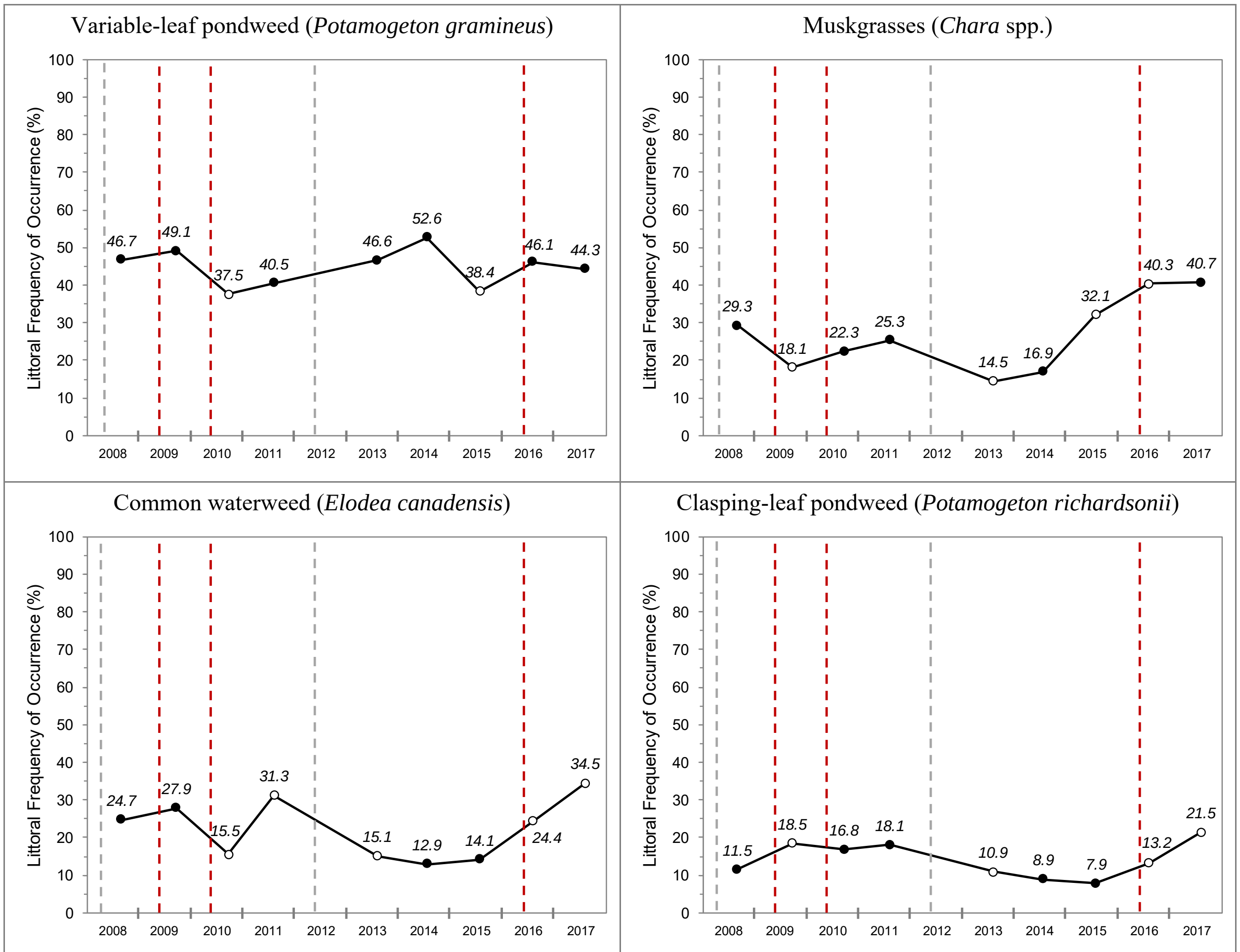


Figure 3.4-28. Littoral occurrence of monocot species that had statistically valid increases in 2016. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatment.

Six additional monocot species were shown to have non-statistically valid changes following the 2016 herbicide treatment (Figure 3.4-29). Onterra's experience has been that fern-leaf pondweed and small pondweed are often impacted by early season herbicide treatments. Fern-leaf pondweed maintained a stable population during this time period, with no statistically valid changes from year to year. However, fern-leaf pondweed populations have had a statistically valid declining population from 2008-2017 (Appendix E).

Small pondweed was greatly impacted from the 2010 2,4-D treatment. Onterra's experience is that this species is impacted during most large-scale 2,4-D treatments, even treatments on the lower range of concentrations and exposure times. The population of small pondweed was highest during 2013, three years after the spring 2010 large-scale treatment. The population of small pondweed has been in decline from 2013 to 2017. It is likely that the 2016 treatment did not result in a statically valid reduction of this species because the population was already quite low.

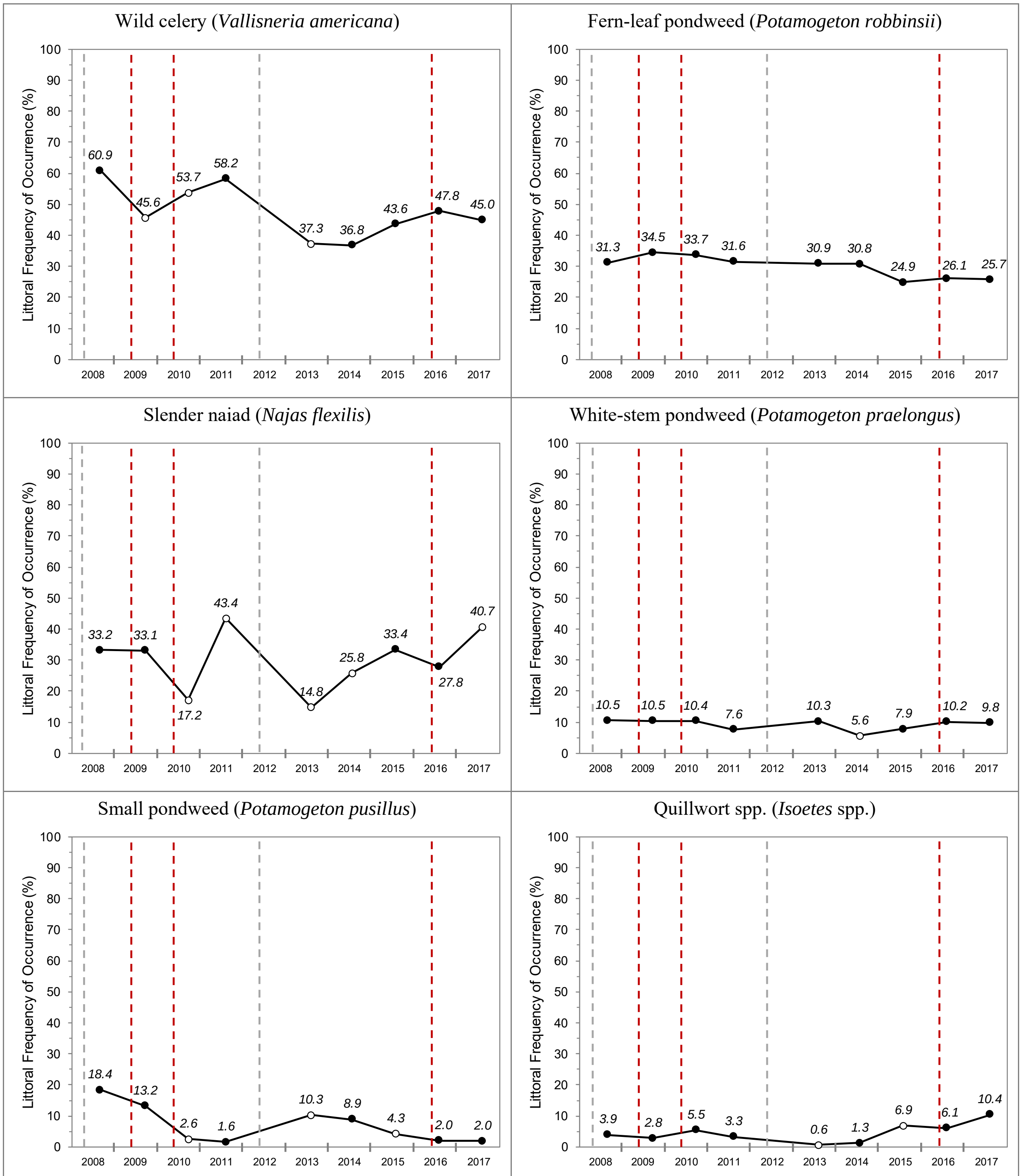


Figure 3.4-29. Littoral occurrence of monocot species that had no statistically valid changes in 2016. Open circle represents a statistically valid change in occurrence from previous survey (Chi-square α = 0.05). Red-dashed lines indicate whole-lake herbicide treatments, gray-dashed line indicates spot treatment.

North Twin Lake EWM Management History

During the 2016 point-intercept survey conducted on North Twin Lake, the EWM littoral frequency of occurrence was found to be 1.1%, slightly lower than the 1.6% observed during a 2011 survey (Figure 3.4-31). This indicates that the lake-wide EWM population in North Twin Lake is relatively low. In North Twin Lake, the lake-wide colonized EWM acreage has remained approximately the same from 2014 to 2016 at roughly 6.5 to 7.5 acres, however has increased in density (Figure 3.4-30).

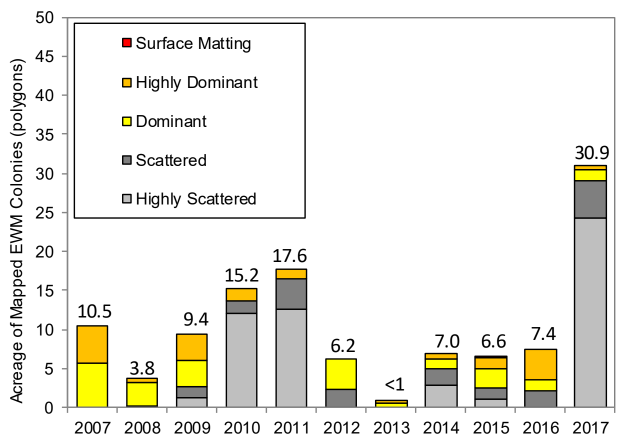


Figure 3.4-30. Acreage of mapped EWM colonies on North Twin Lake from 2010-2016.

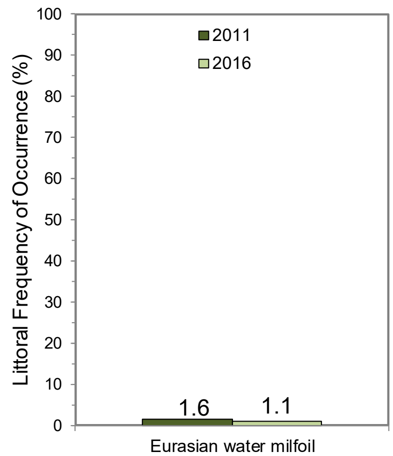


Figure 3.4-31. EWM Littoral occurrence from North Twin Lake.

Prior to 2017, the majority of the known EWM population in North Twin Lake is on the southern end of the lake near the island and the border with South Twin Lake (Map 15). Sparse amounts of EWM comprised of low density occurrences were located in a few other areas of North Twin Lake during the September 2016 survey. This area in the southern end of the lake near the island has been targeted with aquatic herbicides from 2007 to 2013. These treatments were moderately impactful in reducing the EWM density within the treatment areas during the season that the herbicides were applied, but were ineffective at fully killing the target plants and complete rebound occurred by the following year. The justification for rotating herbicide treatment techniques over this period was to increase efficacy as long-term goals were not being met. In 2014, the NSTLRA opted to postpone herbicide treatment strategies until a more efficacious use-pattern could be developed. These locations were targeted with professional-based hand-harvesting from 2014 to 2016 but had little impact on reducing the EWM population within these sites.

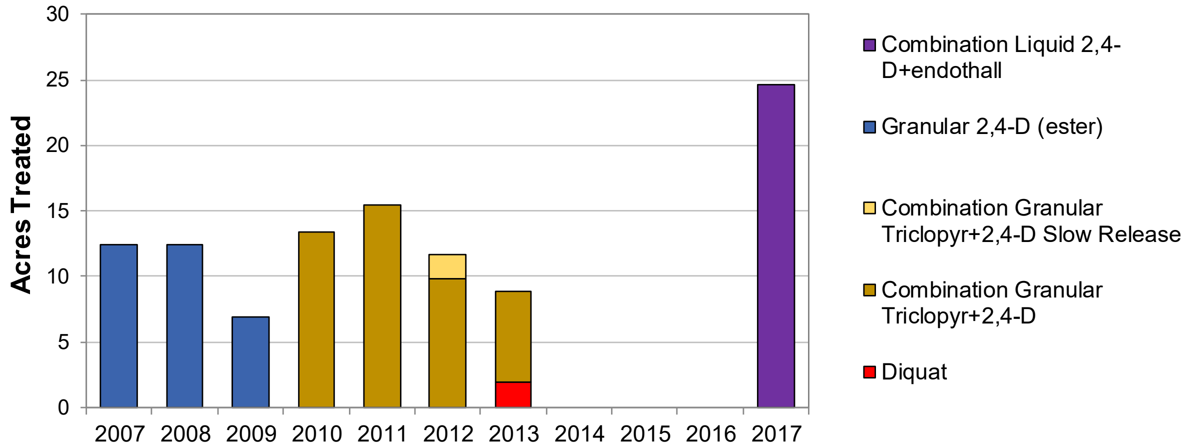


Figure 3.4-32. North Twin Lake Herbicide Treatment History. No herbicide treatments took place in 2014-2017.

The EWM colonies in North Twin Lake, specifically those in the southwestern part of the lake near the island are believed to exceed the size and/or density levels that can be effectively controlled with hand-harvesting methods. Understanding Concentration-Exposure Times (often referred to as CETs) is an important consideration for the use of 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. Numerous past attempts at controlling the EWM population in this part of North Twin Lake have failed, as herbicide dilution was too rapid to kill the EWM.

Ongoing studies are indicating that in small spot treatments (working definition is less than 5 acres) the herbicide dissipates too rapidly to cause EWM mortality if systemic herbicides like 2,4-D are used (Nault et al. 2015). Even in some cases where larger treatment areas can be constructed, their narrow shape or exposed location within a lake may result in insufficient herbicide concentrations and exposure times for long-term control. Ongoing field trials are assessing the efficacy (EWM control) and selectivity (collateral native plant impacts) of herbicides that may be effective with a shorter exposure time such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.).

The long-term control of EWM targeted with diquat continues to be evaluated on many lakes across Wisconsin. As a contact herbicide, diquat does not move (translocate) through plant tissue. Therefore, only the exposed plant material is impacted by the herbicide. Concern exists whether this herbicide has the capacity to kill the entire plant or if the herbicide simply removes all the above ground biomass and the plant rebounds from unaffected root crowns. Diquat also has a high affinity for binding with organic particles. In shallow waters where the application equipment creates disturbance of the lake bottom, the diquat being applied will quickly bind to the suspended particles and be instantly unavailable to cause impacts to the target plants. In lakes with high organic material encrusted on the plant, this may also reduce the efficacy of the treatment.

Dr. Scott Nissen (Colorado State University) is currently investigating herbicide uptake and translocation of various aquatic herbicides. Within a recent United Phosphorus, Inc. (UPI) newsletter-style report, Dr. Nissen is quoted, "Based on our endothall studies in flowing water, we thought that endothall must have some systemic activity, and now we have data that confirms that endothall does translocate from shoots to root tissue. In fact, the ratio of endothall in the root vs.

shoot tissue after 192 hours of exposure was greater for endothall than for other systemic herbicides that we have evaluated." The manufacturers of endothall (Aquathol® K, UPI), have shown that increased systemic activity of the endothall occur when water temperatures are colder (<60°F).

It is theorized, but not proven, that a combination of endothall and diquat or 2,4-D may not require as long of an exposure time as either herbicide alone due to increased systematic impacts to the target plants particularly at cold water temperatures. Numerous spot treatment field trials of 2,4-D/endothall (soon to be commercially available under the Chinook® brand) and diquat/endothall (commercially available under the Aquastrike® brand) are occurring in Wisconsin.

Onterra did not anticipate an herbicide treatment with a systemic herbicide like 2,4-D would meet expectations when targeting the EWM in the southwestern part of North Twin Lake. This is supported by the results of the past herbicide treatment history in this part of the lake. Therefore, it was recommended that a combination 2,4-D and endothall be implemented in 2017 to offset the likely short herbicide exposure time (Figure 3.4-33, top frame). This combination use-pattern has been employed by Onterra in a handful of spot-treatments and the data appear to suggest greater efficacy than 2,4-D alone. On a mid-January conference call between Onterra ecologists and the NSTLRA AIS Committee, a thoughtful conversation about the challenges of controlling EWM in these areas and the secondary impacts of using the proposed herbicide combination took place.

Following the herbicide application by Clean Lakes, water samples from different locations and time intervals after treatment were collected by NSTLRA volunteers. Endothall concentrations were not analyzed but the relative 2,4-D concentration can be used to determine the endothall concentrations. The 2,4-D application rate was 4.0 ppm acid equivalent (ae), which is what the maximum axis value on the charts. The three circle symbols show the 2,4-D concentrations within the herbicide application areas (Figure 3.4-33, center frame). These data indicate the A-17 (NT3) and B-17 (NT2) acted like one large treatment site (as anticipated) whereas C-17 (NT1) contained lower concentrations. The 2,4-D concentrations within A-17 and B-17 may be in the range (with the endothall component) to cause mortality to EWM, whereas the concentrations in C-17 may not be.

The three square symbols show the 2,4-D concentrations outside of the application areas (Figure 3.4-33, bottom frame). These values are quite low and it is safe to say that herbicide moved in all directions almost uniformly and the concentrations observed outside of the treatment areas are almost certainly too low to cause aquatic plant impacts in these areas. Through analysis of the wind data from the nearest collection station (on Deerskin Lake), the winds were low and unspecific in direction (ie swirling). It is suggested that sub-surface currents impacted the dilution more than wind-driven surface movement, especially considering the deep-water injection technique and the low winds during this timeframe.

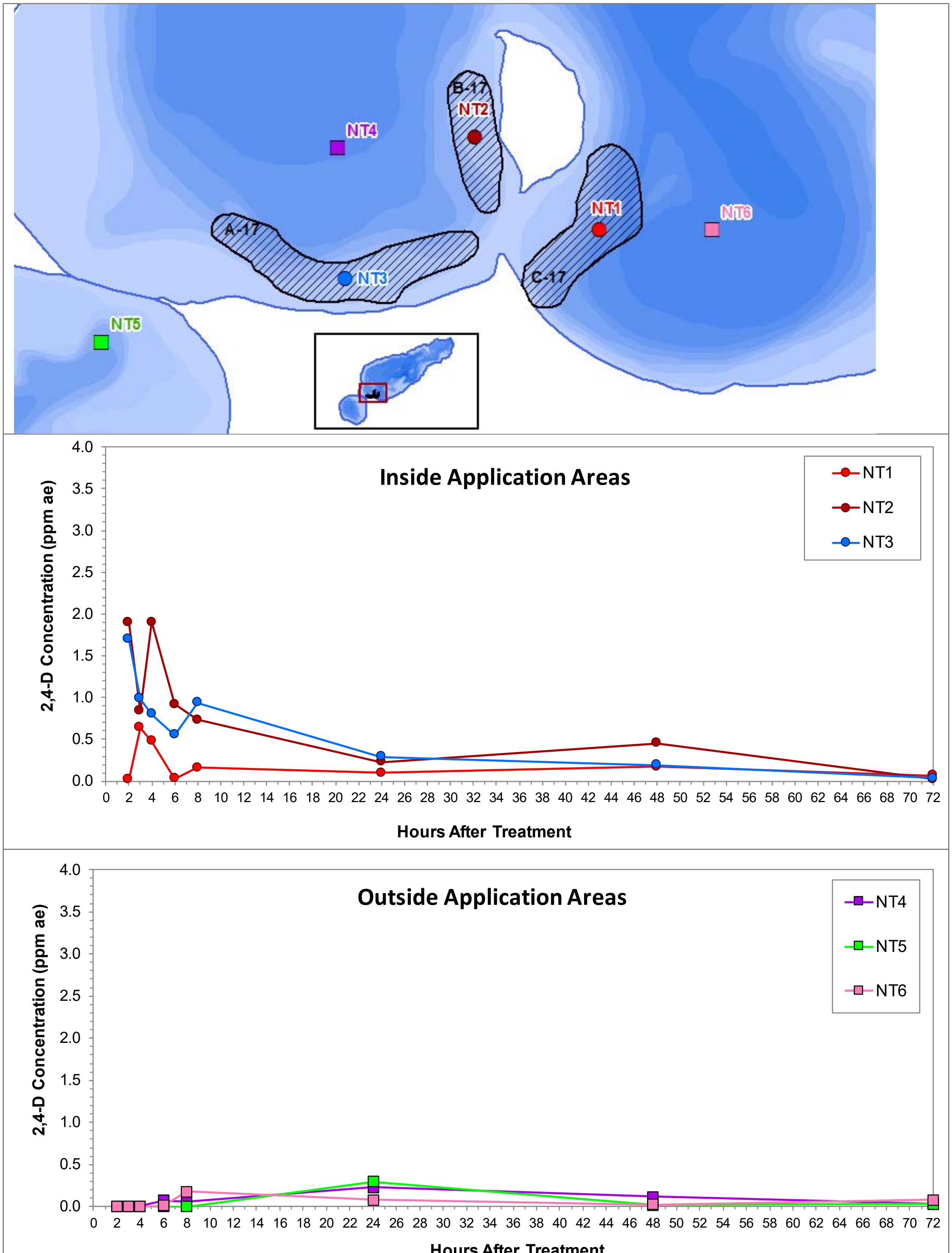


Figure 3.4-33. North Twin Lake herbicide concentration monitoring results.

The late-season EWM mapping survey indicate that large reductions in the EWM populations within the application areas was observed, however survivorship of EWM was documented (Figure 3.4-34). A point-intercept sub-sample survey was conducted over the three treatment areas. During the spring prior to treatment, 34.0% of sampling locations contained EWM (N=94). A 56.3% reduction was observed as only 14.9% of sampling locations contained EWM during the mid-September post treatment assessment (statistically valid - Chi-square $\alpha = 0.05$). The NSTLRA would have liked a greater reduction of EWM to have occurred following the spring 2017 treatment. It is unclear if complete rebound will occur in 2018, similar to the results of prior herbicide control actions in this part of the lake. The NSTLRA AIS Committee will not be pursuing active management of this area in 2018 in order to fully evaluate the 2017 spot treatment.

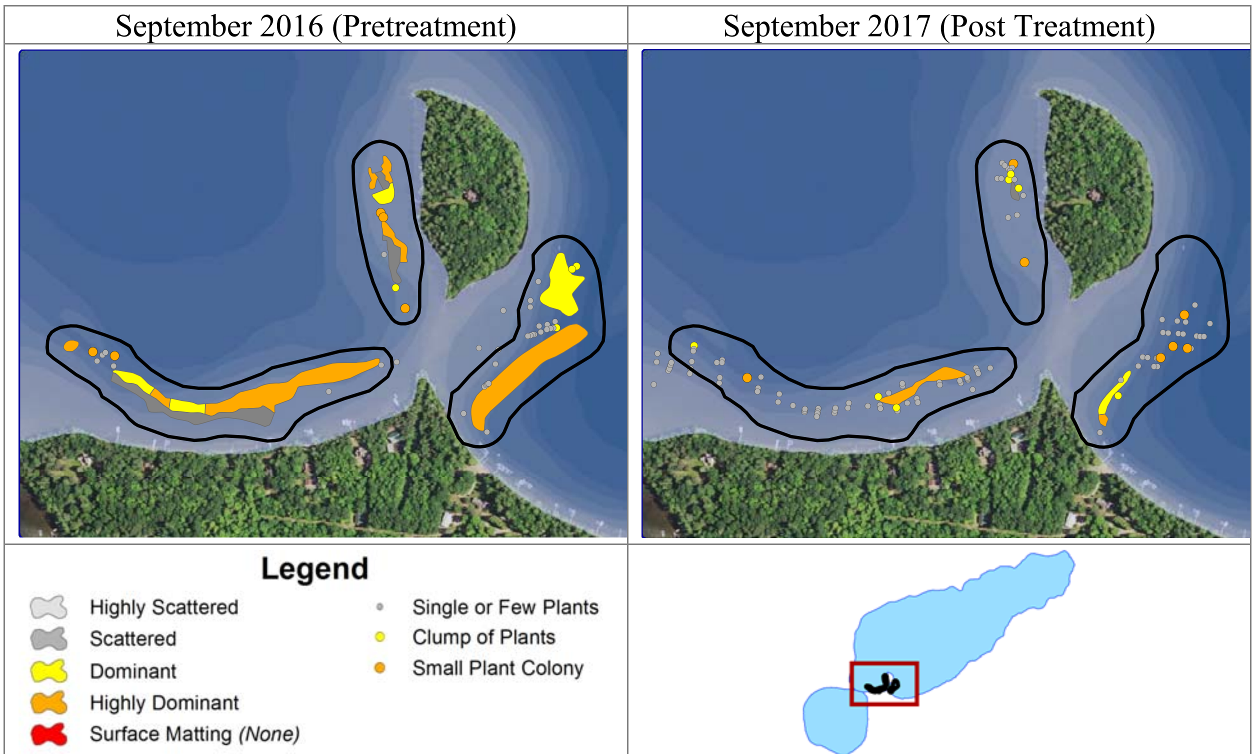


Figure 3.4-34. North Twin Lake herbicide concentration monitoring results.

During 2007 to 2013 when herbicide treatments took place on North Twin Lake, point-intercept sub-sampling took place to understand how the native and non-native plant population reacted to the control measures that took place. These data allow a historic understanding of the aquatic plant populations within this part of the lake (Figure 3.4-35) and are compared to the post treatment survey during the late summer of 2017.

Aside from EWM, coontail and flat-stemmed pondweed populations in 2017 were as low or lower than the range of frequencies during 2007-2013. Wild celery, slender naiad, and muskgrasses were all towards the highest range or higher during 2007 compared to the historic dataset. The other plant species were closer to the average population levels of the historic dataset.

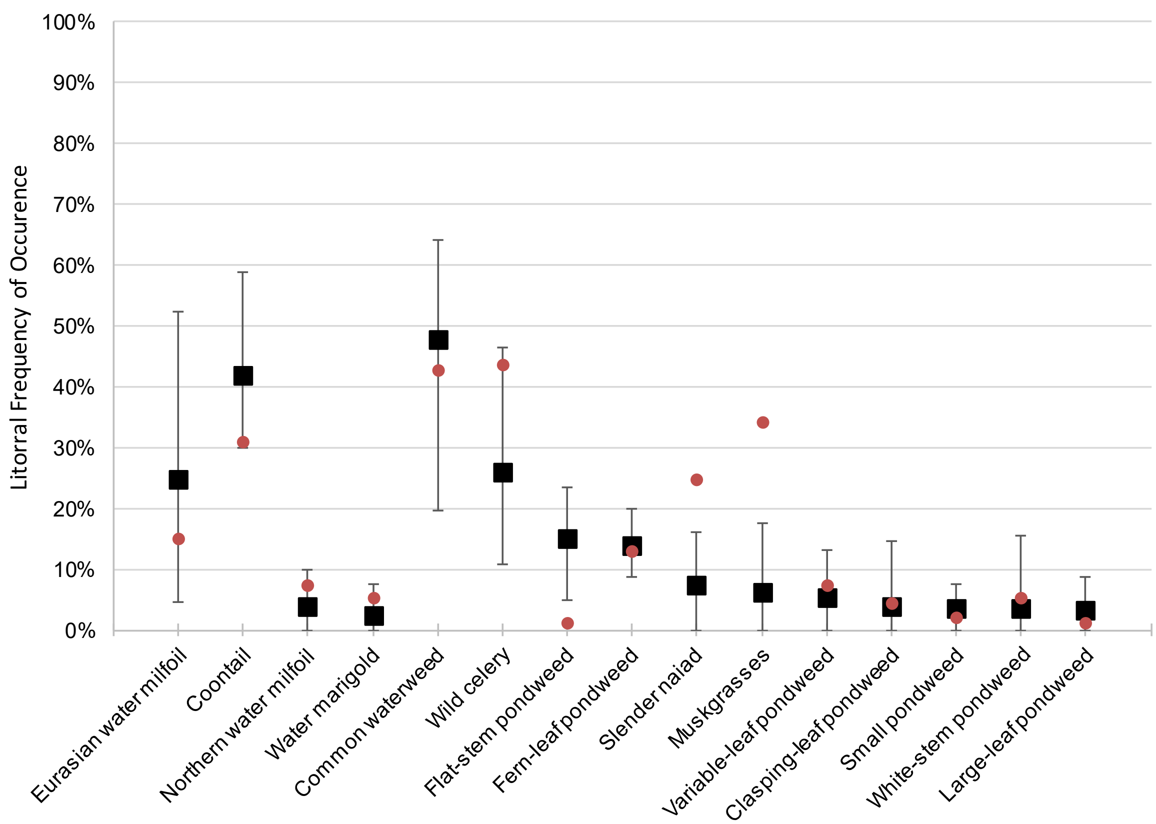


Figure 3.4-35. Historic average aquatic plant frequencies (2007-2013) compared to 2017 within 2017 treatment areas. Square symbol represents mean frequency of occurrence pooled from all sites from 2007-2013, error bars represent range of annual frequencies during the time period. Red circles represent 2017 post treatment plant frequencies.

As the EWM population within this part of North Twin Lake was reduced in 2017, other areas of the lake saw increases in the EWM population. Additional monitoring of the 2017 application areas in 2018 will allow an understanding of longer-term efficacy of the strategy to influence adaptive management strategies of the future on North Twin Lake.

Stakeholder Survey Responses to Aquatic Vegetation within the Twin Lakes

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 survey was approximately 40%. In instances where stakeholder survey response rates are 60% or above, the results can 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 population, the NSTLRA believe the sentiments of the stakeholder respondents is sufficient to provide a generalized indication of riparian preferences and concerns. Said another way, these are the best quantitative data the NSTLRA has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

The planning committee wanted to understand the stakeholders' perceptions on the use of various active management techniques (Figure 3.4-36). 68% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of responsibly using herbicides in the Twin Lakes, whereas 8% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). Similarly, 54% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of responsibly conducting hand-harvesting with divers, whereas 22% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). Only 3% of the stakeholder survey respondents were supportive of not managing the aquatic plants, but continued monitoring.

Question 25: What is your level of support for the responsible use of the following techiniques on the Twin Lakes?

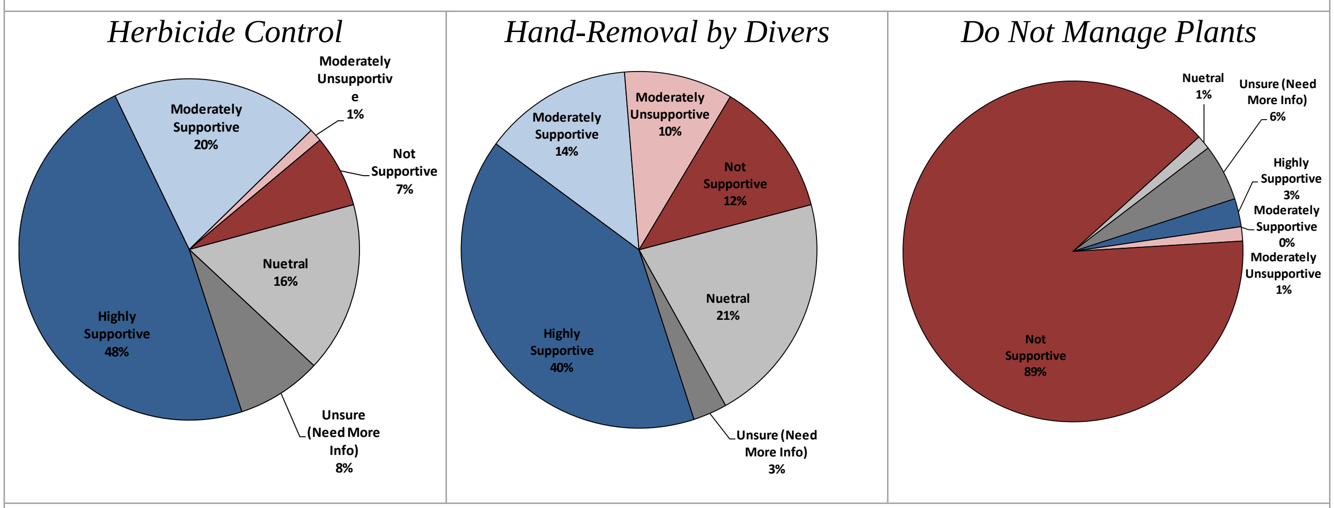


Figure 3.4-36. Select survey responses from the NSTLRA Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

A large-scale, whole-lake treatment of EWM occurred on South Twin Lake in 2016. Figure 3.4-37 displays the responses of the Twin Lakes Stakeholders and how they felt about the treatment that occurred in 2016. Approximately 70% of respondents indicated that they *completely support* the whole-lake treatment that occurred on South Twin Lake in 2016, 16% indicated they *moderately support* the treatment, 11% indicated they were *unsure/neutral*, 1% indicated they *moderately oppose* the treatment, and 2% indicated they *completely oppose* the treatment.

When asked what their level of support or opposition for future aquatic herbicide use to target EWM in the Twin Lakes was, the majority of respondents, 69%, indicated they *completely support* the future use, 19% indicated they *moderately support* future use, 7% indicated they were *unsure/neutral*, 3% indicated they *moderately oppose* future use, and 2% indicated they *completely oppose* the future use of aquatic herbicides (Figure 3.4-38). Almost all the respondents that indicated they either *moderately oppose* or *completely oppose* the future use of aquatic herbicides indicated their opposition is due to the potential impacts to native aquatic plant species, potential impacts to native species such as fish, insects, etc., and that the future impacts are unknown (Question 29, Appendix B).

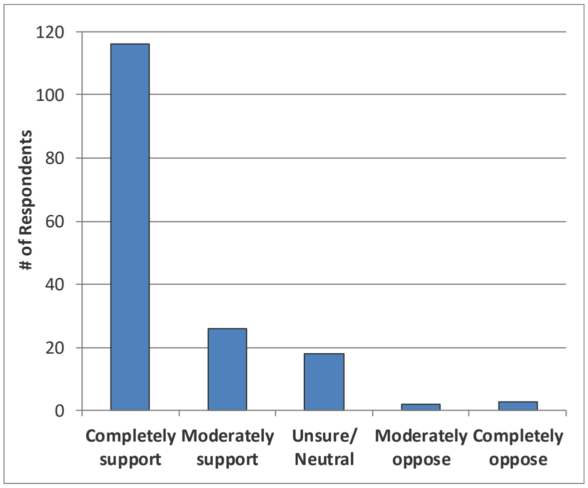


Figure 3.4-37. Stakeholder survey response Question #27. How do you feel about the large-scale treatment that occurred in 2016?

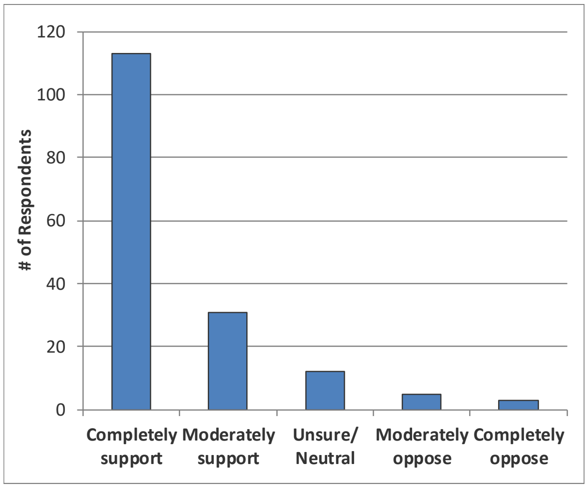


Figure 3.4-38. Stakeholder survey response Question #28. What is your level of support for future aquatic herbicide use to target Eurasian watermilfoil in the Twin Lakes?

Hand harvesting has been used to control EWM in the Twin Lakes. The Twin Lakes stakeholders were asked what their level of support or opposition for hand harvesting of EWM. The majority of respondents, 39%, indicated they *completely support* the use of hand harvesting to target EWM, 24% indicated they *moderately support* hand harvesting, 18% indicated they were *unsure/neutral*, 13% indicated they *moderately oppose* hand-harvesting, and 5% indicated they *completely oppose* hand harvesting (Figure 3.4-39). The majority of respondents that indicated they moderately oppose or completely oppose hand harvesting to target EWM indicated that they oppose it because of the potential to spread EWM and that it is not effective (Figure 3.4-40).

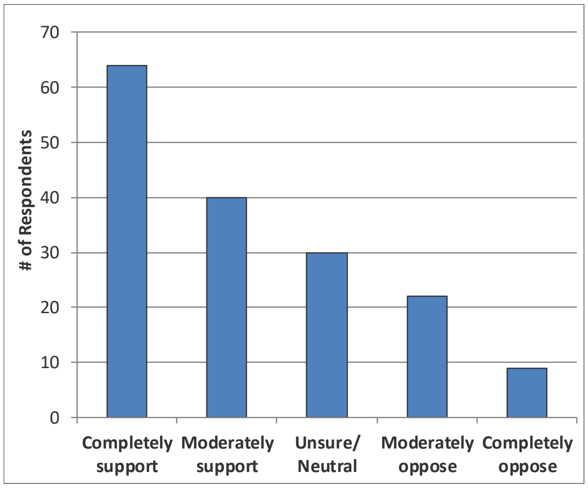


Figure 3.4-39. Stakeholder survey response Question #31. What is your level of support or opposition for hand harvesting/removal to target Eurasian watermilfoil in the Twin Lakes?

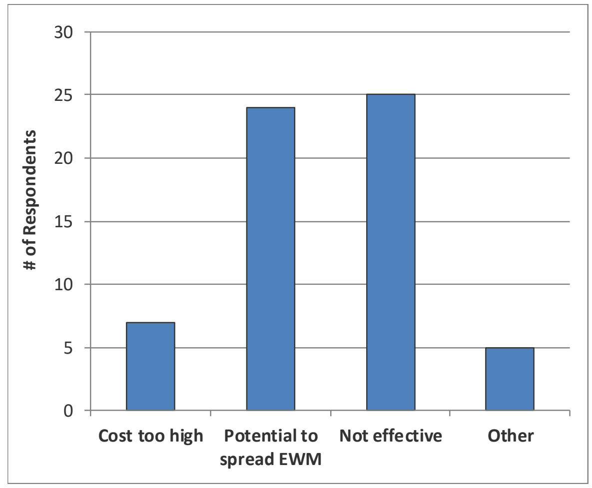


Figure 3.4-40. Stakeholder survey response Question #32. What is the reason or reasons you oppose the future use of hand harvesting/removal to target EWM in the Twin Lakes.

Developing a Large-Scale Herbicide Control and Monitoring Strategy

From an ecological perspective, large-scale treatments are those where the herbicide may be applied to specific sites, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water (of the lake, lake basin, or within the epilimnion of the lake or lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume. A recent article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lakewide low-concentration equilibriums were reached within the first few days after application." WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). As spot treatments approach 10% of a lake's area, they are more likely to have large-scale impacts, which is why the WDNR has this check mechanism within the permitting process.

Predicting success and native plant impacts from large-scale treatments is also better understood than for spot treatments. However, with any large-scale chemical treatment, both the positive and negative effects of this type of treatment strategy are anticipated to occur at a lakewide scale, whereas the impacts from spot treatments are mostly contained within and around the application sites.

Figure 3.4-41 includes the entirety of Onterra-monitored 2,4-D large-scale treatments in the Northern Lakes and Forests Ecoregion that have progressed to at least 1 year after treatment (YAT). Also included on this figure are two lakes that received large-scale 2,4-D treatments that were monitored by WDNR as part of the EWM Long-Term Trends project discussed above. Properly implemented large-scale herbicide treatments can be highly effective, with minimal EWM, often zero, being detected for a year or two following the treatment (Figure 3.4-41). Some large-scale treatments have been effective at reducing EWM populations for 5 or more years following the application, whereas others have rebounded sooner (i.e. South Twin '16, Sandbar '11).

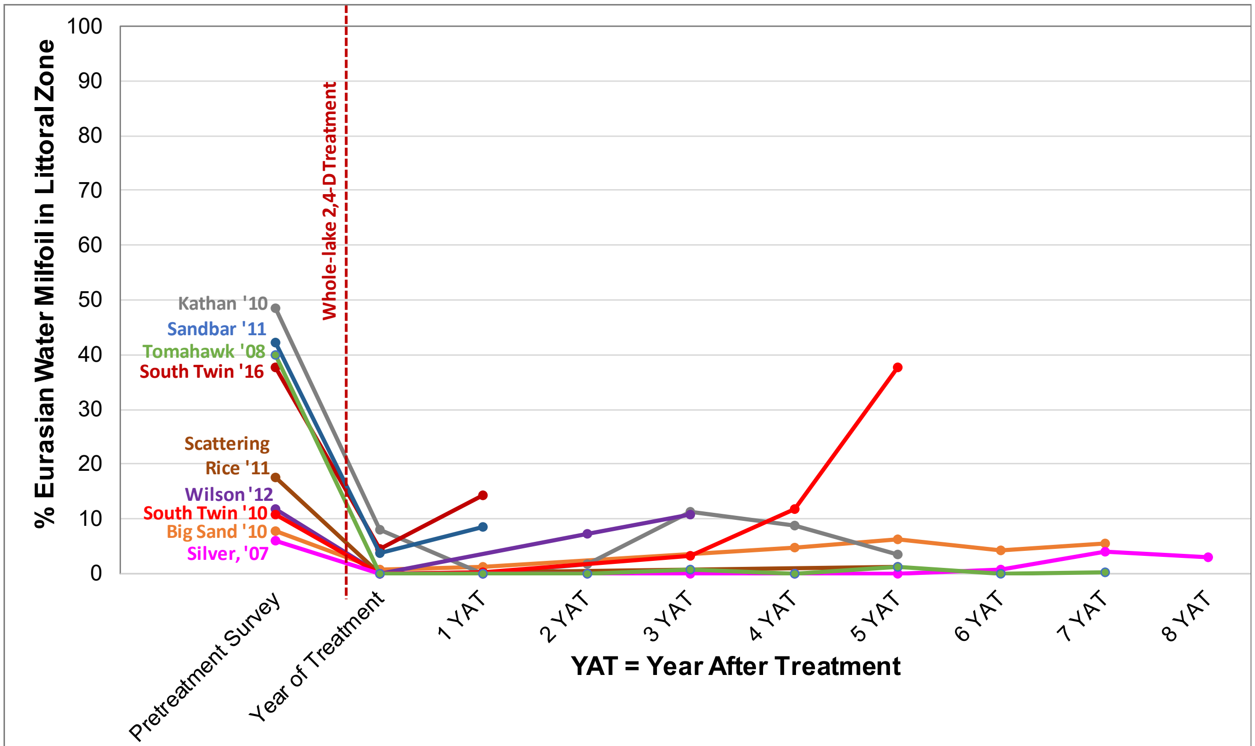


Figure 3.4-41. Littoral frequency of occurrence of EWM in lakes managed with large-scale 2,4-D treatments. South Twin '10 had treatment at 6 YAT, Kathan '10 had treatment at 6 YAT, Sandbar '11 had treatment at 2 YAT, Silver '07 had treatment at 9 YAT. All others are ongoing.

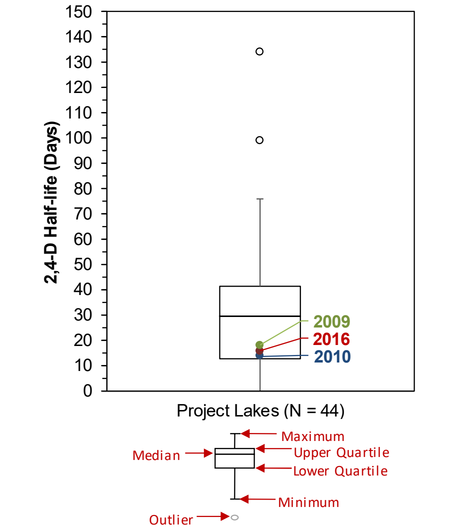


Figure 3.4-42. 2,4-D half-life of South Twin Lake project lakes compared with WDNR/Onterra database.

Lake manager's ability to predict lake-wide herbicide concentrations has improved but understanding the degradation period is not as apparent. In some cases, the biological breakdown of 2,4-D through microbial activity has been slower 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." Adding 16 additional Onterra-monitored projects to this dataset yields a mean 2,4-D half-life of approximately 29.5 days (Heath et al. 2018). Figure 3.4-42 shows that the 2,4-D half-lives of the 3 large-scale treatments on South Twin Lake are relatively low compared to other lakes within the current database.

At this time, Onterra and the committee believe that a large-scale liquid 2,4-D amine treatment would not likely meet their management goals (magnitude of reduction and length of time before subsequent large-scale management is required). This may be partially due to the quick degradation pattern that occurs in the lake or potentially a lowered susceptibility of the current EWM population to this active ingredient. Initially, the planning committee investigated a large-scale triclopyr treatment for their next large-scale control option. Triclopyr has a similar mode of action to 2,4-D, but is broken down via photolysis (exposure to sunlight) and therefore may have a longer degradation pattern that will lead to a more efficacious treatment. The NSTLRA AIS Committee is concerned that a large-scale triclopyr treatment will mimic the results of the 2016 2,4-D strategy, resulting in too short of control to balance the secondary impacts of the treatment.

While understood in terrestrial herbicide applications for years, tolerance evolution is an emerging topic amongst herbicide applicators, lake management planners, and researchers. Herbicide tolerance is when a plant population develops reduced susceptibility to an herbicide over time. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that re-populate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population. Concern exists that the past use-history of 2,4-D on South Twin Lake may have resulted in a population of more-tolerant EWM to auxin hormone mimic herbicides, which includes triclopyr. The NSTLRA Planning Committee does not believe the use of an auxin-mimic herbicide will be able to provide the magnitude nor length of control they are seeking.

The NSTLRA AIS Committee is resolved that the next step in EWM management on South Twin Lake is a large-scale pelletized fluridone treatment. This perspective was reached following independent research by members of the NSTLRA AIS Committee on fluridone. Onterra provided perspective of fluridone projects it has planned and monitored in Wisconsin, including providing the NSTLRA AIS Committee with two formal reports of pelletized fluridone treatments (Cloverleaf Lakes, Shawano County and [Big] Silver Lake, Waushara County). The NSTLRA also held discussions with their herbicide applicator (Clean Lakes) and held a conference call with the Senior Aquatics Technology Leader at SePRO (Dr. Mark Heilman).

Fluridone is a systematic herbicide that disrupts photosynthetic pathways (carotenoid synthesis inhibitor). This herbicide requires long exposure times (>90 days) to cause mortality to HWM. Herbicide concentrations within the lake are kept at target levels by periodically adding additional herbicide ("bump treatments") over the course of the summer based upon herbicide concentration monitoring results.

The use of fluridone has a checkered past in Wisconsin, as early implemented treatments (mid-2000s) resulted in native plant impacts that exceeded "acceptable levels" (Wagner et al. 2007). These collateral impacts are based upon liquid fluridone treatments, typically employed at 6 ppb with a bump treatment later in the summer to bring the concentration back up to 6 ppb. This fluridone use-pattern, commonly referred to as 6-bump-6, produces two relatively high herbicide pulses that taper off slowly as the herbicide degrades. Manufacturers of fluridone (SePRO) believe that the high herbicide pulses are the mechanism causing the native plant impacts. (Dr. Mark Heilman, personal comm.).

A somewhat newer use-pattern of fluridone uses a pelletized product that gradually reaches a peak concentration over time (extended release) and results in a lower, sustained lake-wide herbicide concentration (1.5 to 3 ppb). Within a few limited Wisconsin field-trials, this use-pattern of fluridone appears to provide a similar level of efficacy as the 6-bump-6 approach, but with a lower magnitude (but still notable) of native plant impacts (Heath et al. 2018).

Table 3.4-3 outlines the species present within South Twin and an analysis of each species' corresponding perceived susceptibility to fluridone. The "Liquid Case Studies" referenced are a large dataset of liquid fluridone field trials (many are 6-bump-6) compiled by the WDNR Science Services and made available in spreadsheet format. The two pelletized columns are case studies monitored by Onterra where a fluridone concentration of 1.5-3 ppb was maintained for the majority of the open as well as to have a purposeful and planned fluridone concentration above detectable levels (1 ppb) being within the lake at the end of the open water season. Because fluridone degrades via photolysis (ie sunlight), only limited degradation occurs over the winter and measurable fluridone concentrations were observed in two of the three waterbodies the following spring after ice-out.

Table 3.4-3. Aquatic plant species list and potential sensitivity to differing fluridone use-patterns.

			Fluridone Sensitivity		
Scientific Name	**Common Name**	**2017 LFOO**	**Liquid Case Studies***	**Pelletized Cloverleaf****	**Pelletized Big Silver****
Vallisneria americana	Wild celery	*45.0*	↓ to X	↓ to X	X
Potamogeton gramineus	Variable-leaf pondweed	*44.3*	↓ to X to ↑	X	↓
Najas flexilis	Slender naiad	*40.7*	↓ to X	↓	↓
Chara spp.	Muskgrasses	*40.7*	↓ to X to ↑	X	X
Elodea canadensis	Common waterweed	*34.5*	↓ to X	X	↓
Potamogeton robbinsii	Fern-leaf pondweed	*25.7*	X to ↑	-	-
Potamogeton richardsonii	Clasping-leaf pondweed	*21.5*	↓ to X	↑	-
Ceratophyllum demersum	Coontail	*18.6*	↓ to X	X	-
Myriophyllum spicatum	Eurasian watermilfoil	*14.3*	↓	↓	↓
Heteranthera dubia	Water stargrass	*11.7*	X to ↑	-	↑
Potamogeton zosteriformis	Flat-stem pondweed	*10.4*	↓ to X to ↑	X	↑
Isoetes spp.	Quillwort spp.	*10.4*	X	-	-
Potamogeton praelongus	White-stem pondweed	*9.8*	↓ to X	X	↓
Nitella spp.	Stoneworts	*7.5*	↓ to X to ↑	X	↓
Myriophyllum alterniflorum	Alternate-flowered watermilfoil	*5.9*	-	-	-
Eleocharis acicularis	Needle spikerush	*5.2*	-	-	-
Myriophyllum sibiricum	Northern watermilfoil	*4.2*	↓	-	-
Potamogeton amplifolius	Large-leaf pondweed	*2.3*	↓ to X to ↑	-	-
Potamogeton pusillus	Small pondweed	*2.0*	↓ to X	-	X
Bidens beckii	Water marigold	*2.0*	↓ to X	-	-
Schoenoplectus acutus	Hardstem bulrush	*1.6*	-	-	-
Ranunculus aquatilis	White water crowfoot	*0.7*	↓ to X	-	-
Potamogeton strictifolius	Stiff pondweed	*0.7*	-	↑	-

LFOO = littoral frequency of occurrence.
↓↑ = statistically valid declines/increases observed. X = population remains statically unchanged. - = no data availible.
* Fluridone sensitivity from Wagner KI, WDNR Science Services, 2006, unpubl.
** Fluridone sensitivity from Onterra case studies, 2017

Within the Onterra-monitored fluridone case studies, hybrid EWM populations were reduced to zero (or almost zero) in all instances during the year after treatment (surveys not conducted the year of treatment as the lake is still actively being treated). The analysis presented in Table 3.4-3 suggests that some plant species, such as common waterweed and slender naiad are particularly sensitive to fluridone, regardless of the fluridone formulation or concentration. Other species may be less impacted by the lower concentrations of a pelletized formulation, but it is also important to note that this is a very limited dataset to draw conclusions from.

Maintaining sufficient fluridone concentrations within South Twin Lake will be influenced by the herbicide degradation (breaks down from sunlight) and dissipation out of the system. North Twin flows into South Twin, so herbicide loss upstream into North Twin Lake is going to be negligible. During the 2010 large-scale 2,4-D treatment of South Twin Lake, an herbicide concentration sampling site was located in just inside of North Twin Lake. The results of the monitoring indicated that "2,4-D did not dissipate from South Twin Lake to North Twin Lake" (Skogerboe 2010). So apart from herbicide degradation, water exchange out of South Twin Lake through the Twin Lakes Dam needs to be understood.

According to the watershed modeling (Section 3.2), South Twin Lake's water is completely replaced on average once per year. This modeling looks at historic precipitation in the watershed and the type of landcovers in the watershed. Figure 3.4-43 shows that last decade (2007-2017) of mean monthly discharge quantities from the Twin Lake dam as it relates to the epilimnetic volume and whole-lake volume of South Twin Lake. These data corroborate with the modeling data, that the lake is completely flushed approximately 1.2 times per year, or has a water retention time of 442 days. The mean water exchange from the beginning of May through the end of October, which corresponds with the time period where fluridone concentrations would be maintained between 1.5 and 3 ppb, water residence time within South Twin Lake is approximately 875 days based on the whole-lake volume. However, during the summer months, a system like South Twin Lake likely only exchanges its epilimnetic volume when stratified. According to the mean discharge rates from May-October, the epilimnetic residence time would be approximately 520 days.

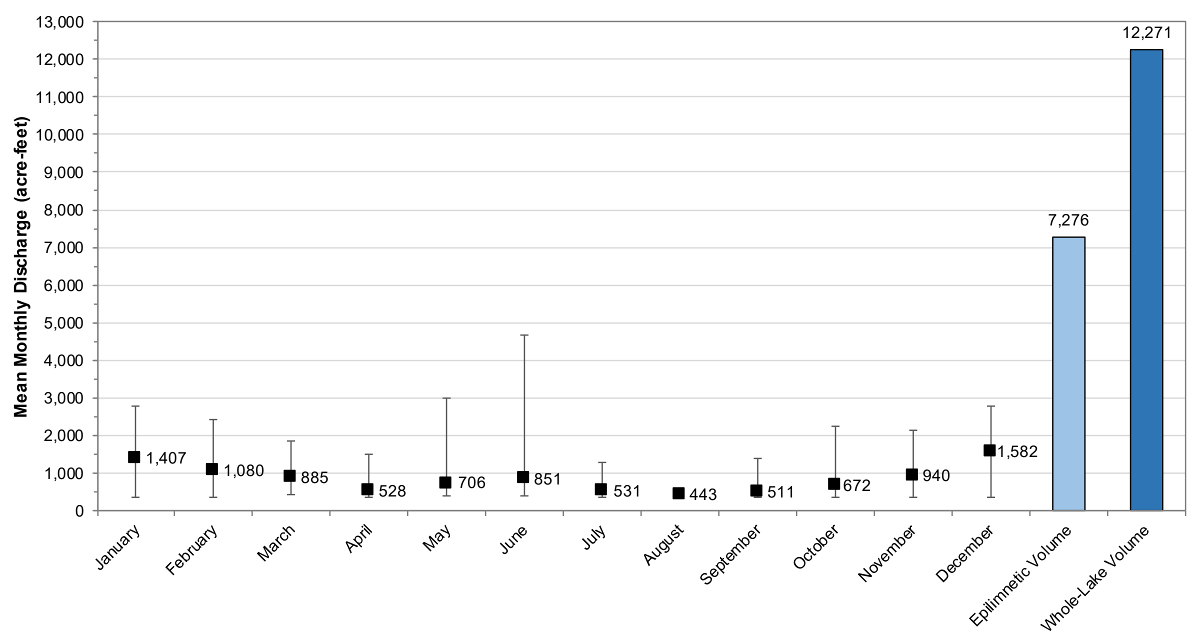


Figure 3.4-43. Twin Lakes dam water discharge and South Twin Lake water volumes. Error bars represent minimum and maximums. Data provided by WVIC.

Within the Onterra pelletized case studies discussed above, Big Silver Lake (Waushara County) is a seepage lake (no inlet or outlet) and the Cloverleaf Lakes are spring lakes with an outlet. Based on the watershed modeling of the Cloverleaf Lakes, the water retention time is about 445 days. This system was able to maintain fluridone concentrations in 2016 similar to Big Silver Lake without requiring larger or more frequent bumps. Actually, the second bump treatment was only 1 ppb on one of the Cloverleaf Lakes whereas Big Silver conducted a 2 ppb bump at the beginning of September.

The use of any aquatic herbicide poses environmental risks to non-target plants and aquatic organisms. The majority of available toxicity data has been conducted as part of the EPA product registration process. These laboratory studies are attempted to mimic field settings, but can underestimate or overestimate the actual risk (Fairbrother and Kapustka 1996). Federal and state pesticide regulations and strict application guidelines are in place to minimize impacts to non-target organisms based on the organismal studies. The use of aquatic herbicides includes regulatory oversight and must comply with the following list. Additional information from the WDNR on aquatic herbicide regulation is included within Appendix F along with the WDNR's fluridone fact sheet. Appendix F also includes additional toxicological perspective from the herbicide manufacturer (SePRO).

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Applied by a DATCP-certified and licensed applicator,

According to EPA product registration, fluridone does not appear to have any short-term or long-term impacts to fish, invertebrates, or birds at labeled rates. Toxicity studies on early life stages of walleye, smallmouth bass, and largemouth have documented minimum lethal concentrations much greater than approved use rates (1,800-13,000 ppb). Hamelink et al. 1986 assessed the impacts of technical grade fluridone (98-99% active ingredient) and a commercial formulation (48% active ingredient; 52% inert) on several invertebrate (amphipods, midge larvae, crayfish) and fish species (fathead minnow, channel catfish), concluding that fluridone does not have adverse impacts to non-target aquatic organisms at labeled use rates. However, Yi et al. 2011 conducted toxicity studies on male water mites that potentially have a more vulnerable life cycle than other aquatic invertebrates, using a commercially available liquid formulation of fluridone (Sonar®AS). Their results indicated the commercially available liquid formulation was 60-fold more toxic than the technical grade, with impacts observed as low as 10 ppb. This suggests that the inert ingredients themselves may be the cause of the increased toxicity. The inert components of liquid fluridone and pelletized fluridone are different, and are outlined within Q16 of SePRO's information included within Appendix F.

The EPA-approved maximum application rate for the pelletized fluridone product being considered (Sonar®One) is 150 ppb. At these rates, there are no restrictions on swimming, fish consumption, or pet/livestock drinking water. There are irrigation restrictions such that specific plants, such as tomatoes and peppers, should not be watered with concentrations above 5 ppb for concerns of herbicidal impacts. The fluridone use pattern being considered for South Twin is between 1.5 and 3 ppb.

3.5 Aquatic Invasive Species in the Twin Lakes

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in the Twin Lakes within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are four AIS present (Table 3.5-1).

Table 3.5-1. AIS present within the Twin Lakes

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.5 – Aquatic Invasive Species
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 – Aquatic Invasive Species
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 – Aquatic Invasive Species

Figure 3.5-1 displays the 14 aquatic invasive species that the Twin Lakes stakeholders believe are in the lakes. Only the species present in the lakes are discussed below or within their respective locations listed in Table 3.5-1. 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. Of the 10 stakeholders that selected "other," 8 referred to swimmer's itch. Swimmer's itch is a native species and is specifically discussed within the implementation plan. More information on invasive species can be found at the following links:

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

Aquatic Animals

Mystery snails

There are two types of mystery snails found within Wisconsin waters, 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 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).

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. 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.

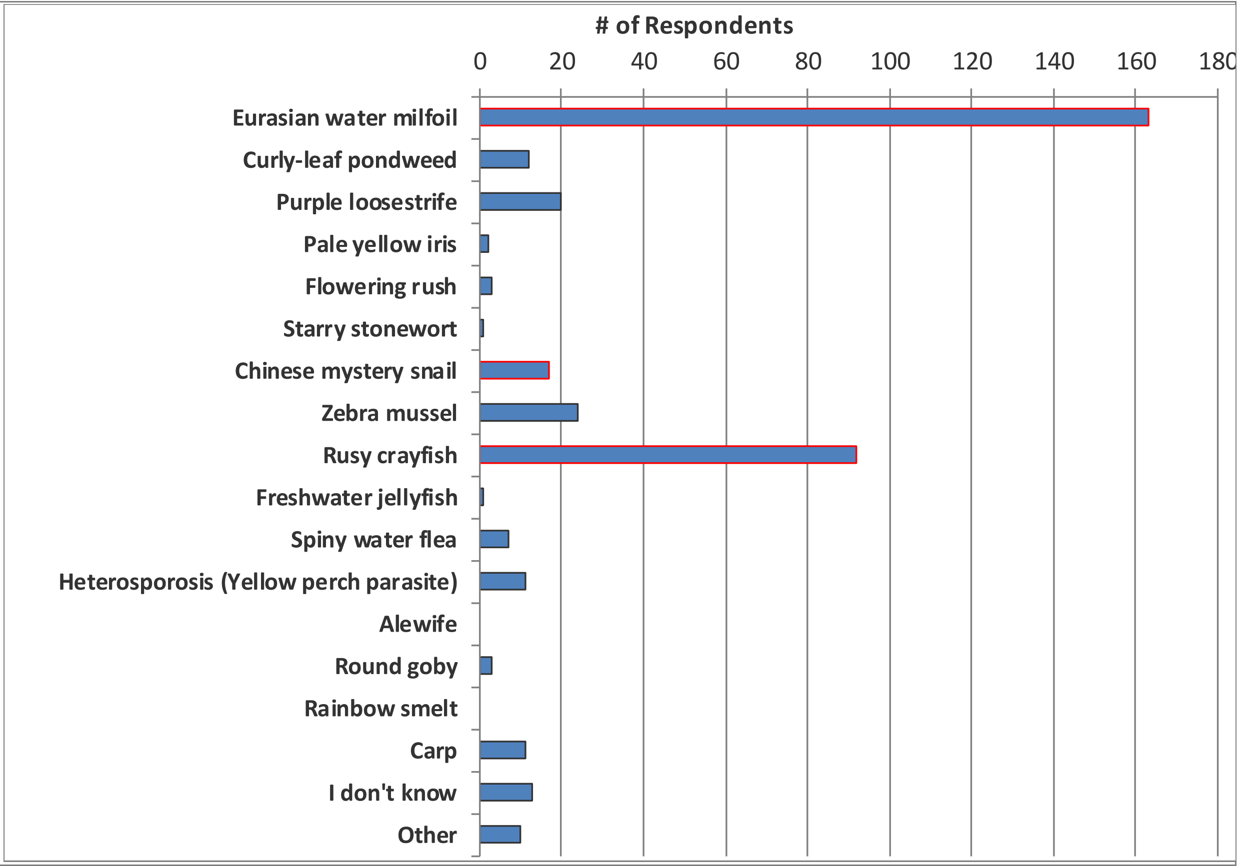


Figure 3.5-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in your lake? Bars outlined in red are species confirmed to be present in the Twin Lakes.

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a 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 North and South Twin Lake. The goal of this section is to provide an overview 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), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Steve Gilbert and Hadley Boehm (WDNR 2017 & GLIFWC 2016).

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest 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 3.6-1.

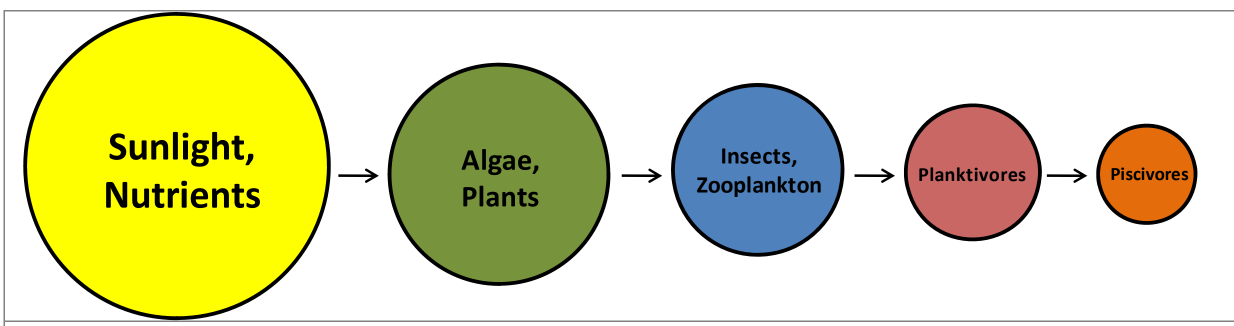


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, North and South Twin Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means North and South Twin Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system. Additional fish species present in the Twin Lakes include: Rock Bass (*Ambloplites rupestris*), Burbot (*Lota lota*), Golden Shiner (*Notemigonus crysoleucas*), Common Shiner (*Luxilus cornutus*) Logperch (*Percina caprodes*), Bluntnose Minnow (*Pimephales promelas*), Mimic Shiner (*Notropis volucellus*) and Mottled Sculpin (*Cottus bairdi*).

Table 3.6-1. Gamefish present in North and South Twin Lakes with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, othe invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Cisco (*Coregonus artedii*)	22	Late November - Early December	Various shoreline substrates.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates.
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, smal mammals, shore birds, frogs
Orangespotted Sunfish (*Lepomis humilis*)	4	Late May - August	Shallow water with sand or gravel bottom	Crustaceans, copepods, mites and aquatic insects
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)
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
White Crappie (*Pomoxis annularis*)	13	May - June	Within 10 m from shore, over hard clay, gravel, or roots	Crustaceans, insects, small fish
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 passive trap commonly used is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and 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 and sort the fish that were captured.

The other commonly used sampling method is electroshocking (Photo 3.6-1). 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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes.

Once fish are captured using the appropriate method, data such as count, species, length, weight, sex, tag number, and aging structures may be recorded or collected and the fish is released. Fisheries biologists use this data to make recommendations and informed decisions on managing the future of the fishery.

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

Fish Stocking

Photograph 3.6-2. Fingerling Muskellunge.

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking of 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. North and South Twin Lake has been stocked between 1933 and 1999 with walleye and muskellunge. Stocking efforts discontinued after 1999 because natural reproduction was occurring (Steve Gilbert, personal communication). Historical stocking activities from 1933 to 1999 are displayed in Tables 3.6-2-5.

Table 3.6-2. Stocking data available for muskellunge in North and South Twin Lakes (1933-1976).

Waterbody	Year	Age Class	# Fish Stocked	Avg Fish Length (in)
North Twin	1933	Fingerling	145	Unspecified
North Twin	1937	Fry	64,500	Unspecified
North Twin	1937	Fingerling	64	Unspecified
North Twin	1938	Fry	40,000	Unspecified
North Twin	1938	Fingerling	76	Unspecified
North Twin	1938	adult	2	Unspecified
North Twin	1939	Fingerling	25	Unspecified
North Twin	1942	Fry	25,000	Unspecified
North Twin	1942	Fingerling	1,750	Unspecified
South Twin	1942	Fry	25,000	Unspecified
South Twin	1942	Fingerling	100	Unspecified
North Twin	1943	Fingerling	150	Unspecified
North Twin	1944	Fingerling	500	Unspecified
North Twin	1945	Fingerling	389	Unspecified
South Twin	1946	Fingerling	900	2 to 5
North Twin	1949	Yearling	250	Unspecified
North Twin	1949	Adult	60	Unspecified
South Twin	1951	Fingerling	1,800	Unspecified
South Twin	1953	Fingerling	910	Unspecified
North Twin	1954	Fingerling	2,836	Unspecified
South Twin	1955	Fingerling	454	Unspecified
North Twin	1956	Fingerling	50	Unspecified
South Twin	1956	Fingerling	30	Unspecified
North Twin	1957	Fingerling	6,170	Unspecified
South Twin	1957	Fingerling	1,000	Unspecified
North Twin	1959	Fingerling	823	Unspecified
South Twin	1959	Fingerling	200	Unspecified
North Twin	1960	Fingerling	5,810	Unspecified
South Twin	1960	Fingerling	900	Unspecified
North Twin	1963	Fingerling	400	Unspecified
North Twin	1964	Fingerling	6,809	Unspecified
North Twin	1966	Fingerling	2,940	Unspecified
South Twin	1967	Fingerling	613	Unspecified
North Twin	1968	Fingerling	3,100	Unspecified
South Twin	1968	Fingerling	600	Unspecified
South Twin	1971	Fingerling	569	Unspecified
North Twin	1972	Fingerling	1,604	13
South Twin	1972	Fingerling	1,000	13
North Twin	1974	Fingerling	2,900	9
South Twin	1974	Fingerling	944	11
North Twin	1976	Fingerling	1,184	11
South Twin	1976	Fingerling	848	11

Table 3.6-3. Stocking data available for muskellunge in North and South Twin Lakes (1977-1995).

Waterbody	Year	Age Class	# Fish Stocked	Avg Fish Length (in)
North Twin	1977	Fingerling	14,518	3
South Twin	1977	Fingerling	1,717	3
North Twin	1979	Fingerling	2,500	8
North Twin	1981	Fingerling	993	11
South Twin	1981	Fingerling	600	12
North Twin	1982	Fingerling	2,320	12
South Twin	1984	Fingerling	500	11
North Twin	1985	Fingerling	2,500	11
North Twin	1986	Fingerling	2,500	12
North Twin	1987	Fingerling	7,500	12
North Twin	1988	Fingerling	2,484	10
North Twin	1989	Fingerling	2,000	11
North Twin	1989	Fry	10,800	3
North Twin	1993	Fry	37,800	0.4
North Twin	1995	Fry	80,000	0.4

Table 3.6-4. Stocking data available for walleye in North and South Twin Lakes (1933-1961).

Waterbody	Year	Age Class	# Fish Stocked	Avg Fish Length (in)
North Twin	1933	Fingerling	25,000	Unspecified
North Twin	1933	Fry	2,000,000	Unspecified
North Twin	1933	Fry	76,454	Unspecified
North Twin	1934		86,142	Unspecified
South Twin	1934		172,884	Unspecified
North Twin	1937	Fry	3,019,500	Unspecified
North Twin	1938	Fry	5,000,000	Unspecified
North Twin	1939	Fry	3,019,500	Unspecified
North Twin	1940	Fry	1,000,000	Unspecified
North Twin	1942	Fry	2,000,000	Unspecified
South Twin	1942	Fry	400,000	Unspecified
North Twin	1943	Fry	1,648,000	Unspecified
North Twin	1943	Fingerling	4,000	3 to 5
South Twin	1943	Fry	327,000	Unspecified
South Twin	1943	Fingerling	3,000	2 to 5
North Twin	1944	Fry	1,500,000	Unspecified
North Twin	1944	Fingerling	5,091	Unspecified
South Twin	1952	Fingerling	6,890	Unspecified
South Twin	1954	Fingerling	6,300	Unspecified
North Twin	1955	Fry	4,521,256	Unspecified
North Twin	1955	Fingerling	10,000	Unspecified
North Twin	1958	Fingerling	20,000	Unspecified
South Twin	1958	Fingerling	12,000	Unspecified
North Twin	1961	Fingerling	29,340	Unspecified
South Twin	1961	Fingerling	6,300	Unspecified

Table 3.6-5. Stocking data available for walleye in North and South Twin Lakes (1962-1999).

Waterbody	Year	Age Class	# Fish Stocked	Avg Fish Length (in)
North Twin	1962	Fingerling	28,360	Unspecified
North Twin	1965	Fingerling	50,745	Unspecified
North Twin	1965	Fry	3,000,000	Unspecified
North Twin	1967	Fingerling	24,306	Unspecified
North Twin	1968	Fry	2,000,000	Unspecified
North Twin	1969	Fry	3,000,000	Unspecified
South Twin	1969	Fingerling	10,000	Unspecified
North Twin	1970	Fingerling	34,615	5
South Twin	1970	Fingerling	8,000	Unspecified
North Twin	1971	Fry	50,000	Unspecified
North Twin	1971	Fry	4,600,000	Unspecified
North Twin	1973	Fingerling	7,480	Unspecified
North Twin	1974	Fingerling	10,800	3
South Twin	1974	Fingerling	10,914	Unspecified
North Twin	1975	Fingerling	52,250	3
North Twin	1976	Fingerling	47,500	3
South Twin	1976	Fingerling	31,000	3
North Twin	1980	Fry	5,440,000	Unspecified
North Twin	1981	Fingerling	50,585	3
North Twin	1981	Fry	1,600,000	Unspecified
North Twin	1982	Fingerling	35,560	3
North Twin	1982	Fry	1,300,000	Unspecified
North Twin	1983	Fingerling	23,000	2
North Twin	1984	Fingerling	25,000	2
North Twin	1984	Fry	1,450,000	1
North Twin	1985	Fingerling	25,000	3
North Twin	1986	Fingerling	25,000	2
North Twin	1986	Fry	2,420,000	1
North Twin	1987	Fingerling	75,000	3
North Twin	1987	Fry	348,000	2
North Twin	1988	Fingerling	25,000	2
North Twin	1989	Fingerling	25,200	1
North Twin	1989	Fry	752,000	3
North Twin	1990	Fingerling	25,200	3
North Twin	1990	Fry	180,000	1
North Twin	1991	Fingerling	25,137	3
North Twin	1991	Fry	2,000,000	0
North Twin	1992	Fingerling	22,040	3
North Twin	1992	Fry	470,500	0
North Twin	1993	Fingerling	25,012	2
North Twin	1993	Fry	300,000	0.2
North Twin	1994	Fingerling	25,002	2
North Twin	1994	Fry	50,000	0.2
North Twin	1995	Fingerling	25,440	2.1
North Twin	1998	Small Fingerling	25,000	1.5
North Twin	1999	Small Fingerling	25,043	1.7

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can 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. The following summaries of gamefish and panfish are largely based off the 2017 fisheries report by the WDNR.

Gamefish

Walleye populations have been estimated periodically in the Twin Lakes based on WDNR or GLIFWC led surveys (Tables 3.6-6 & 3.6-7). The most recent population estimate based on a WDNR spring 2017 mark and recapture survey was 12,814 adult fish or 3.7 walleye per acre. Walleye populations are sustained through natural reproduction in the Twin Lakes (WDNR 2017).

Table 3.6-6. Twin Lakes WDNR Adult Walleye Population Estimates

Waterbody	Year	Primary Recruitment Source	Population Estimate	Lower 95 C.I.	Number / Acre	# Adults <12 Inches / Acre	# Adults 12-15 Inches / Acre	# Adults 15-20 Inches / Acre	# Adults >2(Inches / Acr
Twin Lake, South	1991	Stocked	27	8	0.0	0.0	0.0	0.0	0.0
North Twin Lake	1991	Natural	6,310	5,519	2.3	0.1	1.4	0.6	0.1
North Twin Lake	1996	Natural	14,121	7,586	4.1	0.1	2.6	1.9	0.5
North & South Twin	2007	Natural	10,430	9,219	3	0.2	2.5	0.2	0
North & South Twin	2017	Natural	12,814		3.7				

Table 3.6-7. Twin Lakes GLIFWC Adult Walleye Population Estimates

Lake	Year	Season	Walleye Code	Population Estimate	Density	Coefficient of variation (5)	Male:female ratio
Twin L Chain	2013	Spring	NR	13,441	3.92	4.79	15:01

Smallmouth bass were captured at too low quantities during the spring 2017 surveys to produce a population estimate. Of the adult smallmouth bass captured during the spring survey, 75% were 14 inches long or larger (WDNR 2017).

Largemouth bass were also captured at too low quantities during the spring 2017 surveys to produce a population estimate.

Northern Pike were captured in low quantities during the WDNR spring 2017 survey. Five adult fish were captured of which the largest was a 33.7 inch female.

Muskellunge were targeted during the spring 2017 surveys and of the 85 adult fish captured, 30 were 40” or longer. A re-capture survey is scheduled for 2018 from which a muskellunge population estimate will be made.

Panfish

Yellow perch, **Rock bass and White suckers** were commonly captured during the 2017 spring netting and electroshocking surveys. Other panfish captured in the spring 2017 surveys included black crappie, bluegill, and pumpkinseed.

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second most important reason for owning property on or near North and South Twin Lakes. Figure 3.6-2 displays the fish that stakeholders enjoy catching the most, with walleye, yellow perch and muskellunge being the most popular. Approximately 80% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 90% of respondents who fish North and South Twin Lake believe the quality of fishing has remained the same or gotten worse since they first started fishing the lakes (Figure 3.6-4).

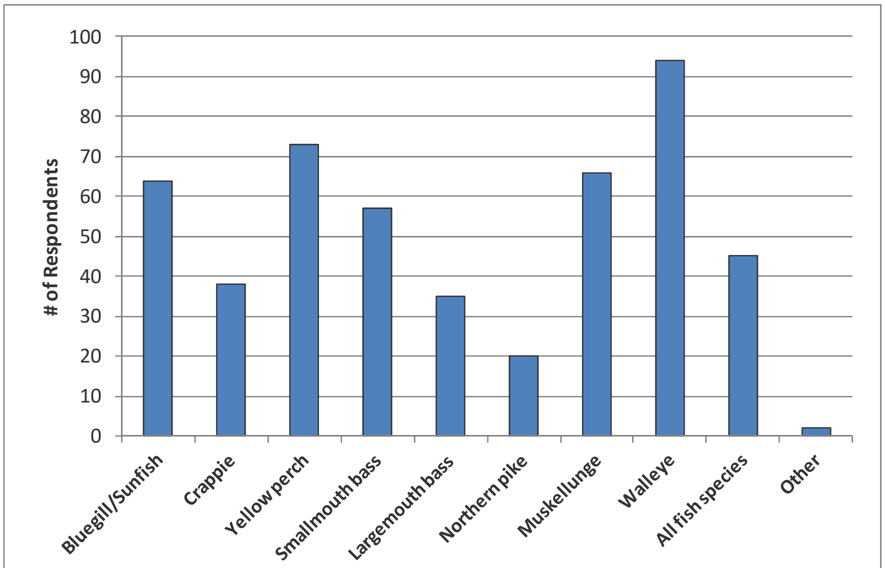


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on North and South Twin Lake?

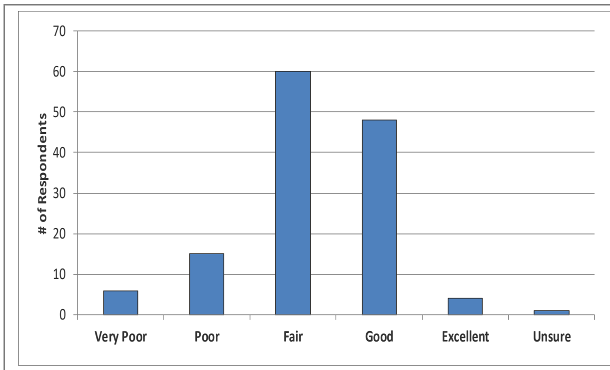


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on your lake?

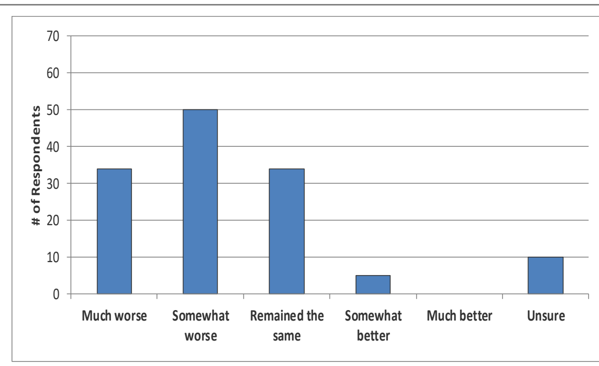


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed since you have started fishing the lake?

Creel surveys have occurred at the Twin Lakes periodically to assess the impact of sport anglers on the fishery. A creel clerk visits lakes to count the number of anglers on the lake and collects information relating to the anglers' targeted species, effort, catch and harvest. Fisheries managers use the information obtained through creel surveys to determine trends in catch and harvest for a particular species. Available creel survey data is displayed in Table 3.6-8. Creel surveys were conducted during the 2017 open-water fishing season and will continue into the winter of 2017-2018.

Table 3.6-8. Twin Lakes WDNR Creel Survey Results.

Species	Year	Directed Effort (Hours)	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort Fish Harvestec
Largemouth Bass	1991	-	43	0	43	0.1	43.0	0.1	-	-
	1996-97	199	-	0.1	254	0.1	27	0	0	0
	2007-08	902	27.4	0.3	561	0.2	20	0.01	6.6	44.6
Muskellunge	1991	-	43	25	453	0.7	0	0	36.5	-
	1996-97	45549	-	13.3	1758	0.5	14	0	27.9	3333
	2007-08	31466	27.4	9.2	592	0.2	26	0.01	57.1	1208.8
Northern Pike		-	43	0.7	20	0	20	0	-	-
	1996-97	0	-	0	23	0.01	23	0.01	0	0
	2007-08	4121	27.4	1.2	2214	0.6	880.00	0.30	5.9	10
Smallmouth Bass	1991	-	43	0.2	23	0	0	0	-	-
	1996-97	520	-	0.2	901	0.3	0	0	0	0
	2007-08	1661	27.4	0.5	497	0.1	12	0	9.1	100
Walleye	1991	-	43	9.6	190	0.3	57	0.1	32.4	107.5
	1996-97	22765	-	6.6	8824	2.6	2357	0.7	2.6	9.8
	2007-08	44278	27.4	12.9	22052	6.4	3802	1.1	2	11.1

North and South Twin Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-5). North and South Twin Lakes fall within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more

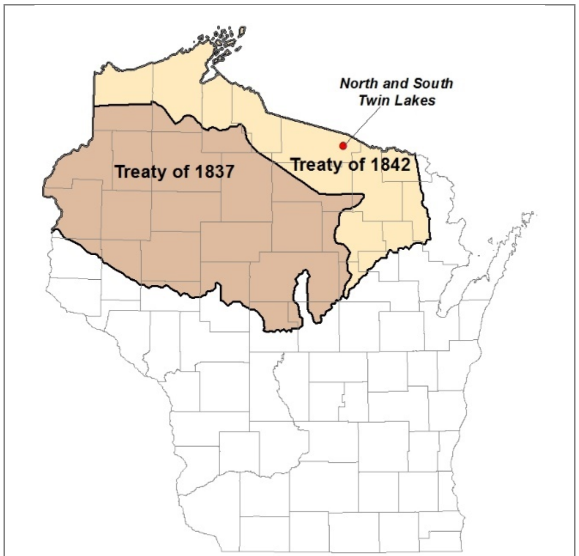


Figure 3.6-5. Location of North and South Twin Lakes within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009).

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.6-6 from 1999 to 2016. As many as 1,485 walleye have been harvested from the lake in the past (2014), but the average harvest is roughly 730 fish in a given year. Spear harvesters on average have taken 89% of the declared quota.

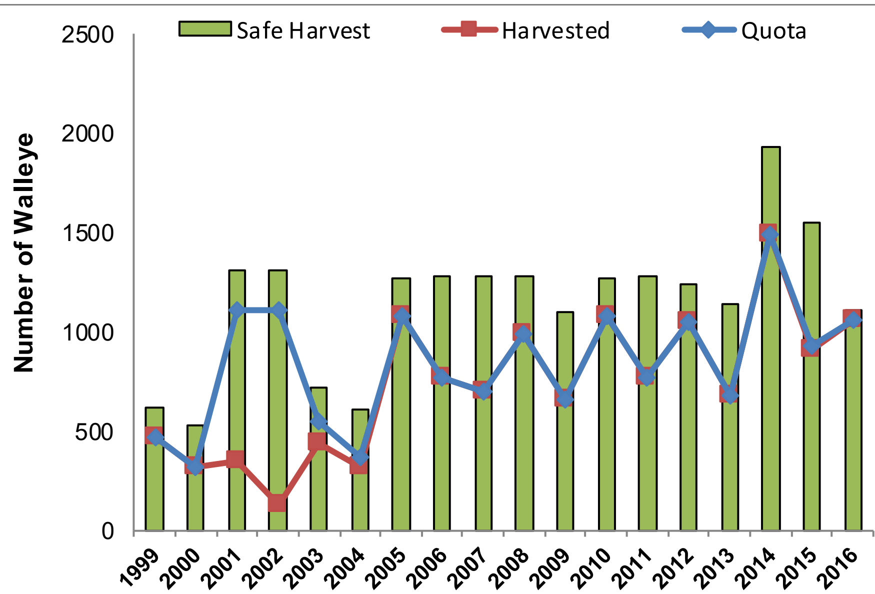


Figure 3.6-6. Twin Lakes walleye spear harvest data (GLIFWC 1998-2016).

Muskellunge open water spear harvest records are provided in Figure 3.6-7 from 1999 to 2016. As many as 17 muskellunge have been harvested from the lake in the past (2007), however the average harvest is four fish in a given year. Spear harvesters on average have taken 16% of the declared quota.

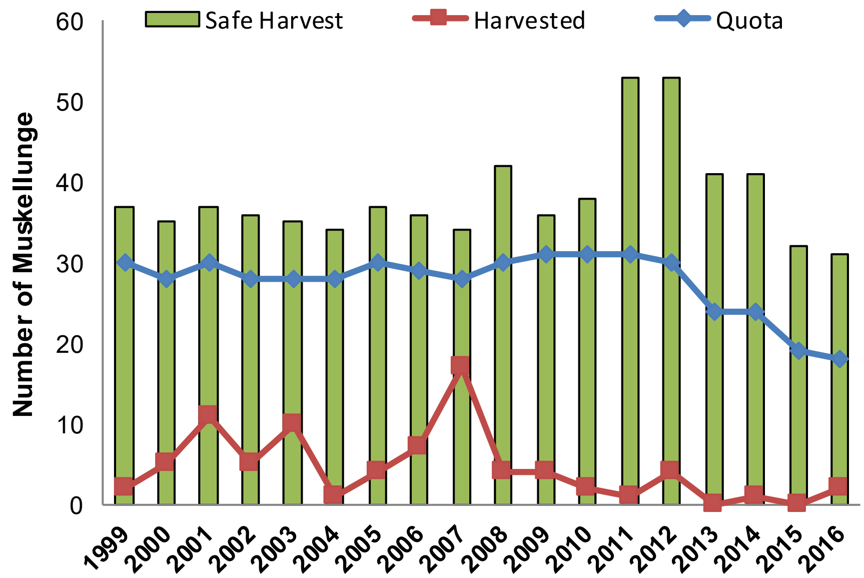


Figure 3.6-7. Twin Lakes muskellunge spear harvest data (GLIFWC 1998-2016).

North and South Twin Lake Fish Habitat

Two-Story Fishery

North Twin Lake is unique compared to most lakes in Wisconsin in that it is a two-story fishery. A two-story fishery is capable of supporting both a warm water and cold water fishery. The top-story supports warmer water species such as bass and pike. The lower-story is colder, deeper, well oxygenated and can support species such as cisco or lake trout. A 2013 survey conducted by the WDNR found Cisco (*Coregonus* spp.*)* in North and South Twin Lake in high relative abundance (Lyons, et al 2015), confirming that the lake supports a two-story fishery.

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 2016, 85% of the substrate sampled in the littoral zone of North Twin Lakes were sand sediments, 14% composed of rock and 1% composed of soft sediments. A 2017 point-intercept survey of South Twin Lake found 55% of the substrate sampled in the littoral zone to be sand, 42% mucky or soft, and 3% rock substrate.

Coarse Woody Habitat & Fish Sticks Program

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 2006).

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 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

Photograph 3.6-3. Fish Stick Example. (Photo courtesy of WDNR 2013).

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 survey documented 357 pieces of coarse woody along the shores of North and South Twin Lake, resulting in a ratio of approximately 25 pieces per mile of shoreline. North and South Twin Lake may be an excellent candidate to consider enhancing coarse woody habitat through the deployment of fish sticks.

Sensitive Area Designations

A 2002, WDNR sensitive area survey report identified several specific locations in North and South Twin Lake that provided valuable ecosystem functions including important fisheries habitat. Several of the sites identified in the survey had valuable fish spawning, feeding or habitat qualities such as favorable substrates for spawning or submersed or emergent plant communities used for cover and feeding.

This detailed report can be found on the WDNR website at:
http://dnr.wi.gov/lakes/criticalhabitat/Project.aspx?project=33335487

Regulations and Management

Current (2017-2018) regulations for North and South Twin Lake gamefish species are displayed in Table 3.6-9. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-9. WDNR fishing regulations for North and South Twin Lake (2017-2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	June 17, 2017 to March 4, 2018
Smallmouth bass	Catch and release only	None	May 6, 2017 to June 16, 2017
Largemouth bass	5	14"	May 6, 2017 to June 16, 2017
Muskellunge and hybrids	1	40"	May 27, 2017 to November 30, 201
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 6, 2017 to March 4, 2018
Cisco and whitefish	25 pounds plus one more fish of either species in total	None	Open All Year

Mercury Contamination & 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 3.6-8. 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	-

Figure 3.6-8. 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/)

**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.*

Fishery Management & Conclusions

Fisheries biologists from the WDNR completed field surveys on North and South Twin Lakes during 2017, the results of which will help to guide the future management of the lakes. The results of the spring 2017 fish surveys on the Twin Lakes are included as Appendix G. Additional information including fall 2017 recruitment survey results and creel survey data may be available for the next draft of this report. A 2018 muskellunge recapture survey is planned and will allow for a population estimate for the species.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Twin Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within each lake.
3) Collect sociological information from the Twin Lakes stakeholders regarding their use of the system and their thoughts pertaining to the past and current condition of the lakes and their management.

Completing a comprehensive management plan for a large system like the Twin Lakes is a large endeavor. The process is made increasingly more difficult due to the ongoing and historic management actions that the NSTLRA are involved with. Overall, the studies conducted as part of this planning process have found that lakes are overall healthy. However, there are challenges that need to be addressed, such as aquatic invasive species and shoreland development, to enhance the Twin Lakes ecosystem.

The Twin Lakes water quality is excellent, with low measured phosphorus, low free-floating algae (measured as chlorophyll-a), and high water clarity. While the total phosphorus levels of North Twin Lake are within the *excellent* category for similar lake types, North Twin Lake is listed on the WDNR's list of impaired waters (303-d) because lake's total phosphorus exceeds the 2016 WisCALM threshold for fish and aquatic life use in a two-story lake. This means that on most lakes that contain similar total phosphorus levels, the productivity of the lake leads to insufficient oxygen in deeper waters of the lake and inhibit the ability of the lake to sustain a coldwater fishery of species like cisco or trout. Analysis in the Water Quality Section (3.1) confirms that there is ample three-dimensional space for the systems healthy cisco population and as the WDNR revises their classification for impaired waters, may remove North Twin from this list.

The favorable water quality conditions observed in the Twin Lakes are a result of the Twin Lakes overall watershed and the condition of near-shore properties. Over 90% of the Twin Lakes watershed contains land cover types that contribute the least amount of phosphorus to the lake. Over half of the Twin Lakes' shoreland is in a *natural/undeveloped*, or *developed-natural* condition. These are the shoreland types that provide the largest nutrient buffering capabilities, as well as providing the greatest habitat for aquatic and terrestrial wildlife. The system's shoreline is approximately 25% composed of *urbanized* and *developed-natura*l conditions, the shoreland types that have the least habitat value and nutrient buffering capacity. While North and South Twin Lakes contain less coarse woody habitat than pre-European settlement, they contained approximately 26 and 21 coarse woody habitat pieces per shoreland mile, respectively. Based on other surveys Onterra has conducted, these values fall in the average to slightly above average range of lakes. That being said, increasing coarse-woody habitat above current levels would have great habitat value to the Twin Lakes.

By all standard metrics, the vegetation surveys revealed that the aquatic plant community of the Twin Lakes is of average or higher quality than lakes within the same ecoregion and throughout the state. While some changes have been noted, the aquatic plant community of North Twin Lake remains largely unchanged since a previous study. However, South Twin Lake has experienced changes in its plant community related to the establishment of EWM in the system and the control actions that have taken place in an effort to maintain a reduced EWM population within the lake.

Of the native plant species impacted by the herbicide control program on South Twin, some have rebounded whereas others continue to exist at population levels lower than before the treatment program took place.

As for many lake groups in this region of Wisconsin, EWM weighs heavy on their minds. There are a number of scientific studies published on the degree to which EWM populations can alter the ecosystem function of the lake. Some of the studies show large-scale changes and others indicate undetectable changes. It is clear to the NSTRLA that a lowered EWM population would allow that lake to function closer to it had historically prior to EWM establishment. The caveat to that statement would be so long as the control actions were not negatively impactful to the flora and fauna of the system. What remains unknown is whether the reductions of some native plant species and other cascading impacts from the herbicide treatments are negatively impacting the lake greater than if the EWM population was not being managed. The NSTLRA has used Best Management Practices when managing the EWM population in the lake to limit potential negative impacts to the lake. The NSTLRA also encourages the WDNR and other entities to conduct research on this subject similar to the current cooperative UW-Steven's Point and WDNR research project entitled *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes*.

The Twin Lakes are a unique and highly sought-after resource that is utilized by recreationalists for varying uses. It is an exceptional water resource for relaxation, wildlife viewing, fishing, swimming, and more. While almost impossible to quantitatively document, the NSTLRA confirms that navigation, recreation, and aesthetic impairment has been observed on South Twin Lake in years with high EWM populations. This was particularly clear in 2015. Studies have documented decreases in lakefront property values when water-based recreational activities exist on lakes (Eiswerth et al. 2000, Horsch and Lewis 2009, Zhang and Boyle 2010). The NSTLRA has made it a priority to ensure the Twin Lakes continue to be a popular vacation destination and property values remain strong.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the NSTLRA Planning Committee and ecologist/planners from Onterra. It represents the path the NSTLRA 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 Twin Lakes 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. The NSTLRA Planning Committee's philosophy of lake management, as it applies to the Twin Lakes, is articulated as follows;

NSTLRA's Philosophy for Lake Management (Created by NSTLRA Planning Committee)

> Management of the Twin Lakes is critical to ensure the long-term lake quality for both owner riparians as well as visiting users of the resource. The Twin lakes are a unique two-story lake which provides economic value through tourism to the neighboring communities. Erosion of the quality of the resource would have significant adverse impact to the local community as well as riparians and as such it is the responsibility of NSTLRA to partner with stakeholders to ensure the continued viability of the Twin Lakes.
>
> The recent stakeholder survey, completed by 40% of our NSTLRA riparians who were provided the survey, clearly emphasized their overwhelming support for active management of the lake to ensure recreational use, stability of property values as well as improved fishery and also commented on swimmer's itch concerns. Survey respondents also signaled their strong support to manage the Twin Lakes with herbicides, if necessary, to ensure Twin Lakes quality.
>
> We define lake management to include but not be limited to evaluation of historical management activities on Twin Lakes, ongoing monitoring of leading edge alternatives to control invasive species, ongoing monitoring of water quality and trends in Twin Lakes invasive species, consideration of results derived by studies, active/passive management techniques and any other data which may assist in the assessment and actions required to achieve the objectives we have outlined in our Implementation Plan.
>
> NSTLRA believes that the active management of Twin Lakes is the critical approach required to achieve goals and objectives outlined in this plan. The Kujawa (2017) study clearly supports that actively managed lakes, over the period of the study, exhibited lower incidence of EWM on average than those lakes which were not actively managed. It concludes, "Our findings indicate that herbicide treatment is a valuable management tool to control EWM."
>
> Additionally, NSTLRA agrees with the MN Interagency of Lakes as it states, "In order to maintain these beneficial uses, lakes need help. With ever increasing recreational use

and growing populations residing near and along waterways, lakes can suffer from small and large cumulative impacts and cannot manage themselves."

Thus, NSTLRA's philosophy is to continue to partner with stakeholders, actively monitor changes in the Twin Lakes, evaluate current and future information regarding lake management and implement actions in order to achieve the objectives in this lake management plan ensuring the long-term health of the Twin Lakes.

While the NSTLRA Board of Directors is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee or an individual director (e.g. Education and Communication Committee, Water Quality Director/Committee, Invasive Species Committee, Shoreland Improvement Director/Committee). The NSTLRA will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Control Existing and Prevent Further Aquatic Invasive Species Infestations within the Twin Lakes

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at critical public access locations
Timeframe:	Continuation of current effort
Facilitator:	Clean Boats Clean Waters Committee
Description:	Currently the NSTLRA monitors the public boat landings using training provided by the Clean Boats Clean Waters program. The Twin Lakes are an extremely popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that originated in the Twin Lakes. The goal would be to cover the critical 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. Due to the large number of activities that volunteers are called upon on the Twin Lakes (AIS monitoring, stakeholder education, etc.), paid watercraft inspectors would be sought. The NSTLRA intends to utilized 300 hours of paid watercraft inspections through Vilas County's student intern program. The committee may also investigate implementing technology enhancements (I-Lids, etc.) that could potentially encourage boating recreationists to remove weed particles from their individual watercrafts upon launch and removal activities
Action Steps:	

	See description above as this is an established program.

Management Action:	Coordinate volunteer monitoring of AIS
Timeframe:	Continuation of current effort
Facilitator:	Lake Management Committee - possibly formation of an AIS Committee
Description:	NSTLRA members have received past training on AIS identification from Onterra and Vilas County staff. The NSTLRA also has purchased a dedicated GPS to transfer information to and from professional surveyors. These surveys would be conducted to augment professional surveys, not replace them. The NSTLRA would appoint a Lake Captain (a member of the planning committee) who is responsible for recruiting riparian property owners to participate in looking for AIS in the water and along specific stretches of shorelines. More volunteers are needed to assure future coverage.
Action Steps:	
1.	Volunteers from NSTLRA update their skills by attending a training session conducted by WDNR/UW-Extension through the AIS Coordinator for Vilas County (Cathy Higley – 715.479.3738).
2.	Trained volunteers recruit and train additional association members.
3.	Complete lake surveys following protocols.
4.	Report results to consultant and NSTLRA, entering hours spent into SWIMS.

Management Action:	Coordinate annual professional monitoring of AIS, particularly EWM
Timeframe:	Continuation of current effort
Facilitator:	Lake Management Committee - possibly formation of an AIS Committee
Description:	As the name implies, the EWM peak-biomass survey is completed when the plant is at its peak growth, allowing for a true assessment of the amount of this exotic within the lake. For the Twin Lakes, this survey will likely take place in late-August or September. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using sub-meter GPS technology. This survey would serve three main roles: 1) document the EWM population at the peak of its growth stage in a given year, 2) access the management efforts that took place over the summer, and 3) be used to propose management for the following year.

	If the management strategy for a given year contains a professional hand-harvesting component, an Early Season AIS (ESAIS) Survey would be conducted during June to setup that years' program. With direction from the NSTLRA, the consultant would coordinate the professional hand-harvest effort by designing the strategy (prioritization if needed) and providing the spatial data to the third-party firm as appropriate.
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Conduct EWM Population Control on North Twin Lake Using Hand-Harvesting and Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	Lake Management Committee - possibly formation of an AIS Committee
Description:	The EWM population of North Twin Lake has remained relatively low since first being exposed to the lake. At these low levels, the EWM population is not likely causing measurable negative ecological impacts to the system. While the population has existed within North Twin Lake since 2001, the relatively low population level may offer an opportunity to effectively reduce or maintain the low population level before expansion and establishment to other parts of North Twin Lake occurs. Along with being a source population for future expansion, the EWM populations may be diminishing the. navigability, recreation, aesthetics in localized areas. <u>Active Management Monitoring Strategy</u>: If the following trigger is met, the NSTLRA would consider conducting herbicide spot treatments: "colonized areas where a sufficiently large treatment area can be constructed to hold concentration and exposure times (preference to *dominan*t or greater density AIS populations)." It is likely that these spot treatments would be conducted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.), similar to what was used on North Twin Lake during 2017. The NSTLRA would also conduct pre- and post-treatment monitoring of these areas by comparing the Late-Summer EWM Mapping surveys the year before and the year of the treatment. A pretreatment survey would be conducting during the spring prior to the herbicide treatment implementation to potentially make refinements and/or dictate timing of the treatment. If the herbicide treatment size exceeds 10 acres, the addition of quantitative (sub-sample point-intercept) sampling component to the monitoring plan would likely occur. Where spot treatments are not anticipated to be effective but control of target areas is still sought (as opposed to just monitoring them), a professional-

	based hand-harvesting efforts may be chosen. As discussed above, the contracted hand-harvesting would occur between the June ESAIS Survey and the Late-Summer EWM Peak-Biomass Mapping Survey. If a Diver Assisted Suction Harvest (DASH) component is utilized, the NSTLRA and contracted firm would be responsible for permit procedures. The contracted firm would be guided with GPS data from the consultant and would track their effort for post assessments. Overall, the NSTLRA will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. Specific details of the proposed control strategy will be included within the NSTLRA's annual report, being provided to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued. Short-Term Management Strategy Specifics: The 2017 Late-Summer EWM Mapping Survey data indicate that the EWM population is starting to spatially expand from this part of the lake to other parts of the lake. The NSTRLA have created a 3-year strategy where the entirety of the EWM population on North Twin is being considered for active management. The goal of the NSTLRA is to use hand-harvesting as a preferred control mechanism but would employ the above management trigger when herbicide spot treatment would be considered. Three primary areas of established EWM exist in North Twin and are shown within the insets of Map 15. • Area 1 has been outlined as a likely 2018 hand-harvesting location. Based on the June 2018 ESAIS, a final strategy would be considered. • A trial 2,4-D/endothall spot treatment occurred on Area 2 in 2017 on the most established and densest population within North Twin Lake. This area will be evaluated in 2018 (EWM mapping survey and point-intercept sub-sample survey) in absence of management. Management may be considered in 2019 and 2020. • Area 3 consists of a highly scattered EWM colony that will be evaluated in 2018. EWM Population declines unrelated to management have occurred in this area in the past. If populations continue to persist and/or increase in density, this area will be potentially added to a 2019 or 2020 hand-harvesting strategy.
Action Steps:	
	See description above

Management Action:	Conduct Large-Scale Herbicide Treatment on South Twin Lake
Timeframe:	Potentially Spring 2018
Facilitator:	Lake Management Committee - possibly formation of an AIS Committee
Description:	Due to the large and broad shape of South Twin Lake, past attempts at conducting spatially targeted "spot" treatments have been only marginally effective. The NSTLRA agree that use of herbicides to control EWM need to have more favorable and predictable results for the control action to be worth the risk of using herbicides. It is also understood that targeting the EWM on a lake-wide basis, similar to conducted in 2009, 2010, and 2016 will produce more predictable results. The NSTLRA will have annual point-intercept surveys conducted on South Twin Lake to quantitatively track the EWM population over time, as well as how the native plant community is rebounded from previous large-scale management actions. Once the EWM population exceeds 12% littoral frequency of occurrence, the NSTLRA will initiate the planning and pretreatment steps necessary to conduct a large-scale treatment on the lake. This threshold was based upon coupling the point-intercept data at these levels with the Late-Summer EWM Mapping Survey data. When EWM populations exceeded 10%, *highly dominant* and *surface matted* conditions started becoming apparent. As these colonies become more one dimensional (i.e. EWM monoculture), native plant diversity declines and an alteration in the lakescape become apparent. WDNR researchers compiled point-intercept data on 397 lakes statewide in Wisconsin finding that the majority of lakes surveyed had EWM populations less than 10 percent of littoral zone (Nault 2016), with only a third of lakes within the study containing EWM populations greater than 15%. Once the trigger has been met and the pretreatment data is collected, the NSTRLA will review the information, and formally make a decision to move forward with the control program based upon data collected and communication with the WDNR regarding the NSTLRA's intent, prior to a vote of the Board of Directors to move forward with such action. The decision to implement a large-scale treatment strategy would have flexibility, particularly if large acreages of high-density EWM colonies (*dominant*, *highly dominant*, or *surface matted*) are confirmed on the lake. Herbicide use patterns may require rotation to avoid population-level herbicide tolerance evolution from occurring. Specific details of the herbicide use pattern to be embraced will be included within the NSTLRA's annual report, being provided to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued.

	<u>Active Management Monitoring Strategy:</u> A cyclic series of steps will be used to plan and implement the control efforts. The series includes conducting the following surveys during the *year prior to the treatment*, *year of the treatment*, and *year following the treatment:* • A lake-wide mapping assessment of EWM completed while the plant is at peak growth stage (peak biomass). • A detailed assessment of bathymetric data from the lake, potentially augmenting with an acoustic survey of the lake. • Quantitative assessments of the native and non-native aquatic plant community of the lake utilizing point-intercept survey methodology. During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy. Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the treatment, as well as collection of post treatment herbicide concentration samples at multiple locations and sampling intervals. The success criteria of a large-scale treatment would be a 70% reduction in EWM littoral frequency of occurrence (LFOO) comparing point-intercept surveys from the *year prior to the treatment* to the *year after the treatment.* This means if the treatment occurs in 2018, the *year before treatment* would be 2017 and the *year after treatment* would be 2019. Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*. If a 70% reduction of EWM LFOO is achieved during the timeline outlined, it is likely that the lowered EWM population will last 3-5 years before additional large-scale management would be needed. Integrated pest management activities, such as hand-harvesting and herbicide spot treatments, are outlined in the next management action (*Develop Long-Term Contingency Strategy for Rebounding EWM Populations in South Twin Lake*). If the NSTLRA's trigger for large-scale treatment occurs sooner than 3-5 years, the treatment will not meet long-term success criteria. Native plant impacts are anticipated from any large-scale management action, but evaluation of the long-term success will also take into account the native plant impacts and population rebound. If the large-scale management strategy does not meet the control goal criteria, the NSTLRA would review their goal of reducing the lake-wide EWM population within the lake. Initially, this would include investigation of alternative herbicides and use-patterns. This concept is elaborated on within

	the management action titled: *Investigate and Study Alternative Management Methodologies*. Short Term Population Management Strategy Specifics: The NSTLRA AIS Committee is resolved that the next large-scale EWM management activity on South Twin Lake will be a pelletized fluridone treatment. For South Twin Lake specifically, SePRO recommends a 4 ppb initial pelletized fluridone treatment, with an understanding that the measured concentrations within each of the lakes would be approximately 2-3 ppb because of the extended release rate, herbicide degradation, and plant uptake. Once measured herbicide concentrations from each of the lakes was observed below 2 ppb, additional bump treatments would occur to keep the concentration between 2-3 ppb for the majority of the growing season. The strategy was outlined within the *North and South Twin 2016-2017 EWM Control & Monitoring Report* (Feb26-2018) and subsequently used with a February 1 AIS-Established Population Control Grant application and a Chemical Aquatic Plant Control Application (Form 3200-004). The WDNR indicated the grant application was ineligible because the draft management plan lacked the specifics of the fluridone strategy and the annual report containing this information was not received by WDNR at least 60 days prior to the application deadline. The permit was denied for concern of additional native plant impacts beyond those that have not rebounded from the previous large-scale actions, as well as the WDNR did not feel that the level of EWM within the lake warranted the treatment.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.

Management Action:	Develop Long-Term Contingency Strategy for Rebounding EWM Populations in South Twin Lake
Timeframe:	Potentially 2019
Facilitator:	Lake Management Committee - possibly formation of an AIS Committee
Description:	Many lake groups initiate a whole-lake herbicide strategy with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when EWM begins rebounding. This is referred to as Integrated Pest Management (IPM). Occasionally, the EWM rebounds in a fashion that does not lend well to IPM. If the rebounded EWM population exceeds a level that can be controlled using best management practices, the NSTLRA will cease coordinated population level management until the population again exceeds the predefined threshold to trigger another whole-lake treatment. Although EWM population-level control efforts would be ceased, active management may be directed towards areas that are impacting the recreation and navigation of the lake. The management activities would contain the smallest footprint possible to reach the stated goal as well as not limiting the effectiveness of the control action. Spot herbicide treatments likely will need to embrace herbicides or herbicide combinations thought to be more effective under short exposure situations. Specific details of the proposed control strategy will be included within the NSTLRA's annual report, being provided to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design. Please note that conducting management for the purpose of increasing navigability or recreation are not eligible for WDNR grants.
3.	Initiate control and monitoring plan.

Management Action:	Investigate and Study Alternative Management Methodologies
Timeframe:	Potentially 2019
Facilitator:	Lake Management Committee with assistance from Consultant - possibly formation of an AIS Committee
Description:	The NSTLRA understand that management of EWM will be a long-term part of the management of the Twin Lakes. The NSTLRA would like to be on the front edge of Best Management Practices for controlling EWM. What constitutes a Best Management Practice (BMP) changes in time as science and adaptive management progresses through science. For instance, small spot-treatments using 2,4-D was once the BMP for controlling EWM in

	Wisconsin waters. Science and monitoring has determined that these treatments rarely meet their target concentrations and are unpredictable on their effectiveness. National and regional aquatic plant management industries and trade associations have partnered with scientists (academia and government) to better understand control actions, their benefits and risks, and applicability. The NSTLRA would continue to be updated on the management efforts being conducted in surrounding states as well as the nation when it pertains to invasive milfoil management. This would include, but not be limited to new herbicide use-patterns and their potential environmental and human toxicological profile. Other emerging technologies may include non-herbicide options.
Action Steps:	
	See description above

<u>Management Action:</u>	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3-4 years, Community Mapping every 7-8 years
Facilitator:	Lake Management Committee
Description:	As part of the ongoing EWM management program, particularly for South Twin Lake, point-intercept surveys are likely to take place annually or semi-annually. For both lakes, whole-lake point-intercept surveys should be conducted at a minimum once every 3-4 years. This will allow an understanding of the submergent aquatic plant community dynamics within the Twin Lakes. Point-intercept surveys have been conducted on South Twin almost every year since 2008 and have been conducted on North Twin Lake at a five-year increment (2011, 2016). In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in the Twin Lakes, a community mapping survey would be conducted every 7-8 years. The community mapping survey has been conducted on the Twin Lakes approximately every 4-5 years (2007, 2011, 2016) in the past as part of each lake management planning project update.
Action Steps:	
	See description above as this is an established program.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.	
Timeframe:	Continuation of current effort.	
Facilitator:	Lake Management Committee – possibly formation of a Water Quality Committee	
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Water quality data is currently been collected by the Wisconsin Valley Improvement Corporation (WVIC) for a 3-year period, once every 10 years. The next sampling period will be conducted in 2020-2023. In addition to the WVIC's efforts, volunteer water quality monitoring should be completed annually by Twin Lake riparians through 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. The NSTLRA would seek enrollment into this program, likely starting out by monitoring Secchi disk readings in each lake and then enrolling in the advanced CLMN program where water chemistry samples would also be collected (chlorophyll-*a*, and total phosphorus). Samples would be collected three times during the summer and once during the spring, as well as water temperature profiles at the lake's deep hole using Vilas County's dissolved oxygen and temperature probe. Sandra Wickman (715.365.8951) or the appropriate WDNR/UW Extension staff should be contacted to enroll in this program, ensure the proper training occurs, and the necessary sampling materials are received. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.	
Action Steps:		
	1.	Contact Sandra Wickman (715.365.8951) to enroll in the CLMN program.
	2.	Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting.
	3.	CLMN volunteer and/or NSTLRA would facilitate new volunteer(s) as needed

Management Goal 3: Increase NSTLRA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Use education to promote lake protection and enjoyment through stakeholder education
Timeframe:	Continuation of current efforts
Facilitator:	Social Events-Publicity Committee, Board of Directors, or possibly formation of an Education Committee
Description:	Education represents an effective tool to address many lake issues. The NSTLRA regularly distributes quarterly newsletters and maintains a website (http://www.nstlra.com/). 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. The NSTLRA will continue to make the education of lake-related issues a priority. 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* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Sedimentation • Boating safety (promote existing guidelines, Vilas County Courtesy Code) • Swimmers itch • Shoreline habitat restoration and protection • Fireworks use and impacts to the lake • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lakes
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue NSTLRA's involvement with other entities that have responsibilities in managing (management units) the Twin Lakes
Timeframe:	Continuation of current efforts
Facilitator:	Social Events-Publicity Committee, Board of Directors, or possibly formation of an Education Committee
Description:	As outlined on the NSTLRA's website: "The Association's mission is to educate citizens on issues that affect the quality of life on and around the lakes; to provide a collective voice to address issues that may concern lake front property owners; to maintain a working relationship with the DNR and other organizations that can influence the quality of the lakes; to create a sense of community and stewardship for the fragile resource of the lakes; to recommend and work toward zoning that will protect land owners from undesirable land and water use." 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 NSTLRA 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
Town of Phelps and Town of Conover Chamber of Commerce	www.phelpswi.us www.conover.org	Provides information and networking related to the advancement of the community.	Once a year, or more as needed. May check website	The Chamber of Commerce serves a valuable role in promoting local businesses, tourism, and community within the Twin Lakes Lake area.
Town of Phelps Lakes Committee	Chairman (Dave Roberts 715 545-2829)	The Twin Lakes Lake falls within the Town of Phelps.	Once a year, or more as needed. May check website (http://townofphelps.com/town-lakes-committee-) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Vilas County Lakes & Rivers Association	President (Rollie Alger– president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator (Cathy Higley – 715.479.3738)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	<u>Spring:</u> AIS training and ID, AIS monitoring techniques <u>Summer</u>: Report activities to Coordinator
Vilas County Land & Water Conservation Department.	Conservation specialist (Mariquita Sheehan – 715.479.3721)	Oversees conservation efforts for land and water projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Fisheries Biologist (Hadley Boehm– 715-356-5211 ext. 246)	Manages the fishery of the Twin Lakes Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715.365.8937)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	<u>Late winter</u>: arrange for training as needed, in addition to planning out monitoring for the open water season. <u>Late fall</u>: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	NSTLRA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.
Wisconsin Valley Improvement Company	Ben Niffenegger or Peter Hansen (715.848.2976)	Within the confines of their FERC license, operates the dam on Long Lake.	Once a year, or more as issues arise.	General water-level communications.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Social Events-Publicity Committee, Board of Directors, or possibly formation of an Education Committee
Description:	Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Twin 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 2016, 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 Goal 4: Improve Lake and Fishery Resource of the Twin Lakes

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Initiate 2018
Facilitator:	NSTLRA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	As discussed in the Shoreland Condition Section (3.3), 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. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, the NSTLRA has decided to take the following steps to increase shoreland restoration on the Twin Lakes:

	1. Educate riparians about the importance of healthy and natural shorelands. 2. Solicit 3-5 riparians to allow shoreland restoration and storm water runoff designs for their property. 3. The NSTLRA work with Vilas County (Quita Sheehan) or private entity to create design work. Small-scale WDNR grants may be sought to offset design costs. 4. Designs be shared with NSTLRA members to provide further education of shoreland restoration projects. 5. Move forward with implementing shoreland restoration per the designs that were developed for those riparians that wish to. Project funding would partially be available through the WDNR's Healthy Lakes Implementation Plan (see below). 6. The NSTRLA's goal would be to have 3 shoreland restoration sites to serve as demonstrations sites to encourage other riparians to follow same path of shoreland restoration. 7. The NSTRLA's goal would be to get 5-10 properties to conduct formal shoreland enhancement activities within the next 5 years. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Vilas County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available
Action Steps:	
1.	Recruit facilitator from Planning Committee
2.	Facilitator contacts the Vilas County Land and Water Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the County Conservationist would be asked to speak to NSTLRA members about shoreland restoration at their annual meeting.

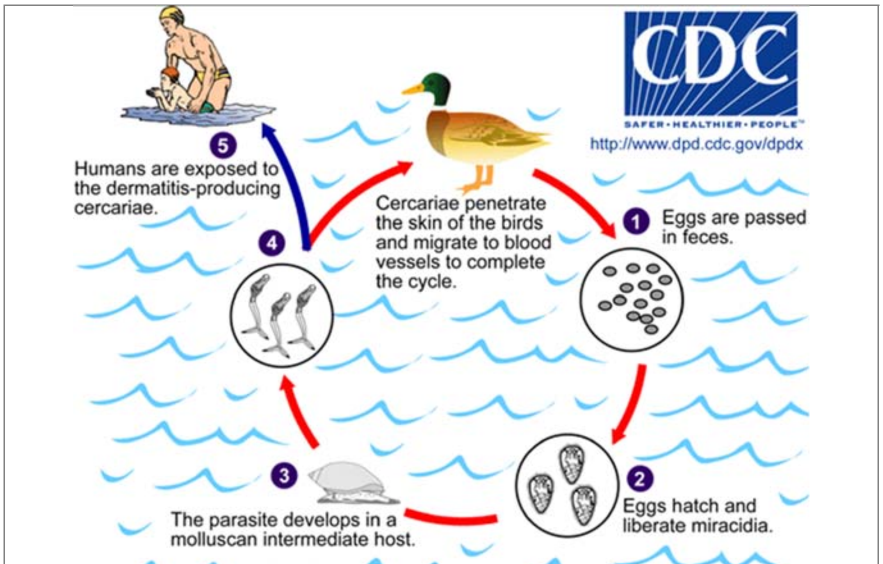
3.	The NSTLRA would encourage property owners that have restored their shorelines to serve as demonstration sites.

Management Action:	Protect natural shoreland zones around the Twin Lakes
Timeframe:	Initiate 2018
Facilitator:	NSTLRA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee
Description:	Approximately 7.4 miles (51%) of the Twin Lake's shoreline was found to be in either a *natural* or *developed-natural* state. It is therefore very important that owners of these properties become educated on the benefits their shoreland is providing to the Twin, and that these shorelands remain in a natural state. Maps 3-4 indicates the locations of Natural and Developed-Natural shorelands on the Twin Lakes. Private shorelands that are in either a *natural* or *developed-natural state* should be prioritized for education initiatives and physical preservation. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the NSTLRA in preserving the Twin Lakes shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Vilas County Land and Water Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.northwoodslandtrusts.org/) • UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).
2.	Facilitator gathers appropriate information from sources described above.

Management Action :	Coordinate with WDNR and private landowners to expand coarse woody habitat in the Twin Lakes
Timeframe:	Initiate 2018
Facilitator:	NSTLRA Board of Directors – possibly formation of a Shoreland Improvement Director or Committee

Description:	NSTLRA stakeholders must realize the complexities and capabilities of the Twin Lakes ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.5) discuss the benefits of coarse woody habitat in detail.
	
	The NSTLRA will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with WDNR fisheries biologist.
	
	The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or :
	    o The landowner would need to commit to leaving the area un-mowed
	    o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts Kevin Gauthier (WDNR Lakes Coordinator) and Hadley Boehm (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat projects.
3.	The NSTLRA would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Management Action :	Educate Stakeholders on Swimmers Itch
Timeframe:	Ongoing
Facilitator:	Social Events-Publicity Committee, Board of Directors, or possibly formation of an Education Committee
Description:	Cercarea dermatitis or swimmer's itch is a type of skin reaction that is caused when the larval stage of a shistosome flatworm accidentally burrows into a human's skin when that person is spending time in the water (Figure 5.0-1).  **Figure 5.0-1. Swimmer's itch life cycle.** Obtained directly from the Centers for Disease Control & Prevention website (CDC 2012). The skin reaction varies from one individual to another, but is usually accompanied by intense itching and a rash of small red bumps that look similar to insect bites. Each of the red bumps is caused by localized, inflammatory immune response to an individual parasite which will die within hours of entering into the skin. While perfectly harmless, it can greatly compromise the recreational value for those who enjoy spending time in the water. Young children seem to be more affected by this condition; as they typically spend more time in

the water, have more sensitive skin, and have a tendency to spend more time in near-shore areas of the lake where the flatworms may be more concentrated.

The larval stage (cercariae) of this group of flatworms needs to burrow into the skin of certain bird species to complete its lifecycle ❹. While the primary hosts are ducks, gulls, geese, swans, and red-winged blackbirds, other non-bird species (e.g. muskrats, mice) have also been shown to complete this parasite's life cycle. Mergansers have been known to have some of the highest infection rates of this group of parasites. After the flatworm matures in the bird host, it produces eggs that are released into the water through the bird's feces ❶. The eggs hatch ❷ and the immature life stage (miracidia) of the parasite seeks out a snail host to continue maturation ❸. While not all snail species will suffice as intermediate hosts for the flatworms, nine or more species have been known to host flatworm species associated with swimmer's itch. Once the flatworm matures the larval cercaria emerges and seeks out a definitive host to complete the lifecycle. However, sometimes the cercariae accidently encounter a human and attempt to burrow into the skin ❺, causing the skin reaction discussed above.

Historically, molluscicides have been used to combat swimmer's itch by targeting the intermediate host, snails. The pesticides are non-selective towards snails, mussels, and other mollusks that play an integral part of the aquatic ecosystem. For that reason, along with the high expense and uncertain long-term consequences of applying these metal-based pesticides, this management technique has gone out of favor and typically is not permitted in Wisconsin.

The NSTLRA would like to use education to help riparian understand the steps that can be taken to prevent or reduce the discomfort caused by swimmer's itch. The following summary list is based off information available on the WDNR's website:

- Avoid spending time in shallow water, especially if swimmer's itch has been known to be a problem in the area.
- Avoid spending time in the water between noon and 2 p.m, during which cercariae are most prevalent.
- Towel off immediately after getting out of the water. Cercariae will not penetrate the skin until after the person leaves the water. There may be an opportunity to remove the parasite before this occurs.
- Discourage ducks and other waterfowl from congregating in or near swimming areas by keeping near-shore areas vegetated, and by avoiding feeding the birds.
- Avoid using riprap or seawalls along the shoreline, as this provides an excellent substrate for many snail species. Host

	snails are known to live on all types of substrate (sand, rock, mulch, vegetation) with an increased preference for sandy beaches.
Action Steps:	
	See description above

Management Action :	Continue the Loon Watch Program
Timeframe:	Ongoing
Facilitator:	Loon Watch Committee
Description:	The NSTLRA has formed a Loon Watch Committee to monitor the Twin Lakes for loon activity. 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 Twin Lakes were originally thought to not contain reproducing loon populations. However, sightings of loon chicks on the backs of parents were observed in both 2016 and 2017. While the loon chicks were thought not to have survived the season due to predation, it provides documentation that the loons on the Twin Lakes have been reproducing.. The NSTLRA will continue this program, providing information and education to its membership at the association's annual meetings.
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 the Twin Lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on the Twin Lakes during June 30 and July 5, 2016 field visits, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the Twin Lakes to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on July 28 and August 17-18, 2016. A point spacing of 100 meters was used resulting in approximately 1164 points for North Twin Lake and a point spacing of 63 meters was used resulting in approximately 622 points for South Twin Lake.

Community Mapping

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

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

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