Lost Lake

Vilas County, Wisconsin

Comprehensive Management Plan

September 2019

Sponsored by:

Lost Lake Protection & Rehabilitation District

WDNR Surface Water Grant Program

AEPP-505-17

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Onterra, LLC
Lake Management Planning

Lost Lake

Vilas County, Wisconsin

Comprehensive Management Plan

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Funded by: Lost Lake Protection & Rehabilitation District
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Acknowledgements

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

Lost Lake Planning Committee

Jim Ulett – LLPRD Chair	Jim Guckenberg	John Eckerman
Ted Ritter – Town of Saint Germain Lakes Committee Chair	Robert Truppe	Gary Heeler
	Marv Anderson	

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

APPENDICES

1.0 INTRODUCTION

At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP)*, collected in the summer of 2015. Based on heads-up digitizing the water level from that aerial photograph, this lowland drainage lake was determined to be 553 acres. According to a 2017 acoustic survey of the lake, Lost lake has a maximum depth of 24 feet and a mean depth of 11 feet. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Lost Lake contains 34 native plant species, of which slender naiad (*Najas flexilis*) is the most common plant. Two exotic plant species are known to exist in Lost Lake, Eurasian watermilfoil and curly-leaf pondweed.

Field Survey Notes

The waters of Lost Lake are stained due to the natural shorelines and wetlands present within the watershed.

Photograph 1.0-1. Lost Lake, Vilas County.

Lake at a Glance - Lost Lake

Morphology	
Acreage	553
Maximum Depth (ft)	22
Mean Depth (ft)	11
Shoreline Complexity	2.1
Vegetation	
Number of Native Species	58
Threatened/Special Concern Species	-
Exotic Plant Species	Eurasian watermilfoil, Curly-leaf pondweed
Simpson's Diversity (2018)	0.92
Average Conservatism (2018)	6.3
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Transitional
Water Acidity (pH)	7.6
Sensitivity to Acid Rain	Not Sensitive
Watershed to Lake Area Ratio	20:1

The Town of Saint Germain Lakes Committee sponsored a series of WDNR Lake Planning Grants to complete a management plan on seven lakes in the Town, including Lost Lake, in 2004. An update to this plan was completed in April 2013.

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first confirmed from Lost Lake during the summer of 2013. In response to this finding, the Lost Lake Protection and Rehabilitation District (LLPRD) sponsored and completed a WDNR AIS-Early Detection and Response (EDR) Grant. Another exotic invasive species, Curly-leaf pondweed (*Potamogeton crispus;* CLP) was located in Lost Lake during surveys conducted in 2014. A second WDNR AIS-Early Detection and Response Grant was secured to fund monitoring and control of this species.

Following the AIS-EDR phase of monitoring and management, the LLPRD decided to create an updated lake management plan to guide the district in management of Lost Lake. While primarily focused on the district's approach to managing AIS, the LLPRD also aimed to create a holistic understanding of the Lost Lake ecosystem that included assessments of the water quality, watershed, shoreline condition, fisheries, native aquatic plant communities, and district stakeholder perceptions. This would also allow the LLPRD to objectively review their ongoing management activities and establish measurable success criteria standards to evaluate future AIS management efforts. A WDNR-approved lake management plan would also align the LLPRD to be eligible to apply for future WDNR grants to continue to help fund their monitoring and management efforts. This report serves as the final deliverable for this grant-funded project (AEPP-505-17).

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, riparian 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 of district members called a Planning Committee and the completion of a riparian stakeholder survey.

Kick-off Announcement

A project update was sent in July of 2017 instead of an official Kick-Off Meeting. A Kick-Off meeting for the AIS-Early Detection and Response Projects occurred in July 2014.

Planning Committee Roundtable Meeting – CLP Control

On April 10, 2017 Eddie Heath and Tim Hoyman met with members of the Planning Committee as well as WDNR Staff (Kevin Gauthier, Steve Gilbert, Susan Knight) discussed the possibility of conducting an herbicide control strategy during the spring of 2017 for the expanding CLP population. Factors such as environmentally toxicity of the treatment including likely native plant impacts, the need for multiple subsequent annual treatments, and regulatory opposition were discussed. Beckie Gaskill from the Lakeland Times was also in attendance, later writing a summary article on the meeting. This article, as well as a follow-up article are included in Appendix A.

Planning Committee Meeting

On September 13, 2018, Eddie Heath of Onterra met with six members of the LLPRD Planning Committee for nearly four hours. The results of the surveys were presented to the committee. The meeting also discussed the riparian stakeholder survey results and began developing management goals and actions for the Lost Lake management plan. The presentation materials from this meeting are included in Appendix A.

Planning Committee Teleconference Consultation with WDNR

On November 2, 2018, a teleconference between LLPRD (Jim Ulett), Onterra (Eddie Heath), and WDNR (Carol Warden) occurred with the purpose of gaining WDNR feedback on the perspective management goals and actions prior to submittal of the draft Comprehensive Management Plan.

Management Plan Review and Adoption Process

On October 1, 2018, a draft outline of the Implementation Plan was provided to the Planning Committee for review. Additional comments were received and a revised draft was created. This draft outline was provided to WDNR on October 19, 2018. A subsequent teleconference between LLPRD, Onterra, and WDNR (Carol Warden) occurred on November 2, 2018. The Implementation Plan Section (5.0) was created based on the comments received. On November 14, 2018, a mostly complete draft version of the Comprehensive Management Plan was provided to the LLPRD's Planning Committee for final review before opening up comments to the document from a wider audience.

On November 20, 2018, an official first draft of the LLPRD's Comprehensive Management Plan was supplied to the WDNR, Great Lakes Indian Fish and Wildlife Commission (GLIFWC), Lac du Flambeau (LDF) Tribe, Vilas County, and Town of St. Germain Lakes Committee to solicit input from these other stakeholder groups. Review was received from WDNR, GLIFWC, and LDF Tribe through a combined WDNR memorandum dated January 28, 2019. These comments and how they are addressed in the final plan are contained in Appendix E. A second draft of the LLPRD's Comprehensive Management Plan was provided to WDNR, GLIFWC, and LDF Tribe (the three entities that made official comments), along with Appendix E. On August 14, 2019, the WDNR indicated that the updated draft adequately addressed the official comments.

Wrap-Up Meeting
Scheduled for October 3, 2019.

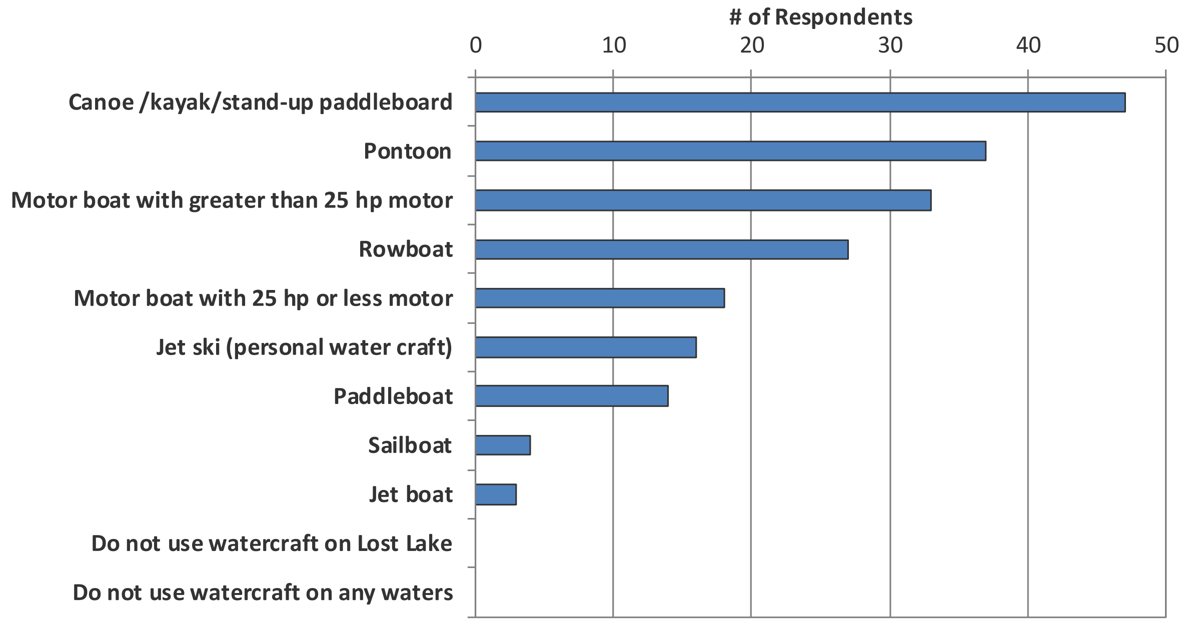
Riparian Stakeholder Survey
As a part of this project, a riparian stakeholder survey was distributed to LLPRD district members around Lost Lake. The survey was designed by Onterra staff and the LLPRD planning committee and reviewed by a WDNR social scientist. During November 2017, the nine-page, 34-question 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 LLPRD volunteer for analysis. Thirty-eight percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the riparian stakeholder survey, much was learned about the people that use and care for Lost Lake. The plurality of stakeholder respondents (41%) visit on weekends throughout the year, while 33% of respondents live on the lake during the summer months only, 13% are year-round residents, 4% are resort properties, and 3% are undeveloped. 52% of stakeholder respondents have owned their property on Lost Lake for over 15 years, and 35% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the riparian 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 canoe, kayak, stand-up paddleboard, or pontoon boat (Question 12). Larger motor boats and rowboats were also popular options.

A concern of stakeholders noted throughout the riparian stakeholder survey (see Questions 21 and 22 and survey comments – Appendix B) was aquatic invasive species in Lost Lake. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question 12: What types of watercraft do you currently use on Lost Lake?



Question 15: Please rank up to three activities that are important reasons for owning your property on Lost Lake.

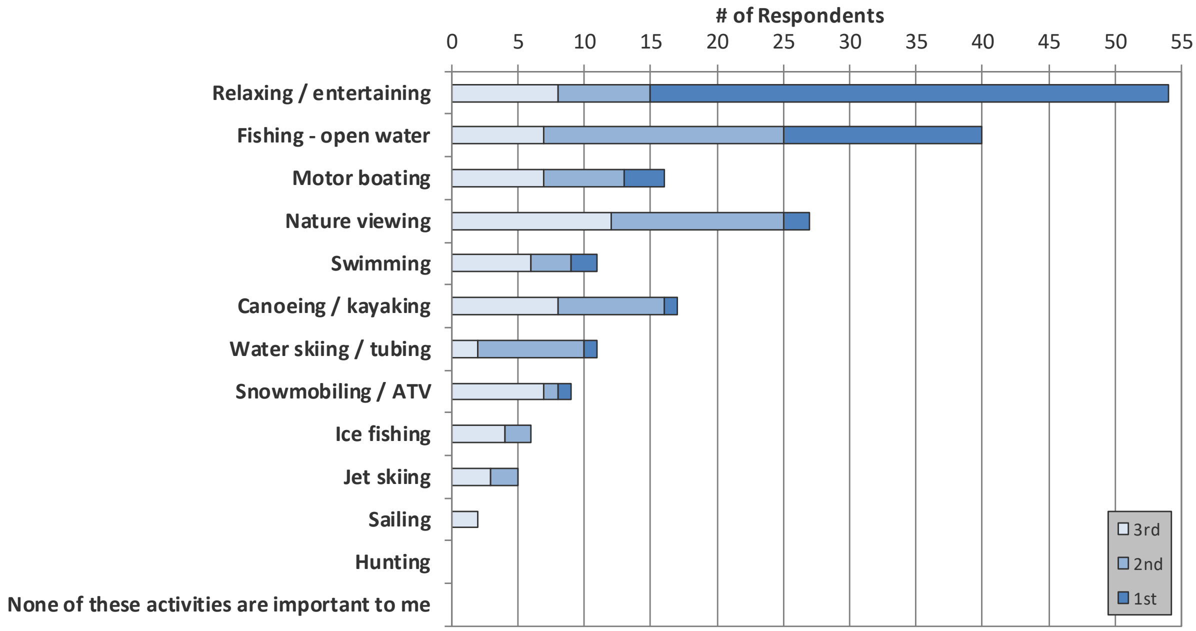
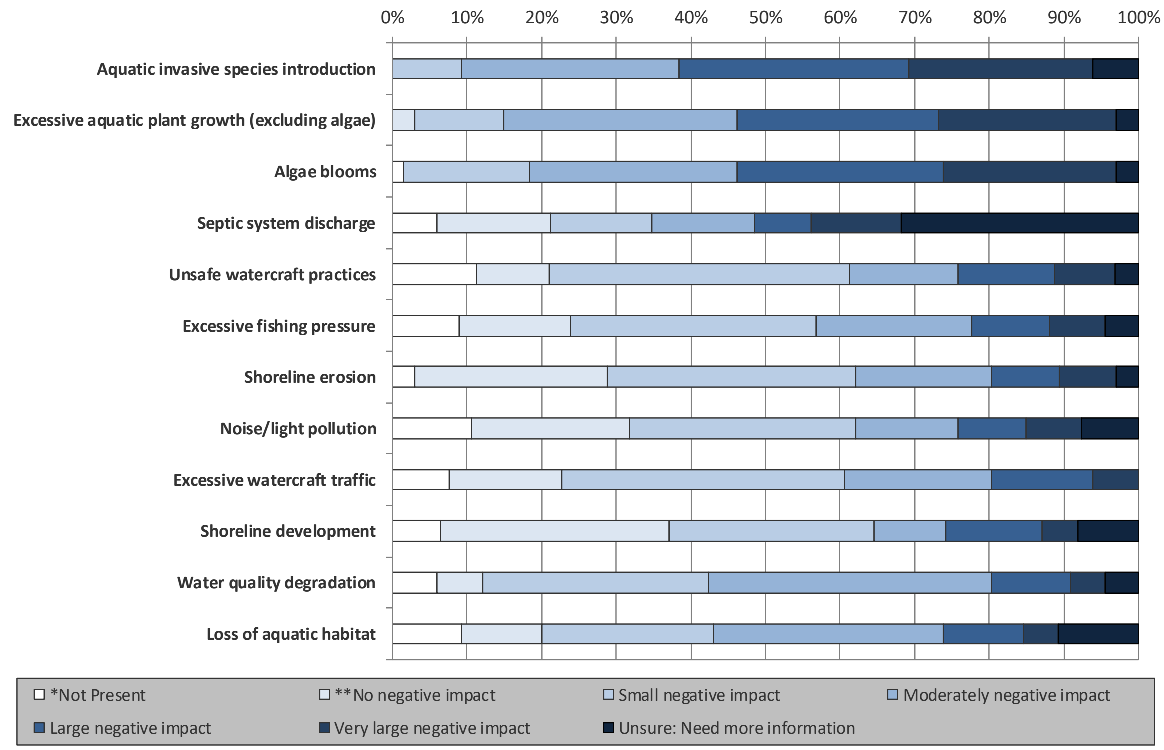


Figure 2.0-1. Select survey responses from the Lost Lake Riparian stakeholder survey. Additional questions and response charts may be found in Appendix B.

Question 21: To what level do you believe these factors may be negatively impacting Lost Lake?



Question 22: Please rank your top three concerns regarding Lost Lake.

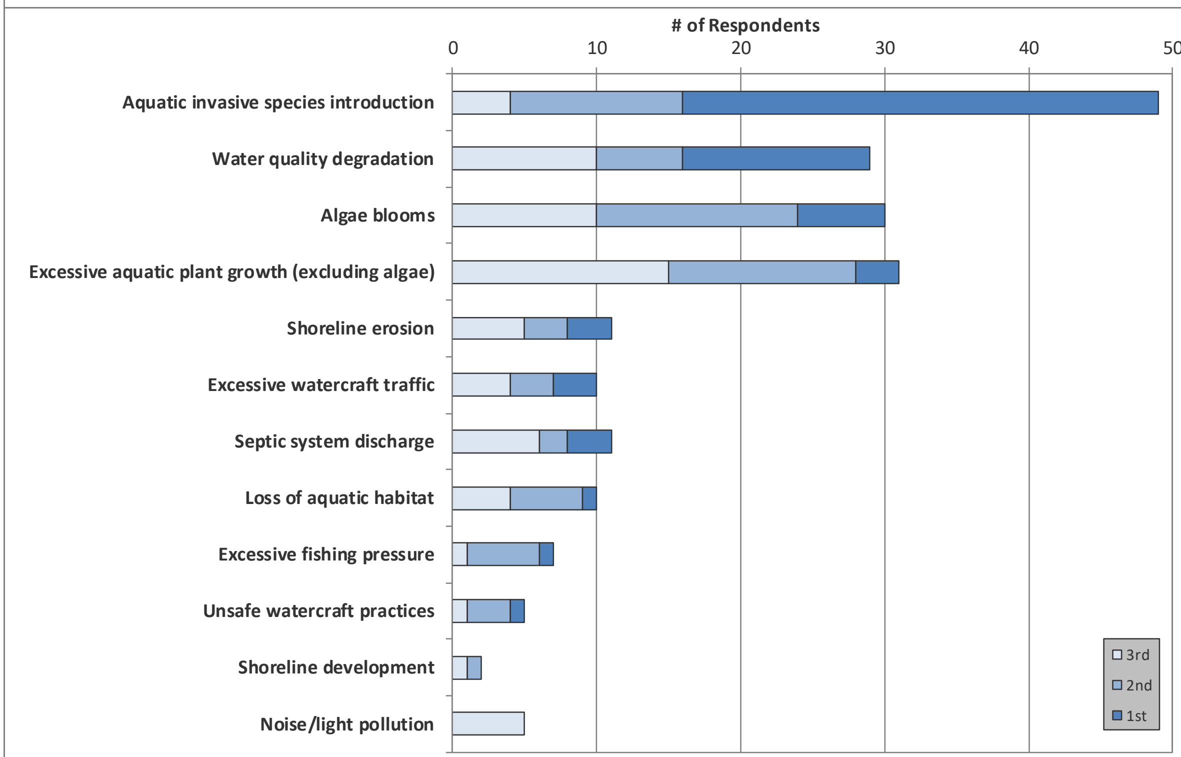


Figure 2.0-2. Select survey responses from the Lost Lake Riparian stakeholder survey, continued. Additional questions and response charts may be found in Appendix B.

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

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process 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 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) 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 Lost Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

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

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

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

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

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

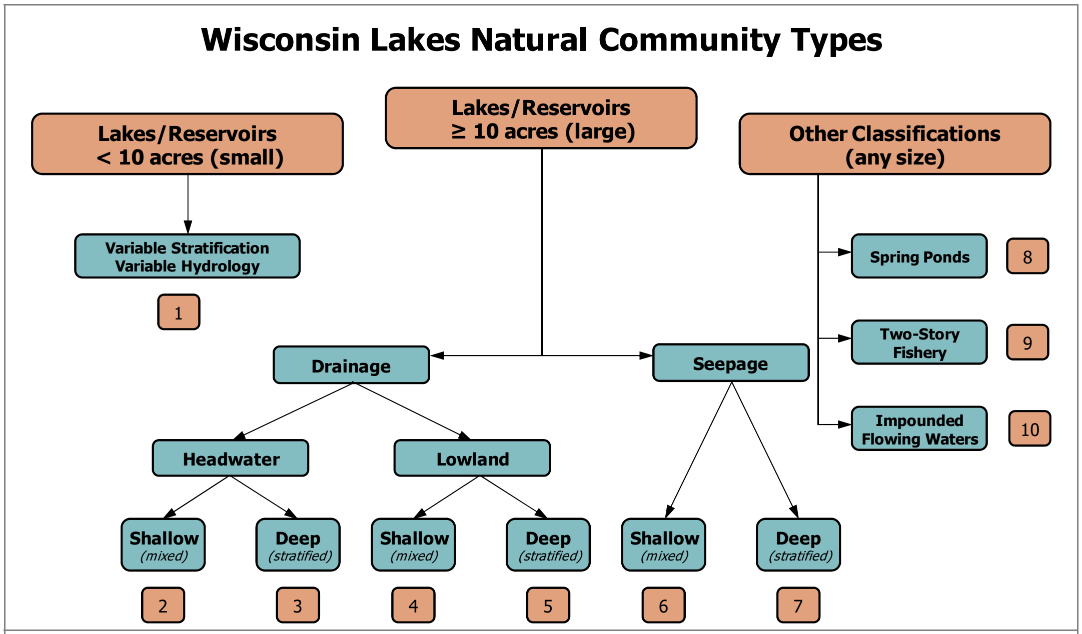


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. Lost Lake is within the Northern Lakes and Forests (NLF) ecoregion.

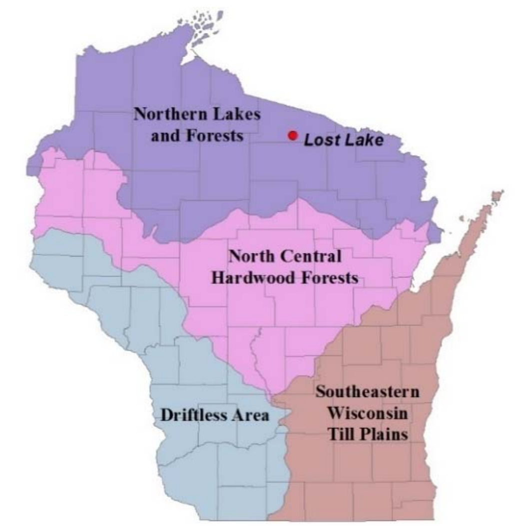


Figure 3.1-2. Location of Lost Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2018 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Lost Lake is displayed in Figures 3.1-3 - 3.1-12. 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.

Lost Lake Water Quality Analysis

Lost Lake Long-term Trends

As discussed previously, three water quality parameters are of most interest when assessing a lake's water quality: total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Volunteers from Lost Lake participating in the Citizens Lake Monitoring Network (CLMN) have been collecting some of these parameters intermittently since 1993, building a continual dataset that will yield valuable information on Lost Lake's water quality through time.

Total Phosphorus

Near-surface total phosphorus data from Lost Lake are available from 1979 and then for nearly every year from 1997-2010. After 2010 data is only available for 2017 (Figure 3.1-3).

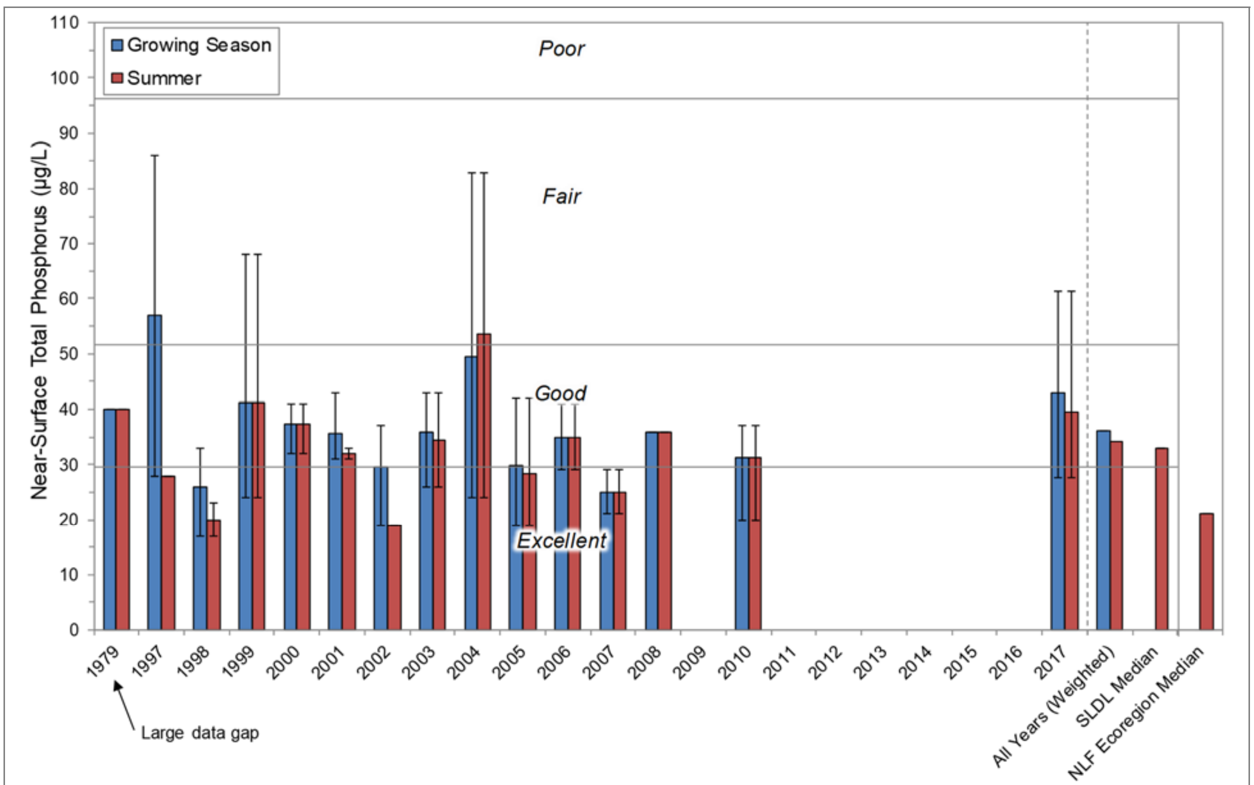


Figure 3.1-3. Lost Lake, state-wide shallow lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

During the period of record, average summer total phosphorus concentrations ranged from 19 µg/L in 2002 to 54 µg/L in 2004; however, it should be noted that the two summer near-surface total phosphorus concentration samples collected in 2004 were very different which implies these data may not be representative of the summer average. The weighted summer average total phosphorus concentration is 34 µg/L and falls into the *good* category for shallow lowland drainage lakes in Wisconsin. Lost Lake's total phosphorus concentrations are similar to the median value for shallow lowland drainage lakes in the state and are considerably higher than the median value for all lake types in the NLF ecoregion which is 21 µg/L.

Chlorophyll-α

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algal growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within a lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance.

Chlorophyll-*a* data are available from Lost Lake from 1979 and then for nearly every year from 1997-2010. After 2010 data is only available for 2017 (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 3 µg/L in 1998 to 24 µg/L in 2010. The weighted summer average chlorophyll-*a* concentration is 13 µg/L and falls into the *good* category for Wisconsin's shallow lowland drainage lakes. Lost Lake's summer average chlorophyll-*a* concentration is higher than the median value for other shallow lowland drainage lakes in the state and is over two times higher than the median value for all lake types in the NLF ecoregion.

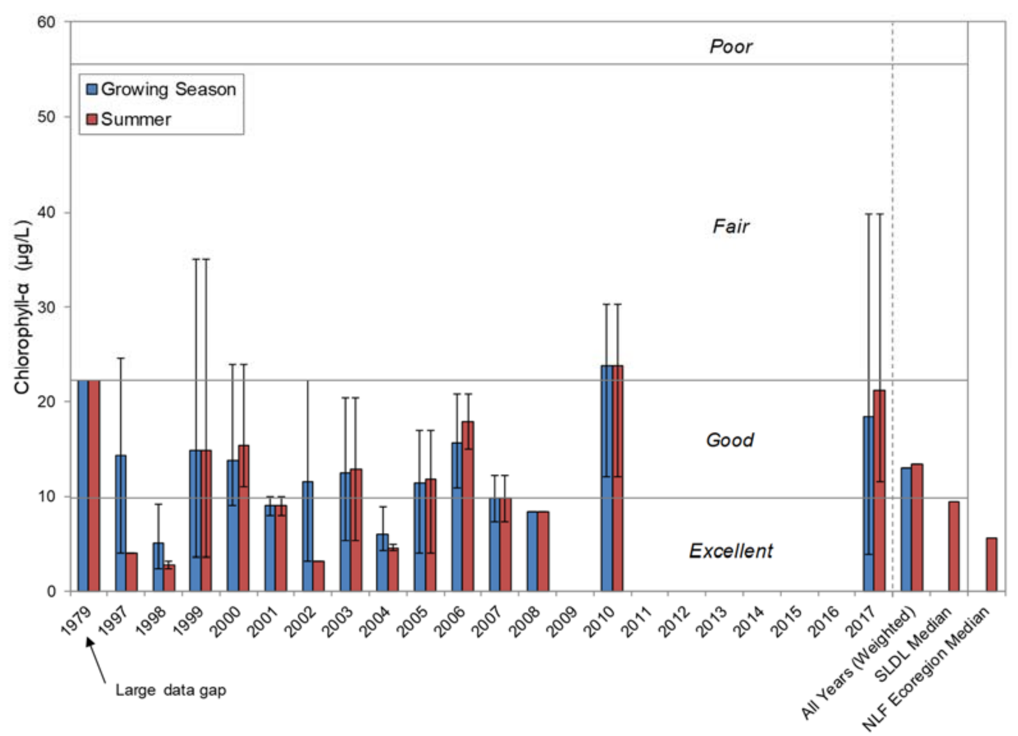


Figure 3.1-4. Lost Lake, state-wide shallow lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

Secchi disk transparency data are available from Lost Lake for most of the same years as phosphorus and chlorophyll-*a* (Figure 3.1-5). Average summer Secchi disk depths ranged from 4.5 feet in 1979 to 11.3 feet in 1995; however, it should be noted that only one summer Secchi disk depth measurement was collected in 1979 and may not be representative of the summer average. The weighted summer average Secchi disk depth is 7 feet and falls into the *excellent* category for Wisconsin's shallow lowland drainage lakes. Lost Lake's weighted summer average Secchi disk depth exceeds the median value for shallow lowland drainage lakes in the state but is shallower than the median value for all lake types in the NLF ecoregion.

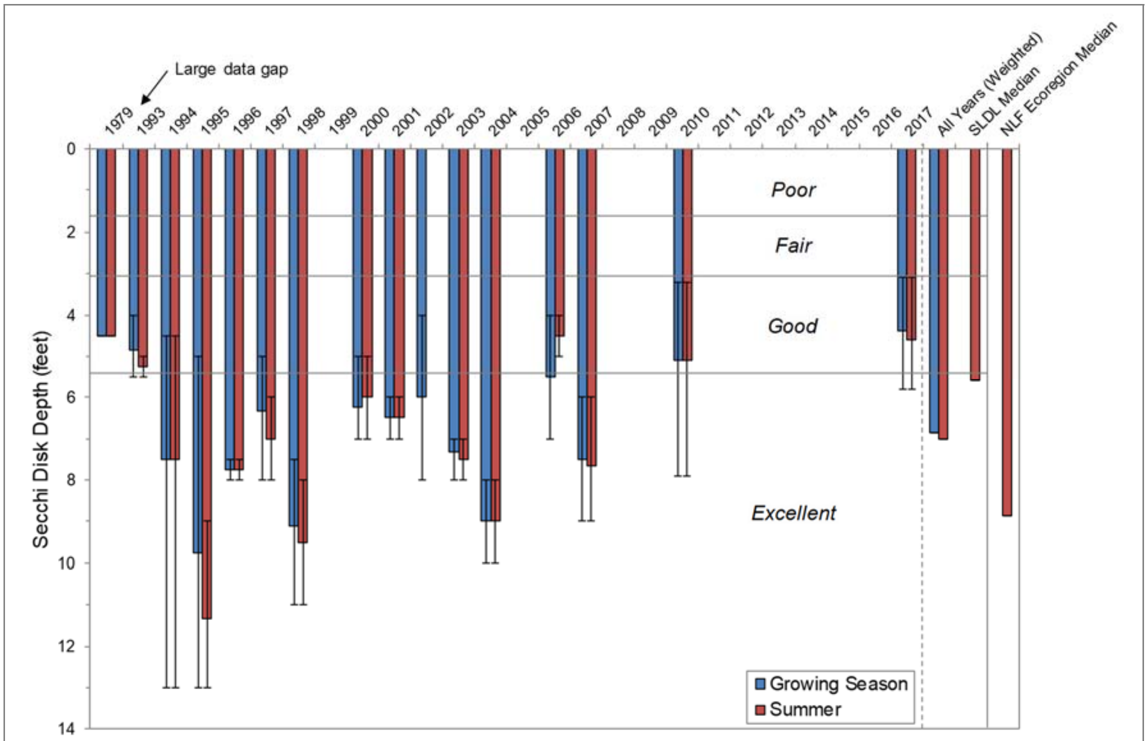


Figure 3.1-5. Lost Lake, state-wide shallow lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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. 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 Lost Lake in 2017 averaged 30 SU (standard units) indicating

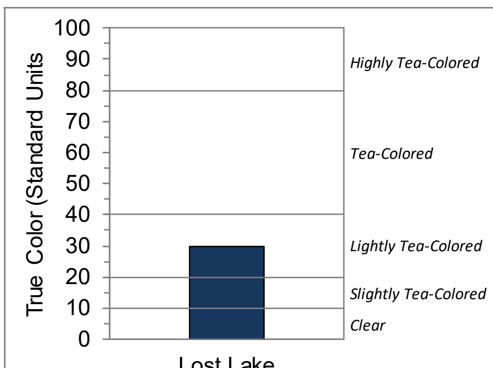


Figure 3.1-6. Lost Lake true color value.

the lake's water is *lightly tea-colored* and that the lake's water clarity is slightly influenced by dissolved components in the water (Figure 3.1-6).

Lost Lake's water clarity can vary significantly from year to year, with some annual growing season Secchi disk readings averaging 9 or more feet while other years, like 2017, averaging 4.4 feet. The water clarity of Lost Lake is largely driven by free-floating algae but also impacted by dissolved humic substances and organic acids which give the lake a light tea color in some years (30 SU in 2017).

The large amount of early season rains delivered increased nutrients and organic acids to the lake that greatly impacted water clarity during 2017. While historic water clarity data is a little spotty, data exists from 15 individual years going back to 1990. The data indicate that 2017 had the lowest average growing season Secchi disk transparency values of this dataset. Water clarity values early in the growing season (April-June) were 4 feet lower than the historic average of 7.5-9 feet (Figure 3.1-7) indicating that the lower water clarity was not a result of warm water algal growth. During June 2017 both chlorophyll-*a* and phosphorus concentrations were higher than in most other years supporting the hypothesis that reduced water clarity in 2017 was because of the high runoff in 2017. Reduced water clarity as the season progresses suggests internal nutrient recycling. This is explored below.

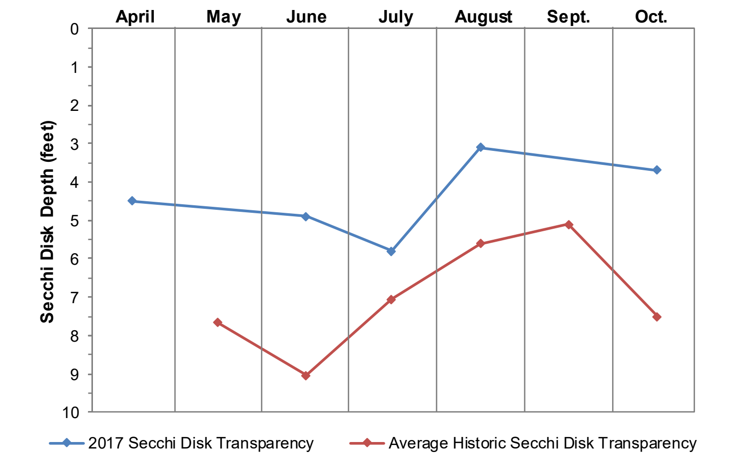


Figure 3.1-7. Average monthly Secchi disk transparency values from Lost Lake

Limiting Plant Nutrient of Lost Lake

Using the 2017 midsummer nitrogen and phosphorus concentrations from Lost Lake, a nitrogen:phosphorus ratio of 14:1 was calculated and in 2010 it was 19:1. This finding indicates that Lost Lake is phosphorus limited as are the vast majority of Wisconsin lakes; however, with large phosphorus inputs the lake could transition to being nitrogen limited. In general, this means that cutting both phosphorus and nitrogen inputs may limit plant growth within the lake.

Lost Lake Trophic State

Figure 3.1-8 contains the weighted average Trophic State Index (TSI) values for Lost Lake. 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 the biological parameters of chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds in the water. The closer the calculated TSI values for these three parameters are to one another, a higher degree of correlation is indicated.

Historically on Lost Lake, only Secchi depth readings were collected in some years (1993-1996), only total phosphorus and chlorophyll-*a* in some years (1999, 2002, 2008), and all three trophic parameters were sampled in other years. When comparing the weighted average of each parameters, the water clarity data appeared to have a decoupled relationship with the biological parameters. Lost Lake experiences a wide range of annual productivity, likely driven by increased nutrients during some years from increased precipitation (quantity and frequency of large storm events) and the influence of aquatic macrophytes and zooplankton. Therefore, it is more appropriate to only compare data from years where all three parameters were sampled. The weighted average of the historical data from Lost Lake for years when all three parameters have been sampled indicates a relatively close relationship between the parameters. This weighted average TSI for total phosphorus and Secchi depth are nearly the same (50.6 vs 50.0). The TSI calculation for chlorophyll-*a*, indicates a slightly more productive lake (53.1).

Based upon the weighted average, it can be concluded that Lost Lake is in a lower eutrophic state but ranges from mesotrophic to eutrophic. Lost Lake's weighted average TSI values indicate it has similar productivity to other shallow lowland drainage lakes in Wisconsin and is more productive than the majority of all lakes in the NLF ecoregion.

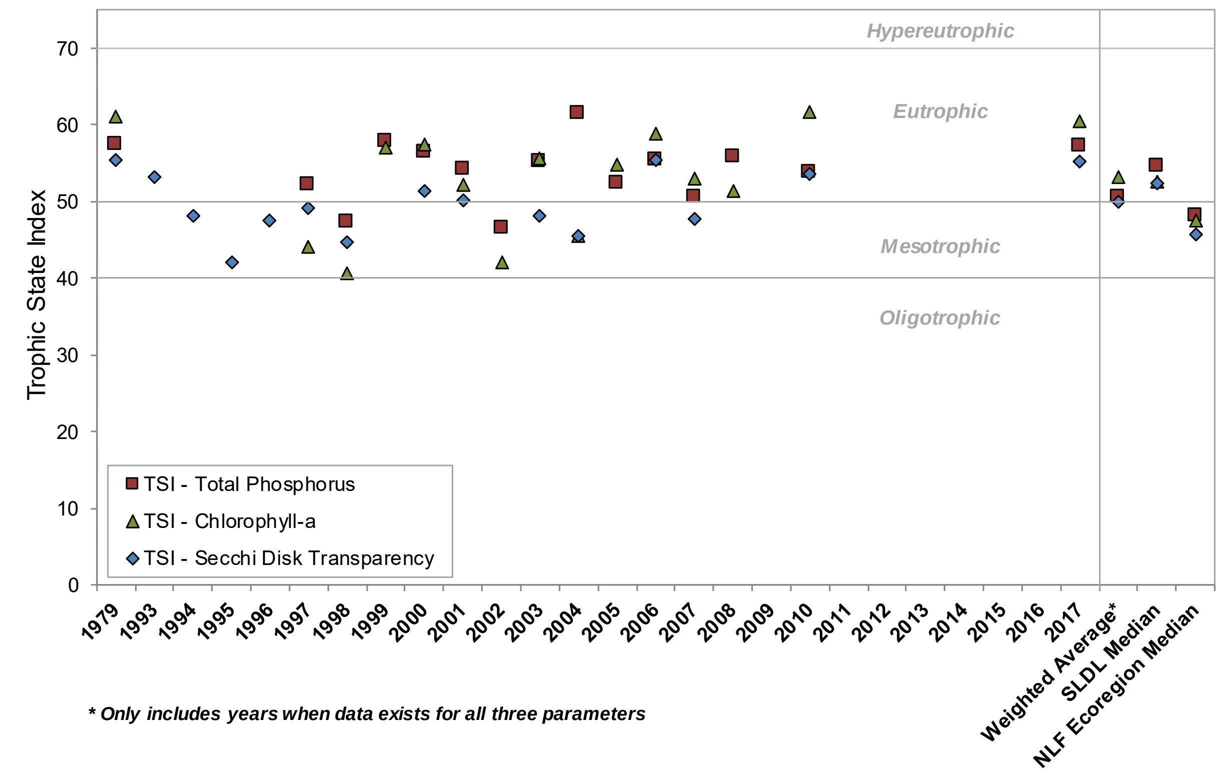


Figure 3.1-8. Lost Lake, state-wide shallow lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Lost Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Lost Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-9. Lost Lake is polymictic [lakes that are too shallow to thermally stratify and can mix throughout the growing season] and the temperature at the bottom was almost 20°C in July 2017, indicating that the lake frequently mixes (Figure 3.1-9).

During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. The data also indicate that there was sufficient oxygen throughout most of the water column under the ice to support the fishery during late-winter sampling (Figure 3.1-9).

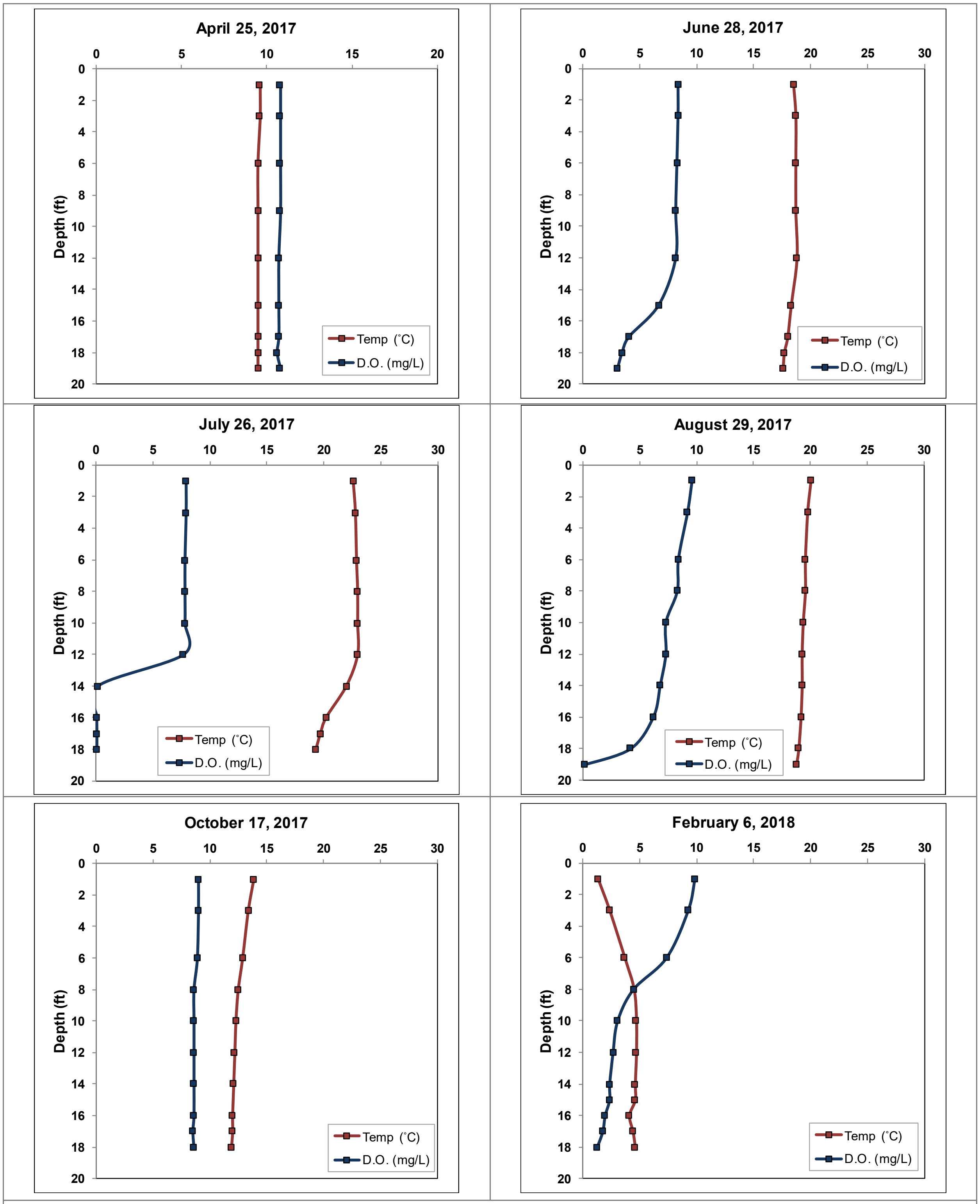


Figure 3.1-9. Lost Lake dissolved oxygen and temperature profiles.

Internal Nutrient Loading

Lakes that experience stratification, or form a distinct cooler, dense layer of water near the bottom (hypolimnion) and a warmer, less dense layer at the surface (epilimnion) may experience internal phosphorous loading. During stratification, due to differences in water temperature and thus density, the hypolimnion becomes isolated and does not mix with the oxygen-rich epilimnion. Without oxygen input from the atmosphere or plants, decomposition of organic material within the hypolimnion utilizes the remaining dissolved oxygen and the hypolimnion becomes anoxic, or devoid of oxygen. When the hypolimnion experiences anoxia, phosphorus bound within the sediment is released into the hypolimnetic waters.

If the lake remains stratified, the phosphorus released into the hypolimnion does not mix into the epilimnion until fall during turnover. At this time, the metabolism of organisms within the lake, including algae, has slowed, and the release of phosphorus from the hypolimnion into the epilimnion in fall may have little to no impact on the lake's productivity. Lakes that remain stratified over the course of summer and experience only two turnover events, one in spring and fall, are termed *dimictic* lakes. However, in some lakes that are relatively shallow or have larger surface area, stratification can be broken multiple times throughout the summer and phosphorus that was released into the anoxic hypolimnion from bottom sediments is mixed up into the epilimnion. Because this occurs during summer, this phosphorus fuels actively growing algae and can create noxious algae blooms. Lakes that tend to break stratification and mix multiple times during the summer are termed *polymictic* lakes. While both dimictic and polymictic lakes experience internal phosphorus loading, the impact it has on the lake's water quality and productivity depends on the timing of phosphorus delivery from the hypolimnion to the epilimnion. As discussed in the previous sub-section, Lost Lake is polymictic.

During the July 2017 sampling, the bottom waters contained no oxygen. This was not the case in August (Figure 3.1-9), implying that the lake had mixed between these dates. When the lake mixed the higher phosphorus level in bottom waters would be mixed into the surface water allowing uptake by algae. In many years, chlorophyll-*a* levels are higher in August compared with June or July.

In polymictic lakes, the frequent delivery of phosphorus from the hypolimnion to the epilimnion generally results in near-surface total phosphorus concentrations increasing over the course of the summer (Robertson et al. 2012). In many years, there was a large increase in phosphorus from early and mid-summer to August, particularly in 1997, 1999, 2004, and 2017 (Figure 3.1-10). In 2017 the average concentration in June and July was 28 µg/L but by late August the concentration had increased to 60 µg/L and this concentration was also present in October. Although internal phosphorus loading likely occurs annually to some extent in Lost Lake, it is believed that differences in early-season thermal stratification in specific years led to the higher phosphorus concentrations.

Another potential source that could cause increases in total phosphorus, particularly in mid-summer as is observed in Lost Lake, is the presence of a curly-leaf pondweed population. As is discussed further in the Aquatic Plant Section, curly-leaf pondweed was recently documented from Lost Lake. Unlike many of our native aquatic plants, curly-leaf pondweed begins growing immediately after ice-out and reaches its peak growth in mid- to late-June and then naturally senesces (dies back) in early summer. The senescence of curly-leaf pondweed populations has been shown to release a significant amount of phosphorus into the water from decomposing plant tissues (Leoni et al. 2016). Modeled using the quantities and densities of curly-leaf pondweed from the 2016 survey, an estimated 51 pounds of phosphorus could be added to the water column. However, the location of the main curly-leaf pondweed population is in front of the Lost Lake outlet. Based on the herbicide concentration data collected in association with the 2017 and 2018 spot treatments, it is likely that the majority of these nutrients are sent downstream as opposed to contributing to the overall phosphorus concentration of the lake. If curly-leaf pondweed populations of similar size and density were located in the eastern part of the lake, its natural mid-summer die-off could be a source of nutrient loading.

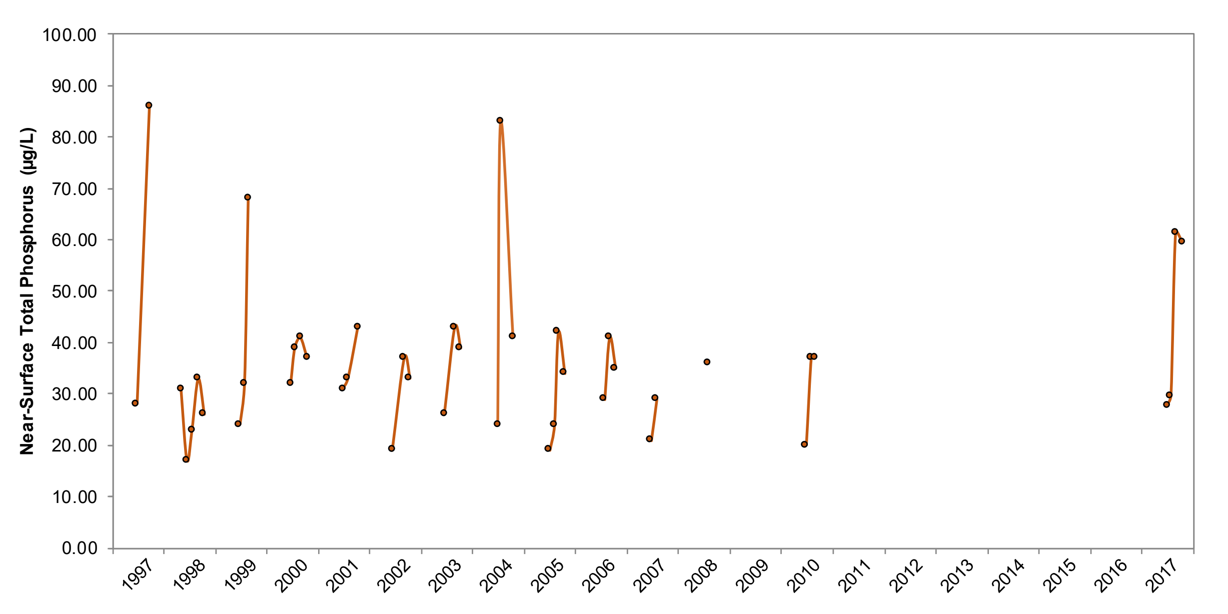


Figure 3.1-10. Lost Lake near-surface total phosphorus concentrations from 1997 – 2017.

Additional Water Quality Data Collected at Lost Lake

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

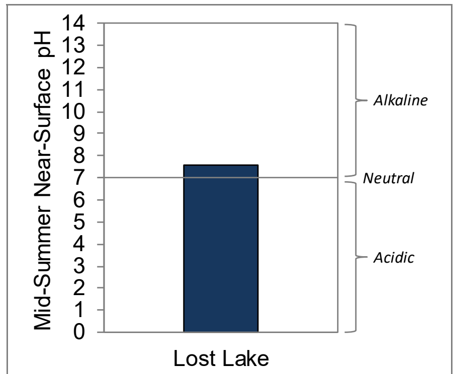


Figure 3.1-11. Lost Lake mid-summer near-surface pH value.

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 Lost Lake was found to be near neutral with a value of 7.6, and falls within the normal range for Wisconsin Lakes (Figure 3.1-11).

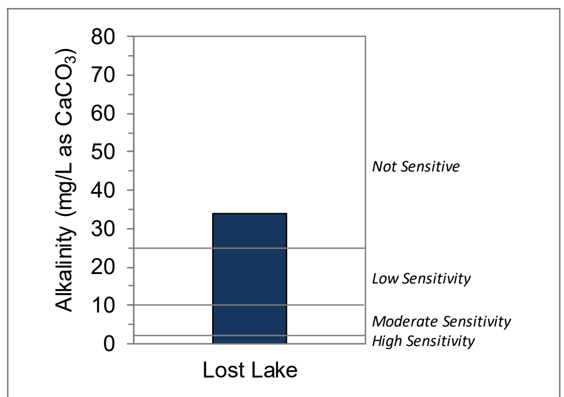


Figure 3.1-12. Lost Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 Lost Lake was measured at 34.0 (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 (Figure 3.1-12).

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 Lost Lake's pH of 7.6 falls inside this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Lost Lake was found to be 9.4 mg/L, falling below the optimal range for zebra mussels (Figure 3.1-13).

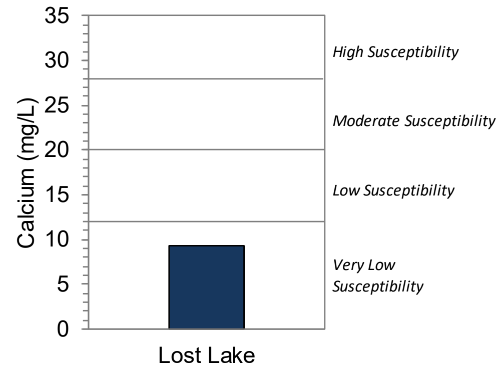


Figure 3.1-13. Lost Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

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

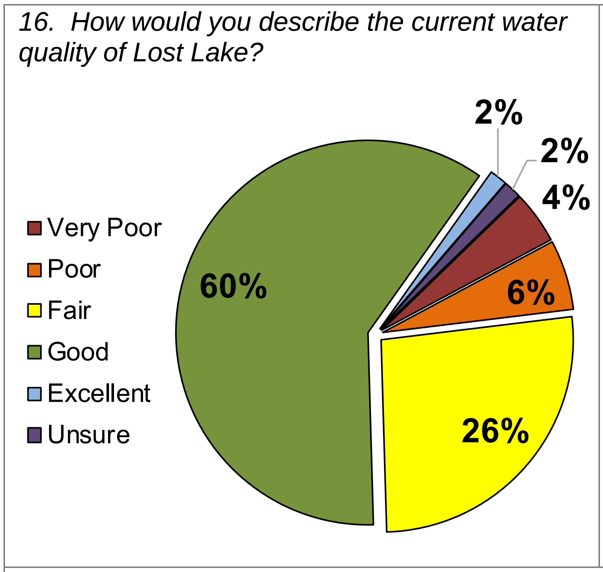
Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is 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, Lost Lake was considered not suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Lost Lake in 2017 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 2017 surveys.

Riparian Stakeholder Survey Responses to Lost Lake Water Quality

As discussed in section 2.0, the riparian stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Of the 189 surveys distributed, 71 (38%) 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 Lost Lake but cannot be stated with statistical confidence.

Figure 3.1-13 displays the responses of Lost Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Lost Lake. When asked how they would describe the current water quality of Lost Lake the majority of respondents, 60%, indicated *good*, 26% indicated *fair*, 6% indicated *poor*, 4% indicated *very poor*, 2% indicated they were *unsure*, and 2% indicated *excellent*.

When asked how they believe the current water quality has changed since they first visited the lake, 38% indicated it has *somewhat degraded*, 31% indicated it has *remained the same*, 12% indicated they were *unsure*, 9% indicated it has *severely degraded*, 7% indicated it has *somewhat improved*, and 3% indicated it has *greatly improved* (Figure 3.1-14). As discussed in the previous section, Lost Lake has good water quality. The proportion of stakeholder respondents who indicated the lake's water quality has somewhat or severely degraded may be taking into account the growth of invasive curly-leaf pondweed and Eurasian watermilfoil in the lake or the decline of native vegetation in the lake, which is discussed further in the Aquatic Plant Section (Section 3.4).



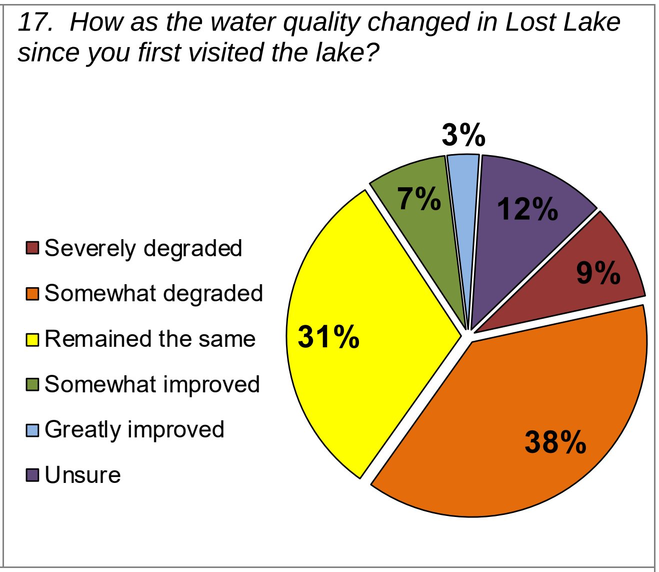


Figure 3.1-14. Lost Lake riparian stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Watershed Assessment

Primer on 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.

Lost Lake Watershed Assessment

Lost Lake's total watershed encompasses an area of approximately 11,602 acres, yielding a watershed to lake area ratio of 20:1 (Map 2). In other words, approximately 20 acres of land drain to every one acre of Lost Lake. According to WiLMS modeling, the lake's water is completely replaced approximately every 179 days (residence time) or 2 times per year (flushing rate).

When one lake feeds into another and phosphorus data are available from the upstream lake, the upstream lake can be modeled as a point source for the downstream lake. These lakes are modeled in series, with phosphorus outflow from the upstream lake estimated using total phosphorus concentrations and by estimating how much water is draining from the upstream lake to the downstream lake. For modeling purposes, the lake's watershed was divided into three main subwatersheds: Lost Lake's direct watershed, Stella Lake's subwatershed, and Found Lake's subwatershed (Map 2). Approximately 47% of Lost Lake's total watershed is composed of Stella Lake's subwatershed, 27% of Found Lake's subwatershed, and 26% of its own direct watershed (Figure 3.2-1).

Approximately 39% of Lost Lake's direct watershed is composed of forest, 30% of wetlands (forested and non-forested), 19% of Lost Lake's surface, 12% of pasture/grass, 1% of row crop agriculture, and less than 0.5% of rural residential areas (Figure 3.2-1). Similarly, Stella and Found lakes watersheds is dominated by forest and wetlands.

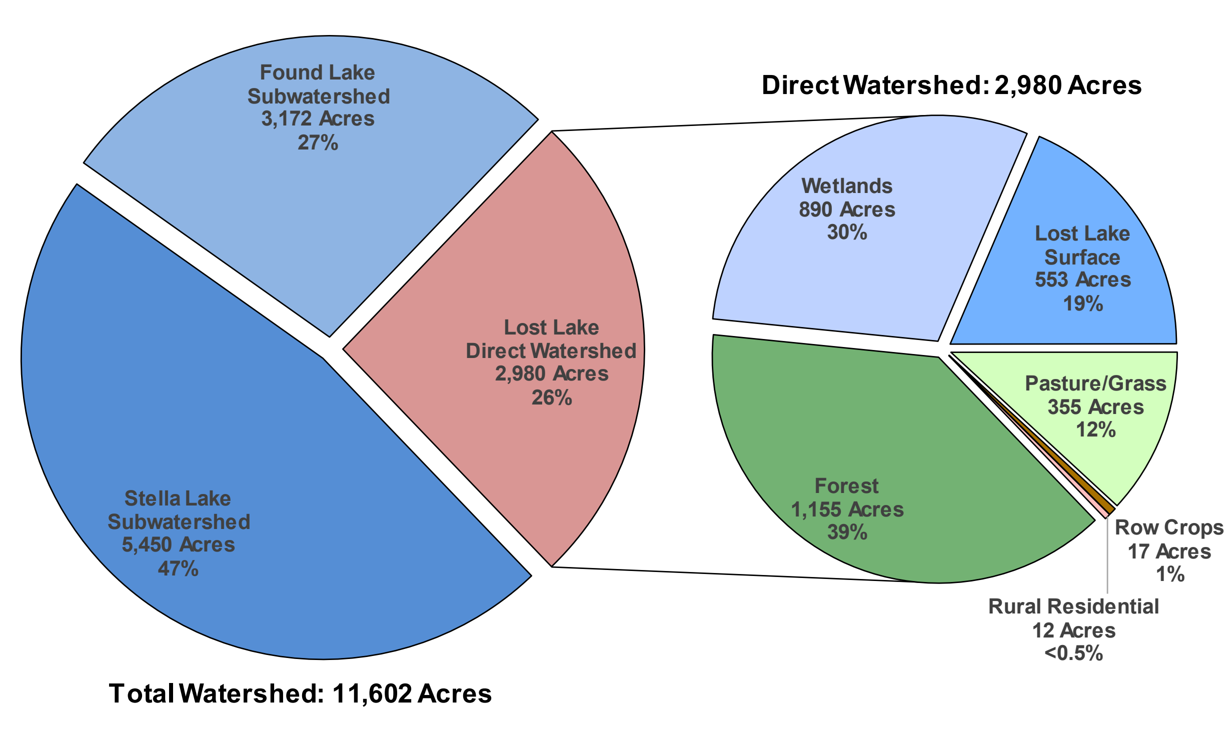


Figure 3.2-1. Lost Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the landcover described above, WiLMS was utilized to estimate the annual potential phosphorus load from Lost Lake's direct watershed and the estimated outflow from Stella and Found lakes subwatersheds. It was estimated that approximately 1,606 pounds of phosphorus is delivered to Lost Lake from its watershed on an annual basis (Figure 3.2-2). Phosphorus loading from septic systems was also estimated using data obtained from the 2017 riparian stakeholder survey of riparian property owners, and indicates that approximately 13 pounds, or roughly 1% of the annual phosphorus load is attributed to septic systems.

Of the estimated 1,606 pounds being delivered annual to Lost Lake, 61% is estimated to originate from Stella Lake's subwatershed,28% from Lost Lake's direct watershed, and 11% from Found Lake's subwatershed (Figure 3.2-2). Within the direct watershed, 33% is estimated to originate through direct atmospheric deposition into the lake, 21% from pasture/grass, 21% from forest, 18% from wetlands, 3% from row crop agriculture, and 3% from septic systems.

Using predictive equations, WiLMS estimates that based on the potential annual phosphorus load, Lost Lake should have a growing season mean total phosphorus concentration of approximately 28 µg/L. This predicted concentration is slightly lower than the measured growing season mean total phosphorus concentration of 36 µg/L and indicates the model is underestimating the amount of phosphorus being delivered to Lost Lake on an annual basis.

This is further evidence that some internal loading of phosphorus is occurring in Lost Lake. In most years phosphorus concentrations increase from early to late summer. This is common in shallow lakes like Lost Lake as phosphorus is released from the bottom sediments when the bottom waters become devoid of oxygen as is discussed in the Water Quality Section (3.2).

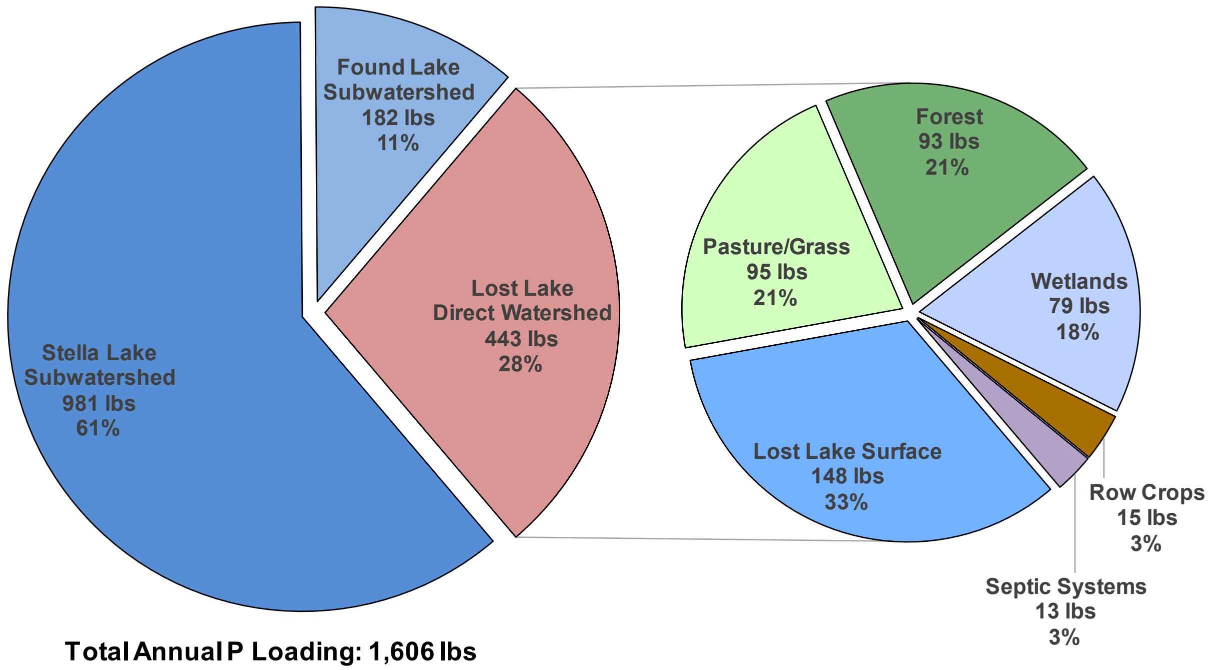


Figure 3.2-2. Lost Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition

Primer on Lake Shoreland Zone and its Importance

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more protective 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, more protective, 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 understanding led former Governor Jim Doyle into passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale, and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1 2010, use of this type of fertilizer is prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

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

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.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forwards shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program is divided based upon the location of the enhancement activity: 1) in-lake, 2) transition zone, and 3) upland. A sub-category of the WDNR Surface Water Grant Program was created to assist landowners with funding, with applications due on February 1st of each year. More information on this program can be found here: https://healthylakeswi.com/

Lost Lake Shoreland Zone Condition

Shoreland Development

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

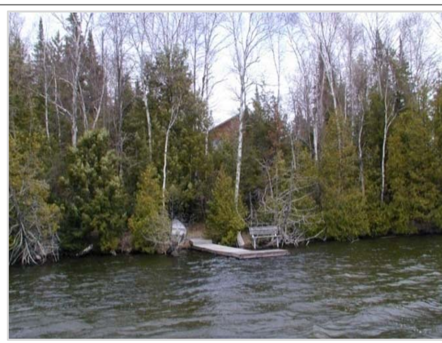
On Lost Lake, the development stage of the entire shoreland was surveyed during fall of 2017, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, 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.

Lost Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.4 miles of natural/undeveloped and developed-natural shoreland were observed during the survey, of which 0.3 miles are state owned land (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.4 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Lost Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

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.

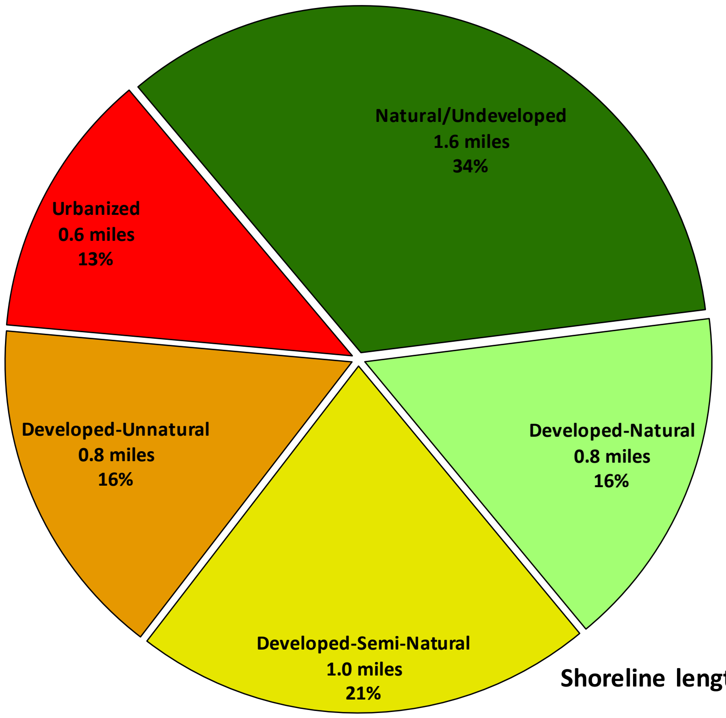


Figure 3.3-2. Lost Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, 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

As part of the shoreland condition assessment, Lost Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, >8 inches in diameter, and cluster of pieces) 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).

During this survey, 101 total pieces of coarse woody habitat were observed along 4.8 miles of shoreline (Map 4), which gives Lost Lake a coarse woody habitat to shoreline mile ratio of 21:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 101 total pieces of coarse woody habitat observed during the survey, 79 pieces were 2-8 inches in diameters, 22 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found.

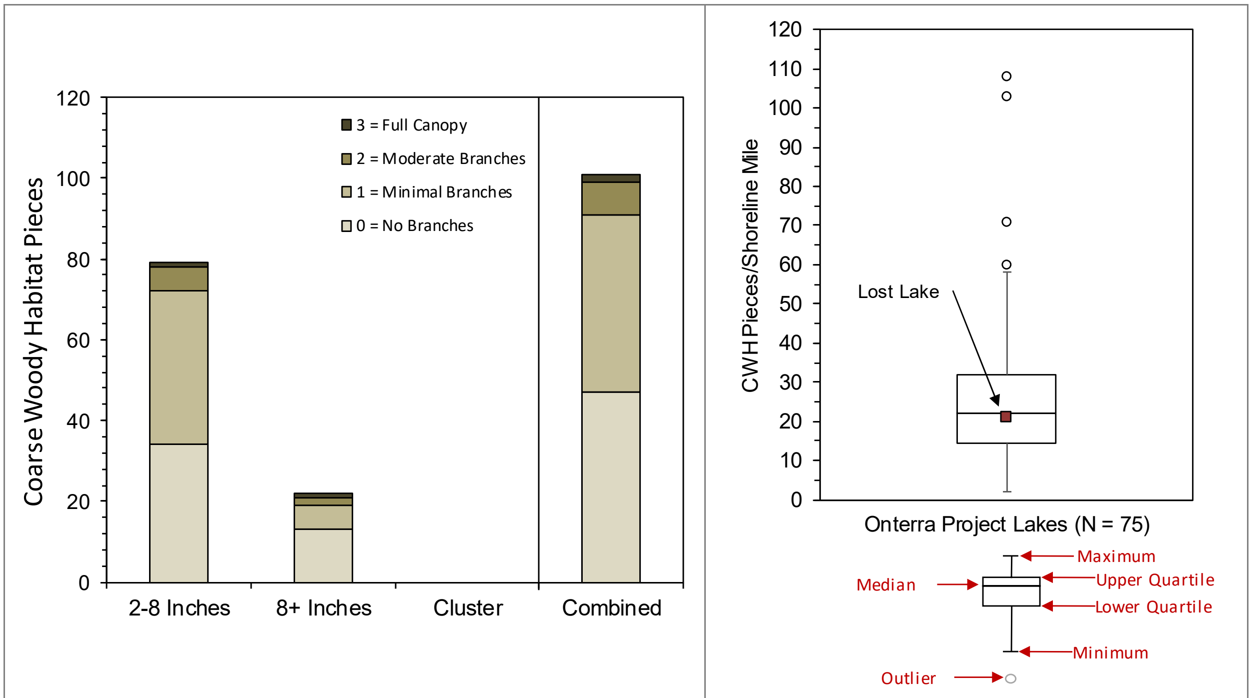


Figure 3.3-3. Lost Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Lost Lake coarse woody habitat can be found on Map 4.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Lost Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 75 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Lost Lake fell into the 45th percentile of these 75 lakes (Figure 3.3-3).

3.4 Aquatic Plants

Introduction to Aquatic Plants

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 watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These species will be discussed further in depth in the Aquatic Invasive Species section. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal (Hand-Harvesting & DASH)

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

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

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

Cost

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

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

Mechanical Harvesting


Photograph 3.4-3. 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 3.4-1. Common herbicides used for aquatic plant management.

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen-benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

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

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

Cost

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

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

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations 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.

Primer on Data Analysis & Data Interpretation

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Lost Lake; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Lost Lake. 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 Lost Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

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

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

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Lost Lake to be compared to other lakes within the region and state.

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

Species Diversity

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

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. However, in a recent study of 1,100 Minnesota lakes, researches concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018). 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 Lost Lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes within the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

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

Exotic Plants

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

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it often does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. In some situations, Eurasian watermilfoil integrates itself into the native plant community without causing wide-scale ecological impacts nor impacts to human uses of the lake.

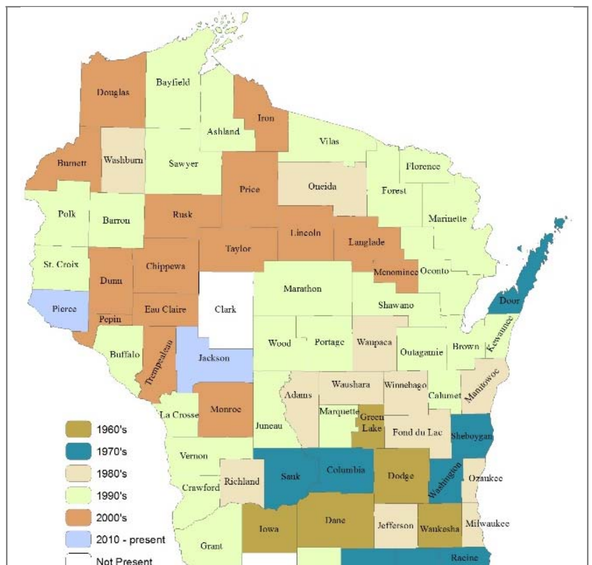


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011.

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

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 aquatic plant survey completed in mid to late summer.

Lost Lake Aquatic Plant Survey Results

Included as a part of this lake management planning project were several surveys with a purpose of assessing the aquatic plant population in Lost Lake. These field surveys, completed in 2017, included an Early Season AIS Survey, a whole-lake point-intercept survey, a community mapping survey and an acoustic survey. Additional plant survey data collected both before and after the 2017 surveys are also discussed in the following narrative. A total of 58 species of plants have been located in Lost Lake during aquatic plant surveys completed between 2007 and 2018 of which two are considered non-native species: Eurasian watermilfoil and curly-leaf pondweed (Table 3.4-2). Because the non-native plants found in Lost Lake have the ability to negatively impact lake ecology, recreation, and aesthetics, the populations of these plants are discussed in greater detail later within this report. 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.

An Early-Season AIS Survey has been completed on Lost Lake annually from 2014-2018. These meander-based, visual surveys focus on locating and mapping potential occurrences of curly-leaf pondweed. The whole-lake aquatic plant point-intercept surveys have been completed on Lost Lake in 2007, 2010, 2014, 2017, and 2018. Emergent and floating-leaf aquatic plant community mapping surveys were conducted on Lost Lake during August 2017.

On September 26-27, 2017, Onterra ecologists completed an acoustic survey on Lost Lake. In addition to water depths, this sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. The acoustic survey also records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Table 3.4-2. Aquatic plant species located on Lost Lake during the 2007, 2010, 2014, and 2017 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2007 (WDNR)	2010 (Onterra)	2014 (WDNR)	2017 (Onterra)	2018 (Onterra
Emergent	*Calla palustris*	Water arum	9				I	
	Carex utriculata	Common yellow lake sedge	7				I	
	Decodon verticillatus	Water-willow	7				I	
	Eleocharis palustris	Creeping spikerush	6			I	I	
	Iris versicolor	Northern blue flag	5				I	
	Pontederia cordata	Pickerelweed	9	I	X	I	I	
	Sagittaria latifolia	Common arrowhead	3				I	
	Sagittaria sp. (sterile)	Arrowhead sp	N/A				I	
	Schoenoplectus acutus	Hardstem bulrush	5			X	I	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I	X			
	Sparganium eurycarpum	Common bur-reed	5				I	
	Typha spp.	Cattail spp.	1			I	I	
FL	*Nuphar variegata*	Spatterdock	6	X	X	X	X	X
	Nymphaea odorata	White water lily	6	X		I	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	9				I	
	Sparganium fluctuans	Floating-leaf bur-reed	10				I	
Submergent	*Bidens beckii*	Water marigold	8		X	X	X	X
	Callitriche palustris	Common water starwort	8				I	
	Ceratophyllum demersum	Coontail	3	X	X	X	X	X
	Chara spp.	Muskgrasses	7	X	X	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	X	X	X
	Eriocaulon aquaticum	Pipewort	9					X
	Heteranthera dubia	Water stargrass	6	X		X	X	X
	Isoetes spp.	Quillwort spp.	8	X	X	X	X	X
	Lobelia dortmanna	Water lobelia	10		X			
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X	X
	Myriophyllum sp.	Watermilfoil sp.	N/A			X		
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive			I	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	10					X
	Myriophyllum verticillatum	Whorled water milfoil	8		X			
	Najas flexilis	Slender naiad	6	X	X	X	X	X
	Nitella spp.	Stoneworts	7		X			
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X	X
	Potamogeton berchtoldii	Slender pondweed	7			X		I
	Potamogeton crispus	Curly-leaf pondweed	Exotic/Invasive			I	X	X
	Potamogeton epihyydrous	Ribbon-leaf pondweed	8					I
	Potamogeton foliosis	Leafy Pondweed	6	X				
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X	X	X	
	Potamogeton illinoensis	Illinois pondweed	6					
	Potamogeton praelongus	White-stem pondweed	8	X	X	X	X	X
	Potamogeton pusillus	Small pondweed	7	X	X	X		
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8				I	
	Potamogeton strictifolius	Stiff pondweed	8		X			
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X			X
	Ranunculus aquatilis	White water crowfoot	8	X				
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A		X		X	X
	Stuckenia pectinata	Sago pondweed	3		X	X	X	
	Utricularia vulgaris	Common bladderwort	7					X
	Vallisneria americana	Wild celery	6	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X	X	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X	X		
	Sagittaria sp.	Arrowhead sp.	N/A	X				
	Sparganium emersum var. acaule	Short-stemmed bur-reed	8			I		
FF	*Lemna trisulca*	Forked duckweed	6					X
	Lemna turionifera		2			I		X
	Spirodela polyrhiza		5			I		

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

Data regarding substrate hardness collected during the 2017 acoustic survey revealed that Lost Lake's average substrate hardness ranges from hard to moderately hard with deeper areas containing softer sediments (Figure 3.4-2). On average, the hardest substrates (sand/rock/gravel) are found within 1 to 7 feet of water. The greatest transition between hard and softer substrates is found between 7 and 12 feet of water, with hardness declining rapidly with depth. In 12 feet of water and deeper, substrate hardness remains relatively constant. Figure 3.4-3 illustrates the spatial distribution of substrate hardness in Lost Lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

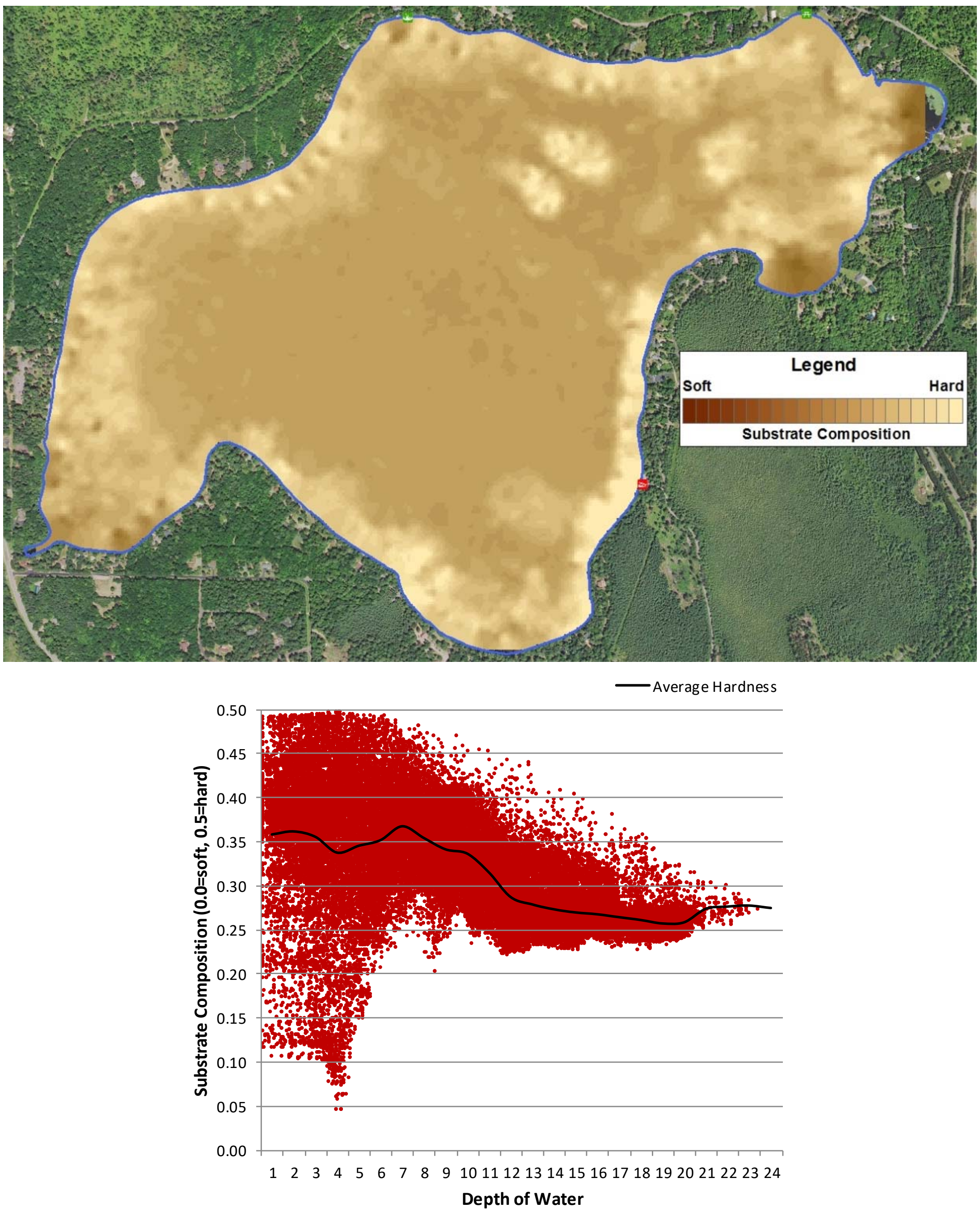


Figure 3.4-3. Lost Lake spatial distribution of substrate hardness (top) and substrate hardness across water depth (bottom). Individual data points are displayed in red. Created using data from September 2017 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire system. The 2017 aquatic plant bio-volume data are displayed in Figure 3.4-3. Areas where aquatic plants occupy most or the entire water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2017 acoustic survey indicates that approximately 19% of Lost Lake contains aquatic vegetation (Figure 3.4-4).

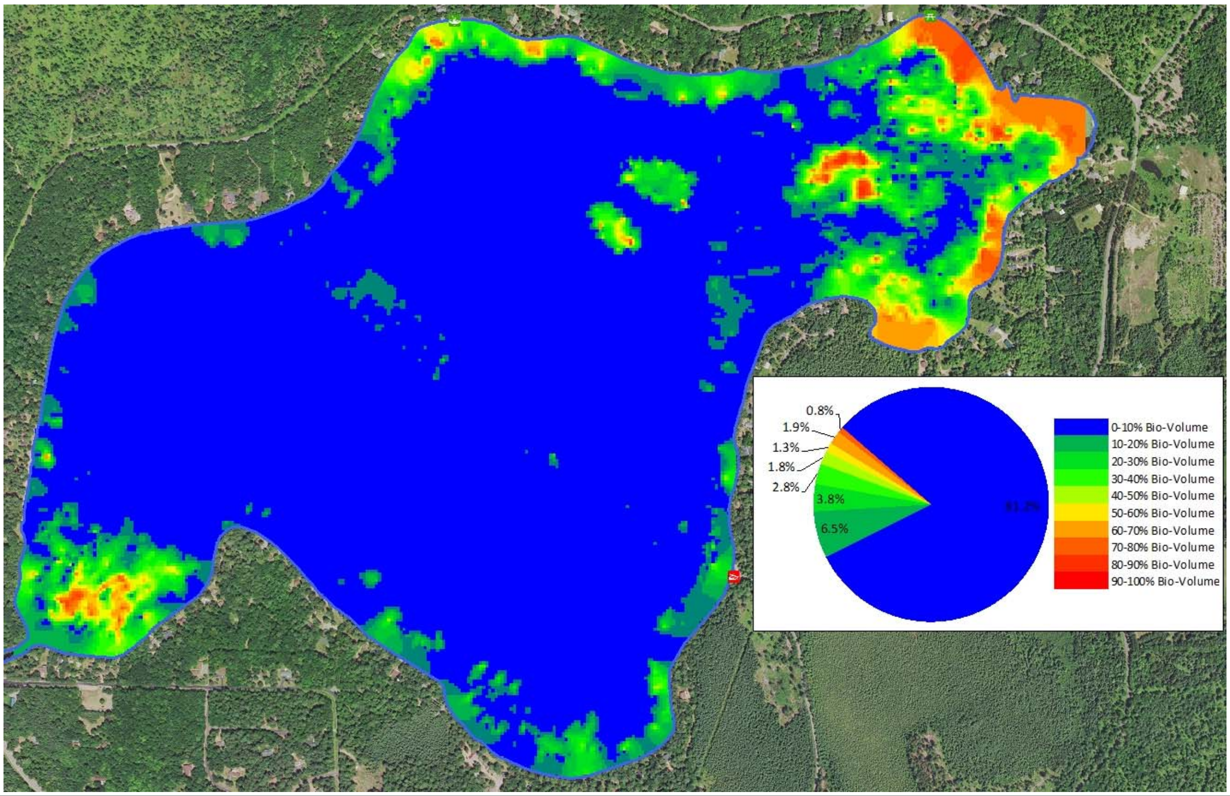


Figure 3.4-4. Lost Lake 2017 aquatic plant bio-volume. Created using data from September 2017 acoustic survey.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species comprise the aquatic plant community. Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 159 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in Lost Lake in 2018, approximately 52% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2018 indicates that 31% of the 159 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 13% had a TRF rating of 2, and 8% had a TRF rating of 3 (Figure 3.4-5). The TRF data indicates that where aquatic plants are present in Lost Lake, they are moderately sparse. Total rake fullness levels in 2017 and 2018 were fairly similar however remain lower than previous surveys completed in 2007, 2010 & 2014 (Figure 3.4-5

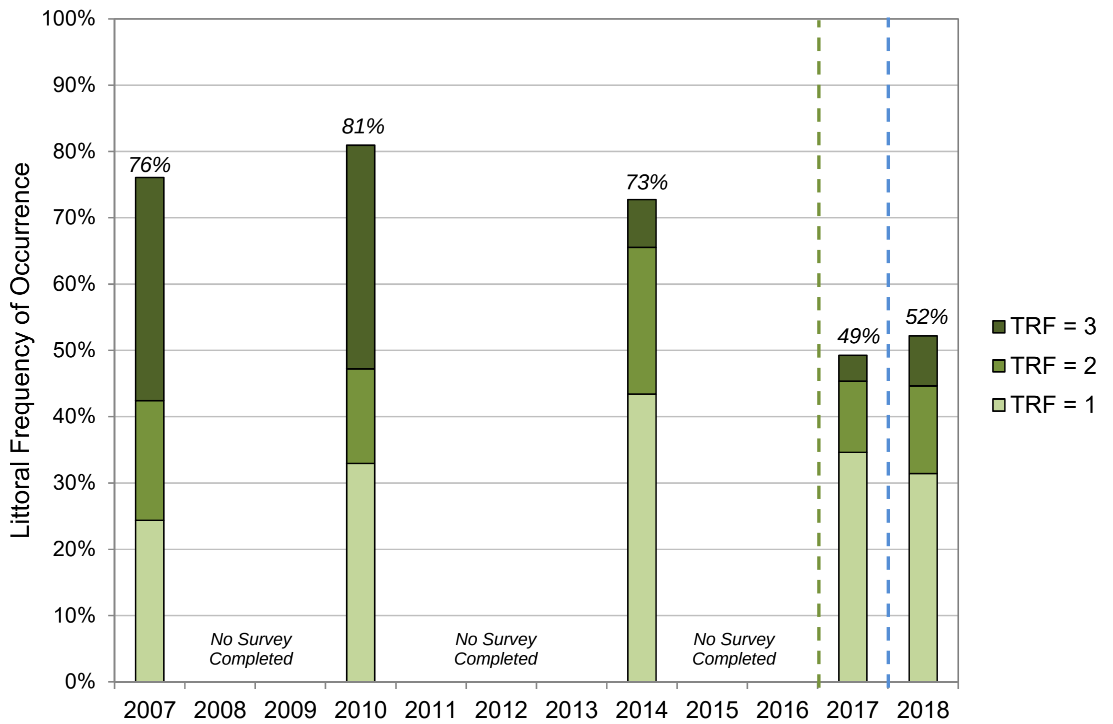


Figure 3.4-5. Lost Lake 2007, 2010, 2014, 2017, and 2018 aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created using data from the 2007, 2010, 2014, 2017 & 2018 whole-lake aquatic plant point-intercept surveys. The dashed line signifies spot herbicide treatments in the western basin..

Of the 26 native aquatic plant species located in Lost Lake in 2018, 24 were encountered directly on the rake during the whole-lake point intercept survey. The remaining two 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 24 species that were sampled on the rake, quillwort was the frequently most encountered species, followed by muskgrasses, wild celery, slender naiad, and coontail (Figure 3.4-5).

Quillwort (*Isoetes spp.*) was the most frequently encountered aquatic plant species with a littoral frequency of occurrence of 15.1%. Quillwort is a relatively short plant that grows in a basal rosette and is often found in harder or sandy substrates. In Lost Lake, all occurrences of quillwort were found in three feet of water or less in 2018.

Muskgrasses (*Chara spp.*) was the second-most encountered species in 2018 with a littoral frequency of occurrence of 12.6%. Muskgrasses are a genus of macroalgae. These macroalgae require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Wild celery, also known as tape or eel grass, was tied for the third-most frequently encountered aquatic plant species with a littoral frequency of occurrence of 11.9% during the 2018 point-intercept survey (Figure 3.4-6). Wild celery is relatively tolerant of low-light conditions and is able to grow in deeper water. Its long leaves provide excellent structural habitat for numerous aquatic organisms while its extensive root systems stabilize bottom sediments. Additionally, the leaves, fruit, tubers, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife. In Lost Lake, wild celery was most abundant between 2.0 and 7.0 feet of water.

Slender naiad, which also had a littoral frequency of occurrence of 11.9% in 2018, is a submersed, annual plant that produces numerous seeds (Figure 3.4-6). Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 2014). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. In Lost Lake, slender naiad was most prevalent between 1.0 and 5.0 feet of water.

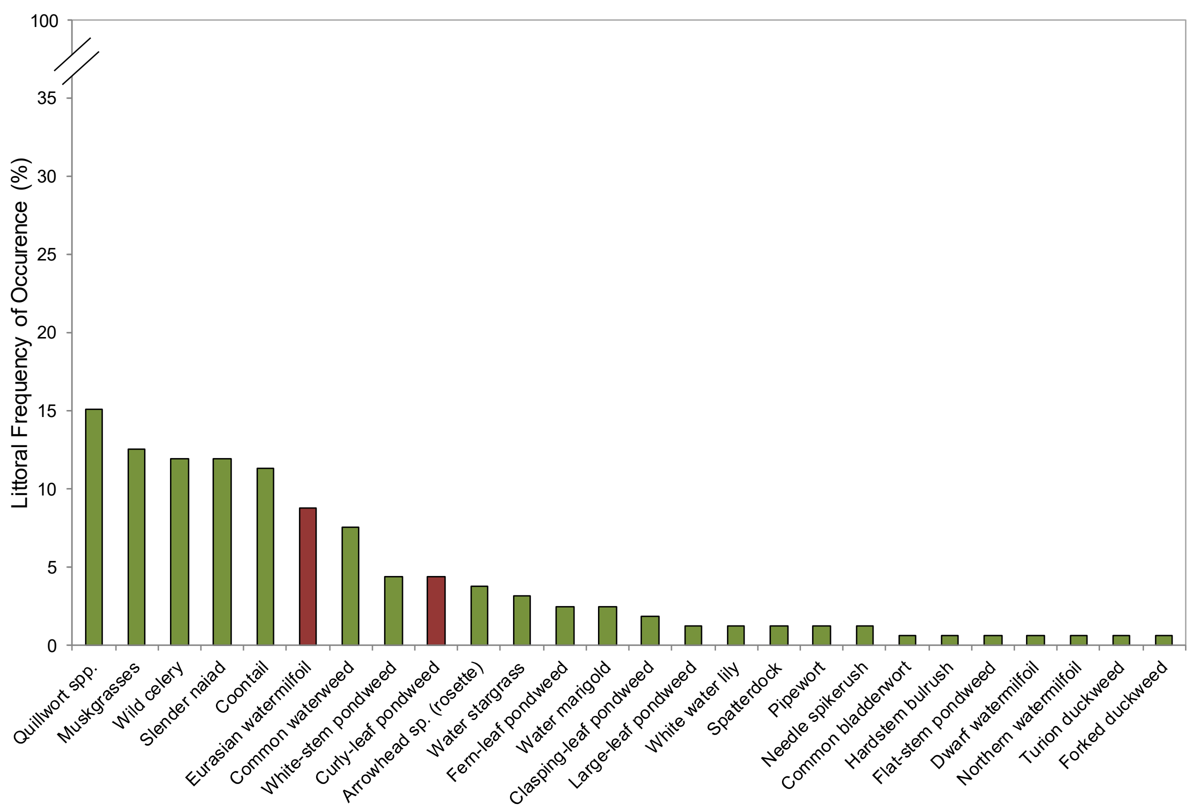


Figure 3.4-6. Lost Lake aquatic plant littoral frequency of occurrence. Created using data from the August 2018 point-intercept survey.

Coontail, arguably the most common aquatic plant in Wisconsin, was the fifth-most frequently encountered aquatic plant in Lost Lake in 2018 with a littoral frequency of occurrence of 11.3% (Figure 3.4-6). It was most abundant between 4.0 and 8.0 feet of water. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives most of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients and low water clarity.

Figure 3.4-7 and Figure 3.4-8 display the littoral frequency of occurrence (LFOO) of aquatic plant species from the 2007, 2010, 2014, 2017, and 2018 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one or more of the five surveys are displayed. Because of their morphological similarity and often difficulty in differentiating between them in the field, the occurrences of small pondweed (*Potamogeton pusillus*), slender pondweed (*P. berchtoldii*) and stiff pondweed (*P. strictifolius*) were combined for this analysis and are called thin-leaved pondweed spp. The full matrix of species LFOO is contained in Table 3.4-2.

In the most recent survey completed in 2018, many aquatic plants were found to have a littoral frequency of occurrence below the mean value of all surveys (Figure 3.4-7). Coontail, northern watermilfoil, fern-leaf pondweed, white-stem pondweed, thin-leaved pondweeds, and large-leaf pondweed were all at their lowest observed littoral frequencies in 2018. Quillworts and muskgrasses along with EWM and CLP exhibited littoral frequencies in 2018 that were above the mean value from all surveys (Figure 3.4-6).

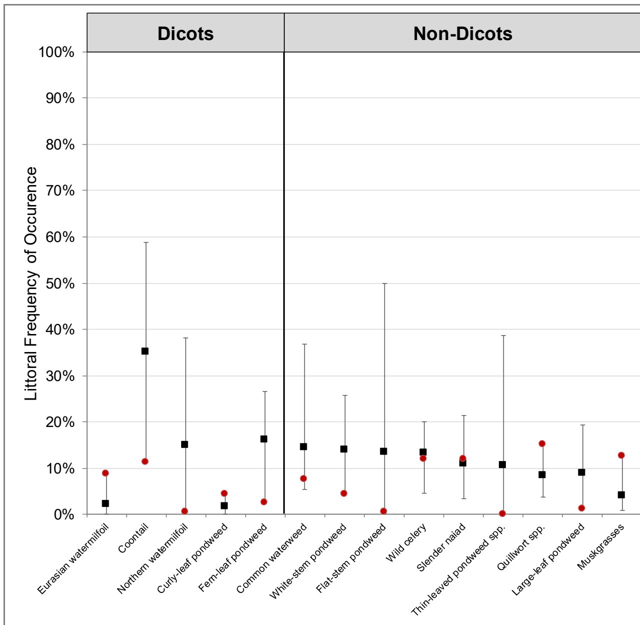


Figure 3.4-7. Lost Lake aquatic plant littoral frequency of occurrence. Created using data from the 2007, 2010, 2014, 2017 & 2018 whole-lake aquatic plant point-intercept surveys. Red circle represents the 2018 point-intercept survey. Black square symbols represent mean littoral frequency of all surveys.

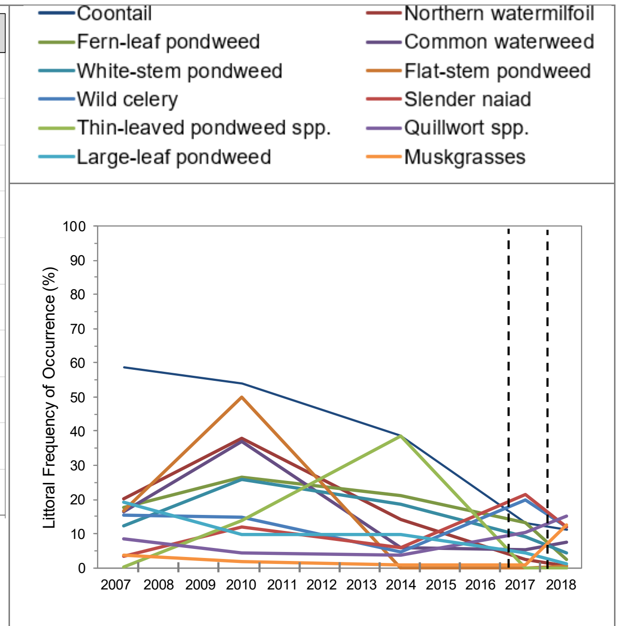


Figure 3.4-8. Lost Lake aquatic plant littoral frequency of occurrence over time Created using data from the 2007, 2010, 2014, 2017 & 2018 whole-lake aquatic plant point-intercept surveys.

A concerning reduction in the overall plant community of Lost Lake has been documented since 2010, with 2017 and 2018 containing some of the lowest aquatic plant populations in the past decade. The *Lost Lake 2018 AIS Monitoring Report & Control Strategy Assessment Report* discuss the declines at a species level as well as provide insight into the mechanism behind the declines. Because 2017 was the first year an herbicide treatment was conducted on Lost Lake, many assumed that the treatment caused the native plant declines. The data indicate that many of the species in decline were already low in 2014, three years before the CLP control program was enacted. Measured herbicide concentrations in 2017 outside of the application area were slightly above detection limits, far below levels anticipated to impact plant populations. While it cannot be ruled out entirely, Onterra believes the evidence presented in the 2018 report suggests that the lake-wide native plant declines were not solely caused by the herbicide control strategy.

Jones et al (2012) investigated 11 Minnesota Lakes in which 8 lakes received whole-lake endothall treatment (0.75-1.0 ppm ai lake-wide target concentration) and 3 served as reference populations. While some native plant impacts were documented, particularly to pondweed species (*Potamogeton* spp.), the authors of the study indicated that "early season, low-dose endothall treatments do not cause substantial damage to native macrophyte communities and may promote increased abundance of some taxa after several years of treatment through effective control of curly-leaf."

Table 3.4-3. Lost Lake aquatic plant chi-square analysis. Created using data from the 2007, 2010, 2014, 2017 & 2018 whole-lake aquatic plant point-intercept surveys.

			LFOO (%)				
	Scientific Name	Common Name	2007	2010	2014	2017	2018
Dicots	*Myriophyllum spicatum*	Eurasian watermilfoil	0.0	0.0	0.0	2.4	8.8
	Ceratophyllum demersum	Coontail	58.8	54.0	38.7	13.2	11.3
	Myriophyllum sibiricum	Northern watermilfoil	20.2	38.1	14.0	2.4	0.6
	Bidens beckii	Water marigold	0.0	2.4	0.9	1.5	2.5
	Nuphar variegata	Spatterdock	1.7	0.8	0.4	0.5	1.3
	Nymphaea odorata	White water lily	0.8	0.0	0.0	1.0	1.3
	Utricularia vulgaris	Common bladderwort	0.0	0.0	0.0	0.0	0.6
	Myriophyllum tenellum	Dwarf watermilfoil	0.0	0.0	0.0	0.0	0.6
	Ranunculus aquatilis	White water crowfoot	0.4	0.0	0.0	0.0	0.0
	Myriophyllum verticillatum	Whorled watermilfoil	0.0	0.4	0.0	0.0	0.0
Non-dicots	*Potamogeton crispus*	Curly-leaf pondweed	0.0	0.0	0.0	4.4	4.4
	Potamogeton robbinsii	Fern-leaf pondweed	17.6	26.6	21.3	13.2	2.5
	Elodea canadensis	Common waterweed	16.4	36.9	6.0	5.4	7.5
	Potamogeton praelongus	White-stem pondweed	12.2	25.8	18.7	9.3	4.4
	Potamogeton zosteriformis	Flat-stem pondweed	16.8	50.0	0.0	0.0	0.6
	Vallisneria americana	Wild celery	15.5	14.7	4.7	20.0	11.9
	Najas flexilis	Slender naiad	3.4	11.9	6.0	21.5	11.9
	Potamogeton pusillus, P. berchtoldii, & P. strictifolius	Thin-leaved pondweed spp.	0.4	13.9	38.7	0.0	0.0
	Isoetes spp.	Quillwort spp.	8.4	4.4	3.8	10.2	15.1
	Potamogeton amplifolius	Large-leaf pondweed	19.3	9.9	9.8	4.4	1.3
	Potamogeton pusillus	Small pondweed	0.4	2.8	27.2	0.0	0.0
	Chara spp.	Muskgrasses	3.8	2.0	0.9	1.0	12.6
	Potamogeton berchtoldii	Slender pondweed	0.0	0.0	17.9	0.0	0.0
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	0.0	4.8	0.0	5.4	3.8
	Potamogeton richardsonii	Clasping-leaf pondweed	1.7	4.4	3.4	2.4	1.9
	Potamogeton strictifolius	Stiff pondweed	0.0	12.7	0.0	0.0	0.0
	Potamogeton gramineus	Variable-leaf pondweed	4.2	4.0	3.4	1.5	0.0
	Filamentous algae	Filamentous algae	2.1	0.0	5.5	4.4	1.3
	Eleocharis acicularis	Needle spikerush	3.4	1.2	0.9	1.0	1.3
	Heteranthera dubia	Water stargrass	0.8	0.0	0.4	0.5	3.1
	Stuckenia pectinata	Sago pondweed	0.0	0.8	1.3	0.5	0.0
	Juncus pelocarpus	Brown-fruited rush	0.8	0.8	0.4	0.0	0.0
	Eriocaulon aquaticum	Pipewort	0.0	0.0	0.0	0.0	1.3
	Schoenoplectus acutus	Hardstem bulrush	0.0	0.0	0.4	0.0	0.6
	Nitella spp.	Stoneworts	0.0	0.8	0.0	0.0	0.0
	Lemna turionifera	Turion duckweed	0.0	0.0	0.0	0.0	0.6
	Lemna trisulca	Forked duckweed	0.0	0.0	0.0	0.0	0.6
	Schoenoplectus tabernaemontani	Softstem bulrush	0.0	0.4	0.0	0.0	0.0
	Potamogeton illinoensis	Illinois pondweed	0.4	0.0	0.0	0.0	0.0
	Potamogeton foliosus	Leafy pondweed	0.4	0.0	0.0	0.0	0.0
	Pontederia cordata	Pickerelweed	0.0	0.4	0.0	0.0	0.0
	Lobelia dortmanna	Water lobelia	0.0	0.4	0.0	0.0	0.0
	Fissidens spp. & Fontinalis spp.	Aquatic Moss	0.0	0.0	0.0	0.5	0.0

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 34 native aquatic plant species were located in Lost Lake during the 2017 surveys, 19 were directly encountered on the rake during the point-intercept survey. Lost Lake's native aquatic plant species richness in 2018 was below the median value for lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and was the same as the median value for lakes throughout Wisconsin (Figure 3.4-8). The species richness in Lost Lake has varied from 19 to 26 species over the five point-intercept surveys dating back to 2007 which falls near or above the ecoregion and state-wide median values (Figure 3.4-9).

The average conservatism has ranged from 6.1 to 6.6 in surveys completed between 2007 and 2018. The average conservatism in the most recent survey completed in 2018 was 6.3 which is slightly lower than the ecoregion median and equal to the state-wide median value. Lost Lake's native aquatic plant species richness and average conservatism are used to calculate the Floristic Quality Index value which yields values ranging from 26.4 to 33.4 for all five point-intercept surveys between 2007 and 2018. In 2018, the FQI for Lost Lake was found to be 30.7 which is very near the median values for lakes within the NLFL ecoregion and is above the median value from state-wide.

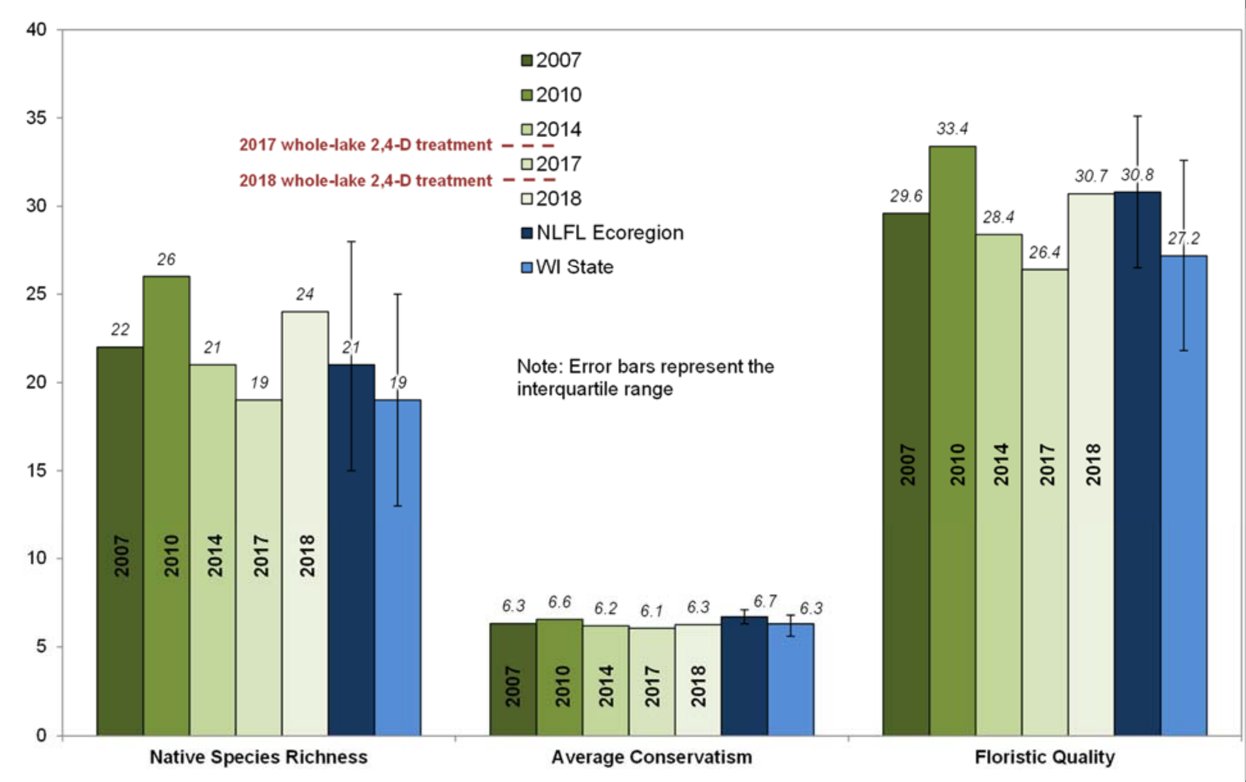


Figure 3.4-9. Lost Lake Floristic Quality Assessment. Created using data from 2007, 2010, 2014, 2017 and 2018 surveys. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion.

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and some hypothesize may have greater resistance to invasion by non-native plants. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018). 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 Lost Lake contains a moderate number of native aquatic plant species, one may assume the aquatic plant community also has higher 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 Lost Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 3.4-10). Using the data collected from the 2007, 2010, 2014, 2017 and 2018 point-intercept surveys, Lost Lake's aquatic plant community is shown to have relatively high species diversity. Simpson's Diversity Index values ranged between 0.87 and 0.92 over the course of the past surveys. Aside from 2007, the diversity values have fallen above the median value of 0.88 for lakes in the NLFL ecoregion.

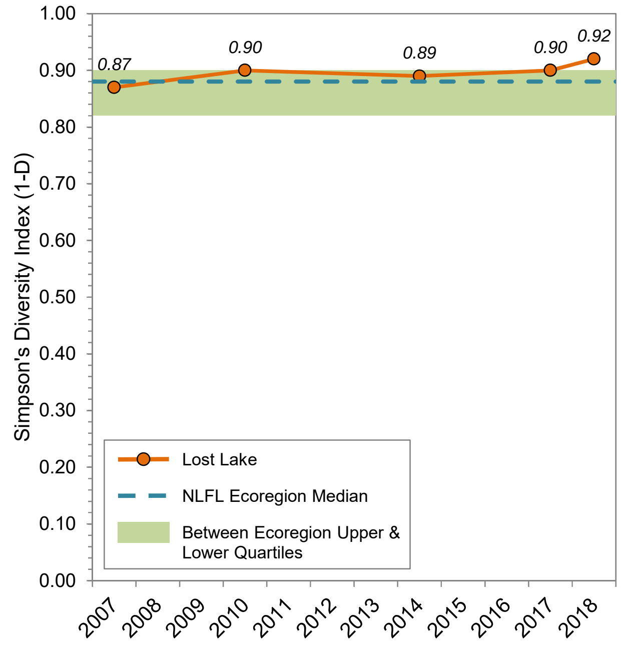


Figure 3.4-10. Lost Lake species diversity index. Created using data from 2007, 2010, 2014, 2017 & 2018 aquatic plant surveys. Ecoregion data from 212 NLFL lakes collected by WDNR Science Services and Onterra.

While Lost Lake contains a moderate number of aquatic plant species, 46% of the plant community is comprised of four species. One way to visualize Lost Lake's species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.4-11 displays the relative frequency of occurrence of aquatic plant species created from the 2018 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. 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, quillwort had a littoral frequency of occurrence of 15.1%, it's relatively frequency of occurrence was 13.4%. Explained another way, if 100 plants were sampled from Lost Lake, 13 would be quillwort.

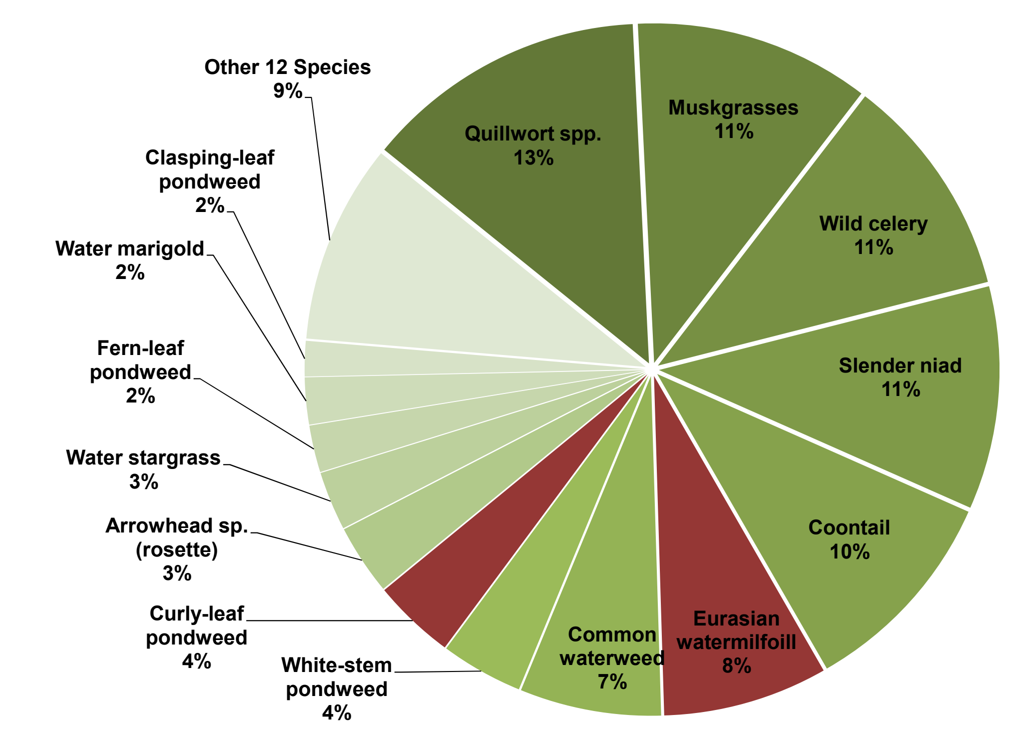


Figure 3.4-11. 2018 relative frequency of occurrence of aquatic plants in Lost Lake. Created using data from 2018 point-intercept survey.

The quality of Lost Lake's plant community is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2017 community map indicates that approximately 9.5 acres (1.7%) of the 553 acre-lake contain these types of plant communities (Table 3.4-4 and Map 5). Fifteen floating-leaf and emergent species were located on Lost Lake, 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. Comparison of previous surveys conducted on Lost Lake indicate relatively stable amounts of colonized floating-leaf and emergent plant communities on Lost Lake.

Table 3.4-4. Lost Lake acres of plant community types. Created from 2017 community mapping survey.

	Colonized Acres		
Plant Community	**2004**	**2010**	**2017**
Floating-leaf	0.8	0.6	0.9
Emergent	0.7	0.5	2.1
Floating-leaf/Emergent	7.5	7.3	6.5
Total	**9.0**	**8.4**	**9.5**

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 Lost Lake. This is important because these communities are often negatively affected by recreational use and shoreland development.

Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Overlaying the 2004, 2010, and 2017 surveys, there are no large-scale differences in the floating-leaf and emergent plant communities on Lost Lake (Figure 3.4-12). Small increases in the coverage of floating-leaf plant communities may be occurring in some areas especially in areas of riparian use.

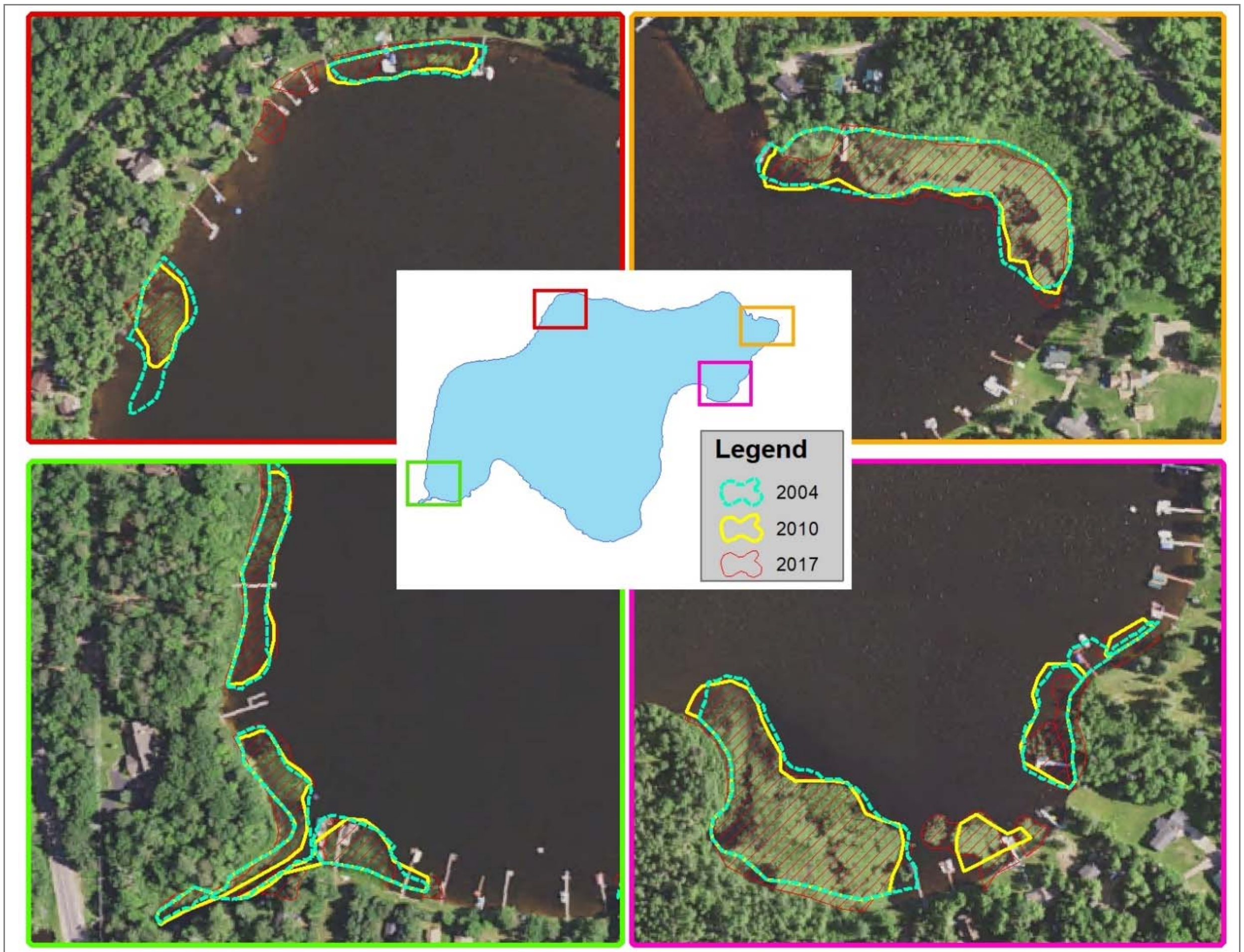


Figure 3.4-12. Comparison of 2004, 2010, and 2017 emergent and floating-leaf plant communities in southern basin of Lost Lake.

Onterra LLC
Lake Management Planning

Non-native Plants in Lost Lake

Eurasian watermilfoil

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 3.4-12). The upper frame of Figure 3.4-12 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected "unmanaged lakes" were moved into the "managed" category as the EWM populations were targeted for control by the local lake organization as populations increased.

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.

Photograph 3.4-6. Eurasian watermilfoil, a non-native, invasive aquatic plant. Photo credit Onterra.

Eurasian watermilfoil (Photograph 3.4-6) was first documented in Lost Lake in 2013. Eurasian watermilfoil populations on Lost Lake were initially targeted through professional hand-harvesting activities (2013-2015). The hand-harvesting provided modest reductions in the areas where the hand-harvesting occurred, but the Eurasian watermilfoil population increase was greater than the amount of Eurasian watermilfoil that was being removed each year (Figure 3.4-14). Specific information regarding the hand-harvesting program is included within each years' *AIS Monitoring & Control Strategy Assessment Report*. Once the population exceeded a threshold where these activities were thought to no longer be feasible, the LLPRD opted to discontinue further active management until it understands if the Eurasian watermilfoil population will continue to increase or if it will plateau at a level where the ecosystem function and navigation, recreation, and aesthetics are not impeded.

The decision to cease active management of the Eurasian watermilfoil population was partially based on the WDNR Eurasian watermilfoil Long-Term Trends Monitoring Program.

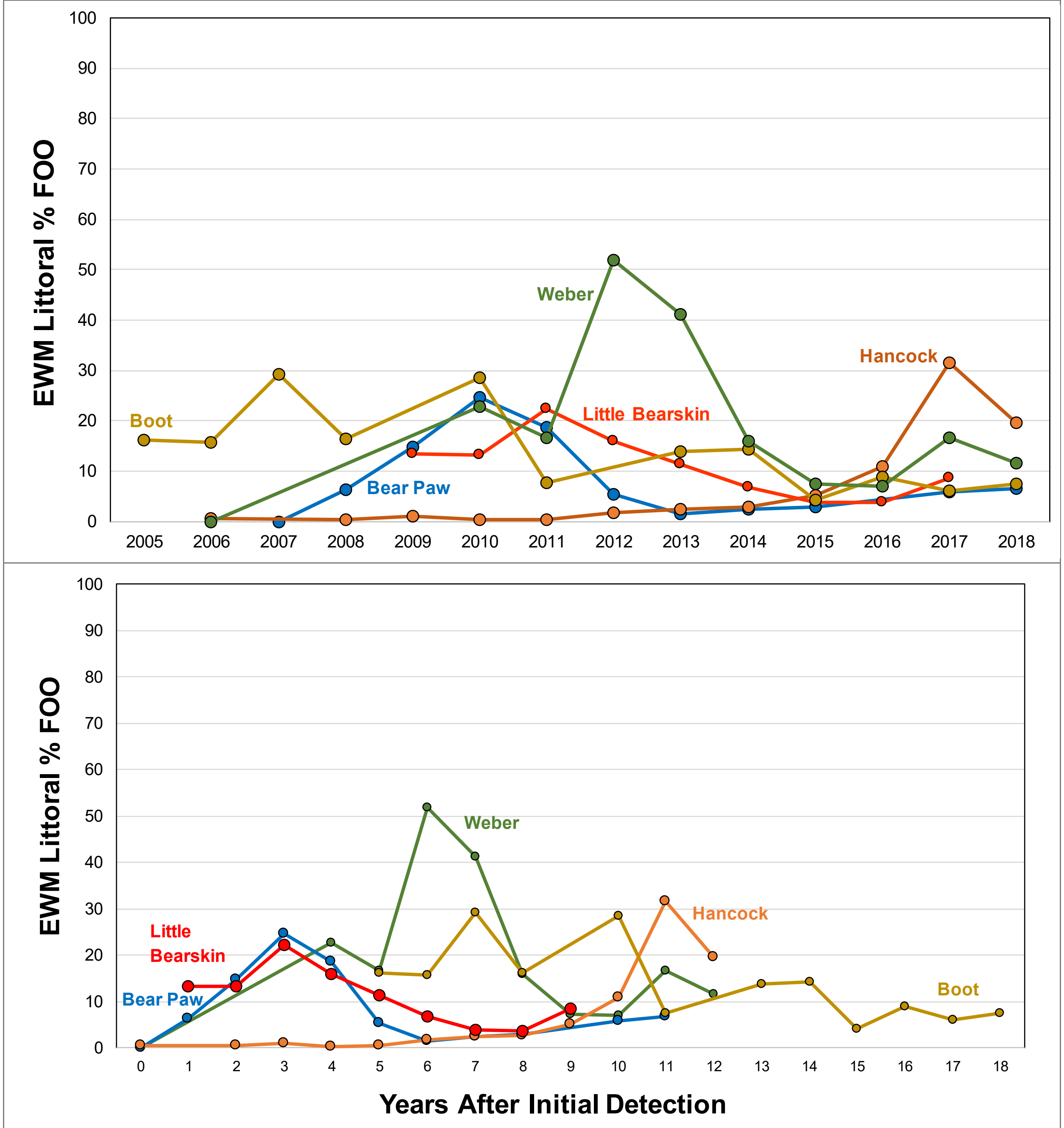


Figure 3.4-13. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from WDNR.

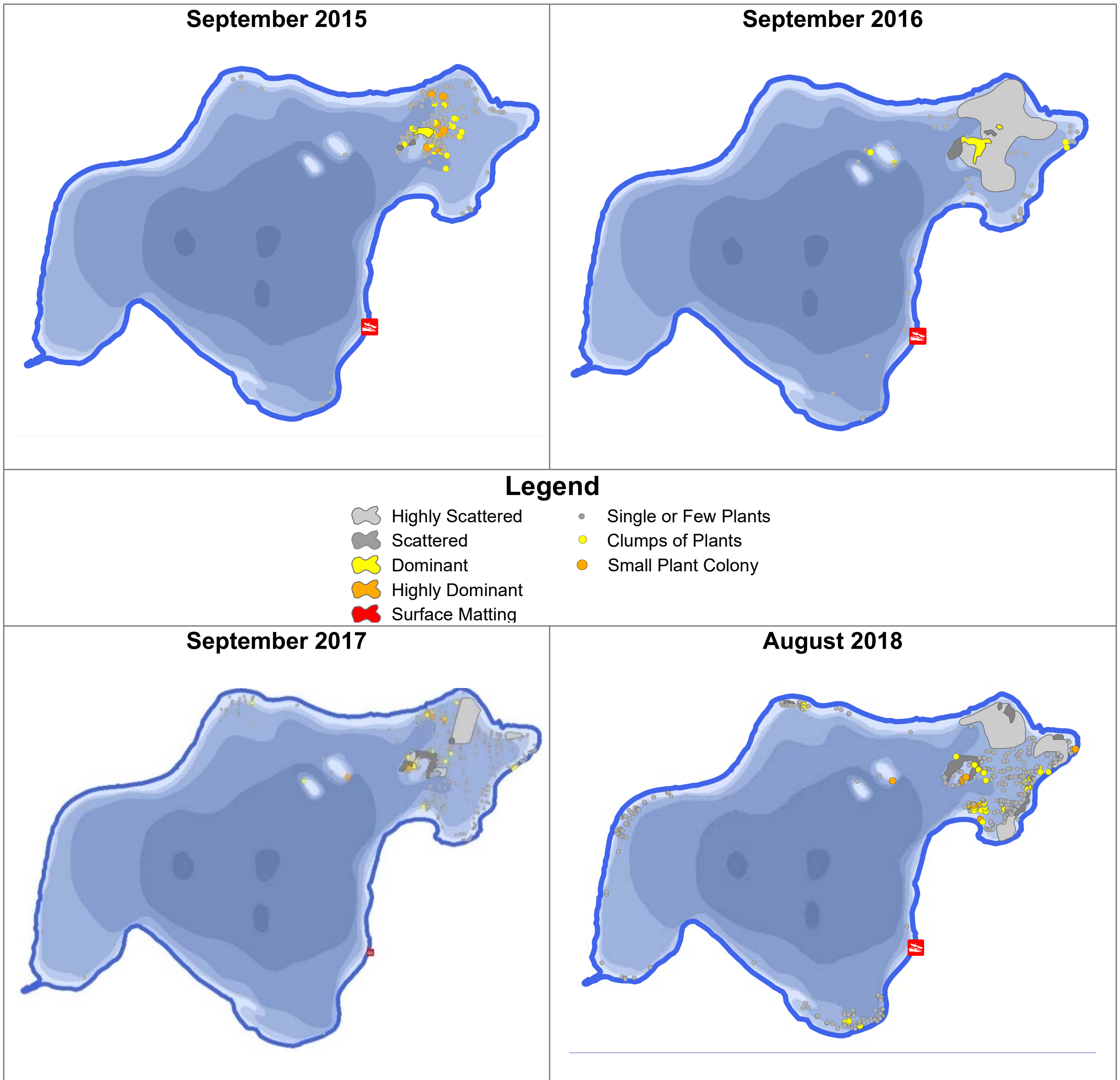


Figure 3.4-14. Eurasian watermilfoil population progression on Lost Lake from 2015-2018.

The EWM population in 2018 was found to be of a similar footprint as previous surveys with the majority of the population located in the eastern bay of the lake (Figure 3.4-14). The majority of the colonized population of EWM was of highly scattered or scattered density ratings. In the 2018 EWM mapping survey, several additional relatively low-density occurrences of EWM were located in various other locations including the southern and western ends of the lake in areas where it was not documented in previous surveys.

Curly-leaf pondweed

Curly-leaf pondweed (Photograph 3.4-5) was first discovered in Lost Lake in 2014. The CLP population in Lost Lake was found to have dramatically increased from 2014 to 2016 (Figure 3.4-15). Much of the curly-leaf pondweed population in the western bay expanded to form large, continuous, and dense colonies in 2016. A total of 17.9 acres of colonized curly-leaf pondweed was mapped during the June 2016 survey, all of which was described of as being of *dominant*, *highly dominant*, or *surface matting*. These highly visible, very dense curly-leaf pondweed colonies completely dominate the aquatic plant population and can significantly inhibit navigation for boaters until the plant dies back in early July. For reasons not completely known, the curly-leaf pondweed population on Lost Lake has been documented to persist much later in the growing season than other waterbodies. Biomass in monotypic colonies of CLP is often much higher than native aquatic plant communities (Kunii 1984, Bolduan et al. 1994).

Photograph 3.4-5. Curly-leaf pondweed, a non-native, invasive aquatic plant. Photo credit Onterra.

As discussed above, some lakes in northern Wisconsin contain curly-leaf pondweed populations that appear to have integrated within the aquatic plant community without becoming a nuisance or causing measurable impacts to the lake ecosystem. Acknowledging that possibility for Lost Lake, the LLPRD did not reactively conduct active management on the curly-leaf pondweed population in 2014-2016, rather monitored the population dynamics. In 2016, the CLP population expanded substantially and reductions in navigation and recreation were documented on Lost Lake. During the late-fall/winter of 2016-17, there were a number of correspondences between the district and Onterra discussing the possibility of conducting an herbicide control strategy during the spring of 2017. Factors such as environmentally toxicity of the treatment including likely native plant impacts, the need for multiple subsequent annual treatments, and potential regulatory opposition where weighed heavily. Following these discussions, the LLPRD board of directors supported pursuing an herbicide spot treatment targeting the largest and densest population of CLP during the spring of 2017.

The LLPRD has developed a CLP control strategy that includes multiple consecutive years of spot herbicide treatments. Additional details relating to the planning, implementation, and monitoring of the CLP control program are reported on in annual treatment reports. Details surrounding the 2017 herbicide treatment can be found in the *Lost Lake 2017 AIS Monitoring and Control Strategy Assessment Report* and the forthcoming *Lost Lake 2018 AIS Monitoring and Control Strategy Assessment Report.*

Continued monitoring of the lake-wide CLP population of Lost Lake indicate that other areas of the lake continue to hold low-density populations (Map 6).

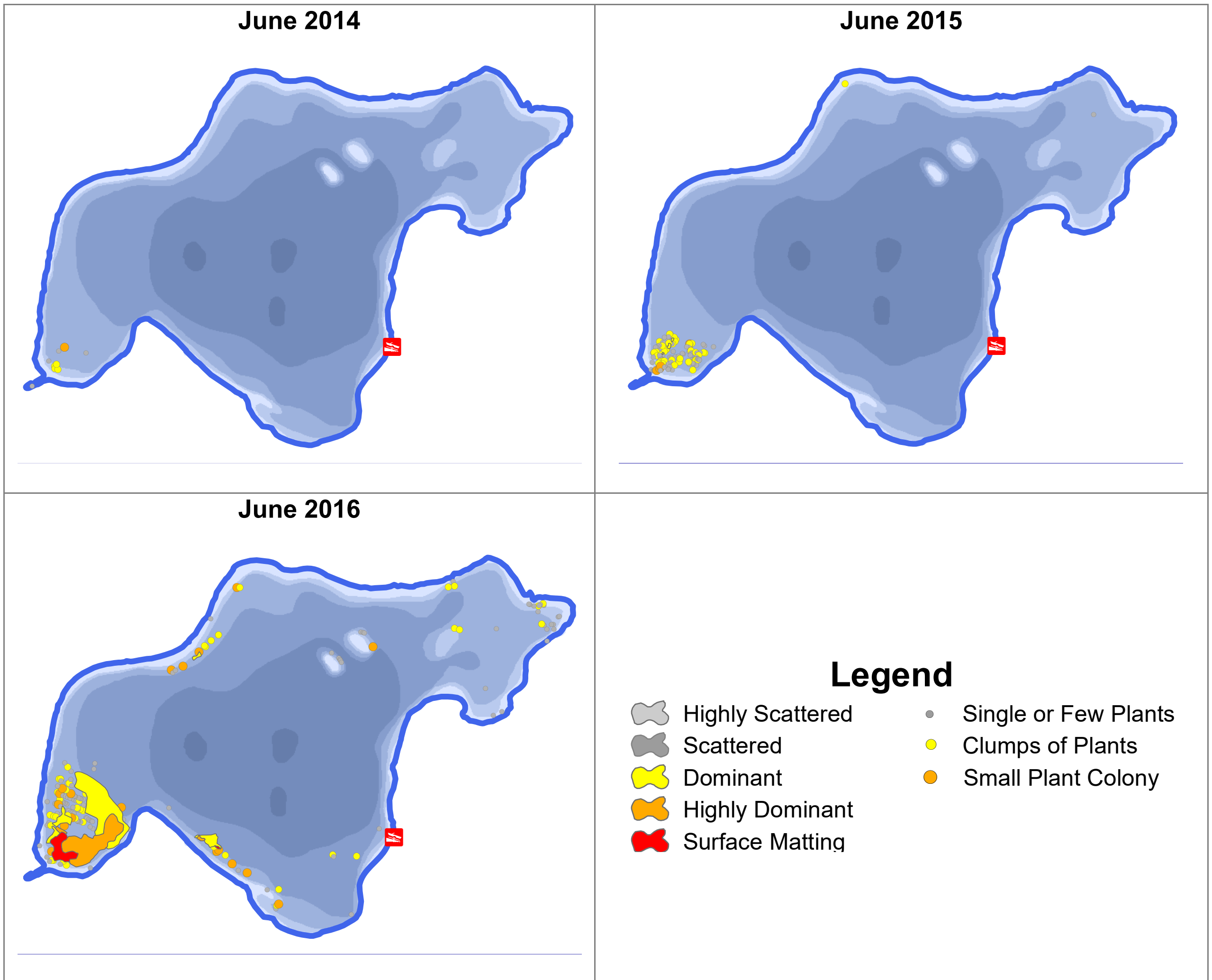


Figure 3.4-15. Curly-leaf pondweed population progression on Lost Lake from 2014-2016. CLP herbicide control program initiated in spring 2017.

Endothall is an aquatic herbicide that is applied as either a dipotassium salt or an amine salt. These active ingredients break down following application to endothall acid, the form that acts as an herbicide (Netherland 2009). The 2017 and 2018 treatment of CLP on Lost Lake used the dipotassium salt at a concentration of 2.0 ppm active ingredient (ai). When broken down into the acid, 2.0 ppm ai equates to 1.42 ppm acid equivalent (ae). The WI State Laboratory of Hygiene is able to test water samples for endothall using an ELISA (enzyme-linked immunosorbent *assay*) method and reports the results as acid equivalent.

The herbicide concentration data from Lost Lake indicate that the concentration in the treatment area was near the target (1.42 ppm ae), in the samples collected on 2, 4, and 8 hours after treatment (HAT), but were reduced by 24 HAT (Figure 3.4-16, left frame). The endothall concentrations were initially higher in 2018 than in 2017, but similar at 3 days after treatment (72 HAT). A longer herbicide collection period occurred in 2018 based on the data recorded in 2017. Minimal endothall was found in the 2018 samples collected on 120 HAT (5 days after treatment) and 168 HAT (7 days after treatment), whereas no herbicide was detected in the 2018 application area in the final sampling interval at 14 days after treatment (omitted from Figure 3.4-16).

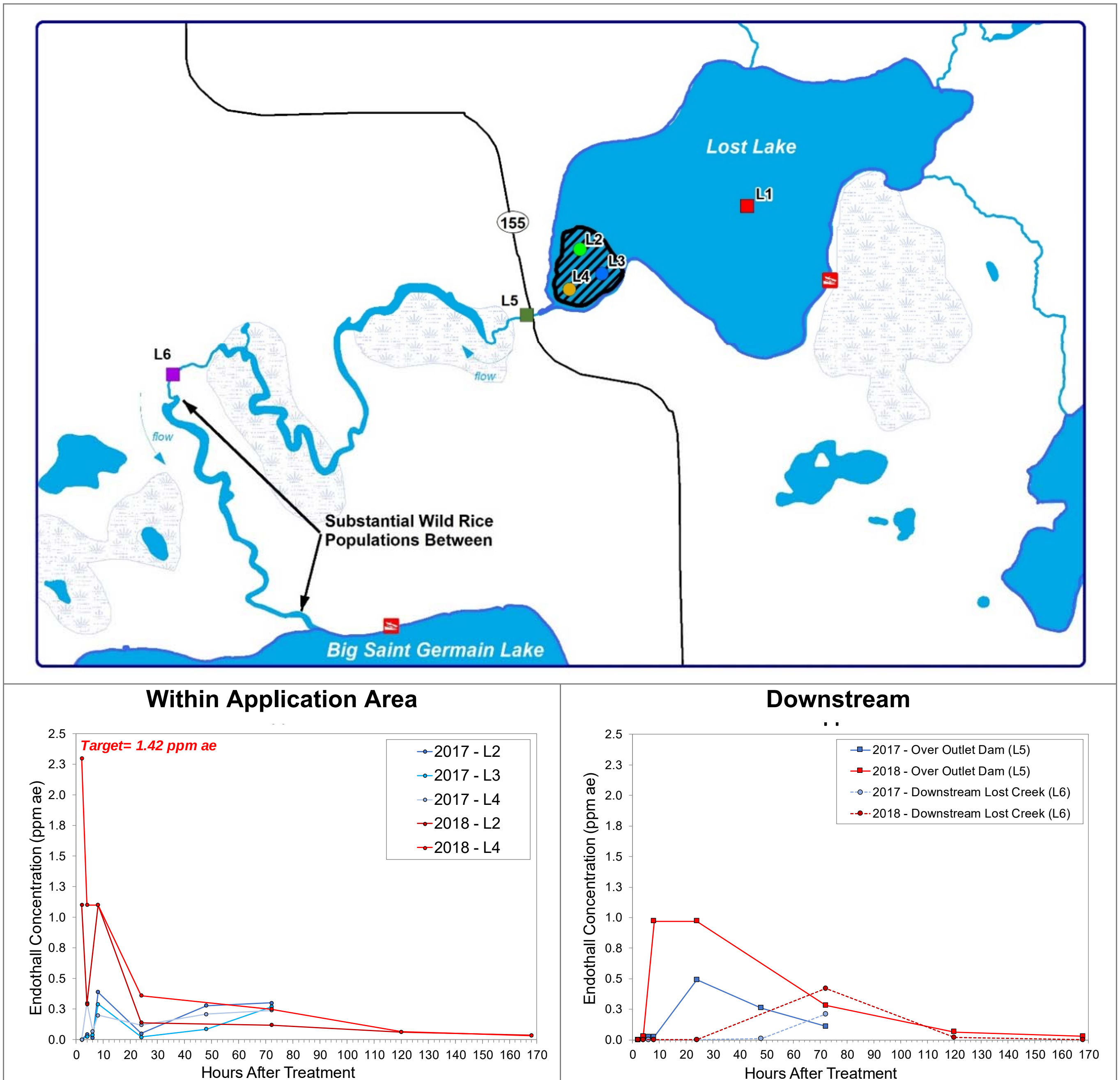


Figure 3.4-16. Lost Lake herbicide concentration monitoring results from the 2017-2018 endothall treatment. Samples collected in 2018 from each monitoring site at 336 HAT (14 DAT) all had no detection of endothall and are not displayed on this figure. Samples were not collected from site L3 during the 2018 monitoring. General location of wild rice population provided by GLIFWC.

Minimal endothall was present at 2 and 4 HAT samples collected from the L5 sampling location on the downstream side of the dam in Lost Creek (Figure 3.4-16, right frame) in 2018. This observation was similar to 2017. By 8 and 24 HAT during 2018, endothall concentrations were just under 1 ppm and were closer to levels that were observed within application area in the hours immediately after the treatment. The 2018 concentrations were higher than those measured in 2017, but generally follow the same concentration curve. Detectable levels of endothall were present through 7 DAT in 2018 and no herbicide was detected on 14 DAT at the outlet sampling location (L5).

The samples that were collected from the L6 downstream sampling location in Lost Creek showed endothall was not detected in the first 24 hours after treatment. A sample collected 3 days after treatment showed low-level herbicide concentrations of (0.42 ppm ae) and by the time of the next collection at 5 DAT, the concentration had declined to just 0.019 ppm ae (Figure 3.4-16, right frame). Endothall was not detected in samples collected on 7 and 14 DAT in Lost Creek.

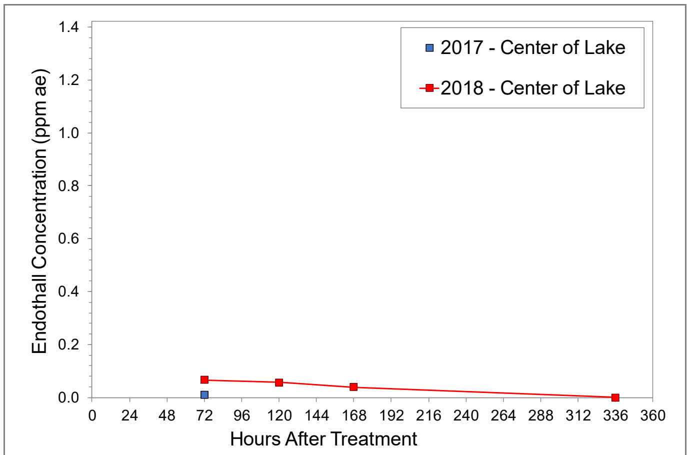
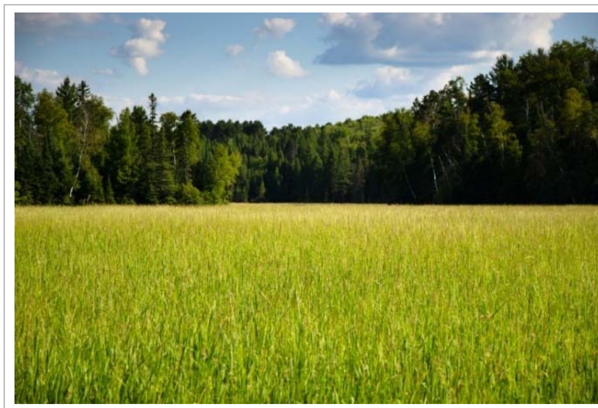


Figure 3.4-17. Center of the lake herbicide concentration monitoring results from the 2017-2018 endothall treatment.

The scientific literature and Onterra's experience suggest that Lost Lake should have had an equilibrium concentration within the entire waterbody by roughly 3 days after treatment. At the center of the lake in 2018, endothall concentrations were 0.066 ppm ae at 3 DAT and concentrations were slightly lower during 5 DAT (0.057 ppm ae) and 7 DAT (0.039 ppm ae) (Figure 3.4-17). No endothall was detected from the site on 14 DAT. These concentrations are higher than observed in 2017, where a single sample from the center of the lake at 3 DAT yielded 0.009 ppm ae). The average concentration from the three sampling intervals in 2018 was 0.054 ppm ae. For whole-lake CLP treatments the manufacturers of endothall (UPI) recommend target concentration of recommend whole-lake target concentrations of 0.53 ppm ae (0.75 ppm ai) to 0.71 ppm ae (1.0 ppm ai). This is an order of magnitude (10X) greater than the measured concentrations from Lost Lake. Based on the endothall concentrations observed in the center of the lake, the impacts of the spot treatment are anticipated to be confined to the approximate area of the application area.



Photograph 3.4-6. Northern wild rice (*Zizania palustris*) population on a northern Wisconsin lake.

Northern wild rice (Photo 3.4-6) is a valuable emergent grass found downstream of Lost Lake in the Lost Creek. In addition to the ecosystem services this plant provides, it also holds great cultural significance to the Native American communities of this area. For this reason, GLIFWC focuses on the "preservation and enhancement of manoomin (wild rice) in ceded territory lakes." The state of Wisconsin works actively with GLIFWC to review all activities that have the potential to negatively impact wild rice populations. While the use of herbicides to control aquatic invasive species has broad intentions of benefiting the lake ecosystem, the herbicides may have the capacity to impact non-target plants such as wild rice.

Natural wild rice populations are known to fluctuate greatly and unpredictably from year to year; therefore, linking population changes of wild rice to herbicide use in field settings can be problematic. Two studies (Nelson et al. 2003; Madsen et al. 2008) evaluated the effects of various herbicides and concentrations on wild rice within outdoor mesocosums (tanks that replicate natural conditions). Madsen et al. 2008 investigates the impact of triclopyr on wild rice, and Nelson et al. 2003 investigates the impact of 2,4-D, diquat, endothall, and fluridone on wild rice. The studies define seedling growth stage as a few days after germination, young plants as being at least 18 inches and having 2-3 aerial leaves, and mature plants were at least 3 weeks old. Of the three distinct wild rice growth stages (seedling, young, mature), this research concludes that wild rice is most resistant to aquatic herbicides when mature, and most vulnerable at the seedling growth stage.

The endothall concentrations that were documented in Lost Creek are lower than what the published literature documents as having impacts to wild rice (Nelson et al. 2003). The laboratory research has documented reduced wild rice seedling biomass at the lowest endothall concentration it tested (sustained 0.71 ppm ae for 72 hours), which is approximately 40% higher concentration and a likely longer exposure time as documented in this area in 2018. Young and mature wild rice growth stages did not have reduced biomass at the lowest tested concentration (0.71 ppm ae). While it depends on the specific weather conditions of a given year, early-season herbicide treatments that occur in early-May are most likely to have exposure to recently germinated wild rice (seedlings). The 2017 treatment was conducted in late-May (May 22) and the 2018 treatment was conducted in late-June (June 21), potentially both when wild rice plants have progressed past the seedling growth stage and are therefore less vulnerable to the impacts from endothall.

Aquatic plant communities are dynamic, and the abundance of certain species can fluctuate from year to year depending on climatic conditions, herbivory, competition, water levels, and disease among other factors, and fluctuations in the abundance of species are to be expected over time. Herbicide treatments, can also impact non-target native plant abundance.

Additional analysis of the Lost Lake aquatic plant community is provided within the *Lost Lake 2018 AIS Monitoring and Control Strategy Assessment Report* (Feb19), including species-specific responses observed. The following paragraphs will focus on more general changes to the aquatic plant community.

Using the presence/absence data from each years' point-intercept survey, an interpolation model (kringing) was created that explores the areas of Lost Lake that have a high likelihood of containing vegetation in a given year (Figure 3.4-18). The model shows the footprint of aquatic vegetation from Lost Lake increased from 2007 to 2010, largely in the lakeward direction. Aquatic vegetation at depth resided in 2014 to an area similar, but perhaps a little smaller than observed in 2010. The models from 2017 and 2018 shows less aquatic vegetation in deeper waters, with most of the vegetation being observed in near shore areas. Vegetation reductions were also observed in the far eastern part of the lake.

Large-scale reductions in aquatic plants are often associated within changes in water clarity within a lake. Lost Lake's water clarity can vary significantly from year to year, with some annual growing season Secchi disk readings averaging 9 or more feet while other years, like 2017, averaging 4.4 feet. The water clarity of Lost Lake is largely driven by free-floating algae but also impacted by dissolved humic substances and organic acids which give the lake a light tea color in some years (30 SU in 2017).

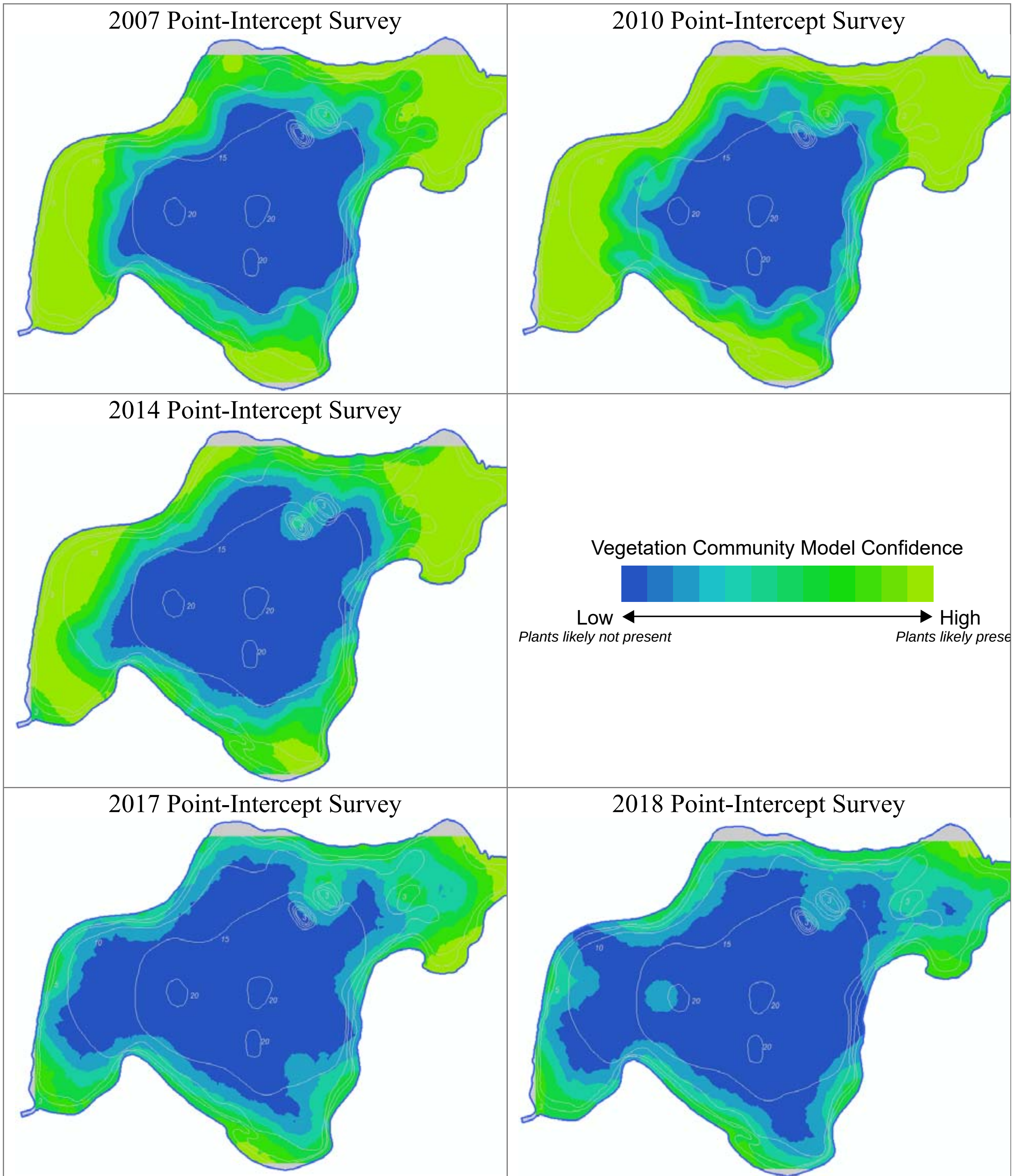


Figure 3.4-18. Distribution of aquatic vegetation in Lost Lake point-intercept surveys. Modeled vegetation likelihood based upon interpolation of presence/absence vegetation at point-intercept locations. Grey areas indicate no data.

The maximum depth of aquatic plants found from the point-intercept surveys has reduced by four feet during the most recent point-intercept survey (Figure 3.4-19). Figure 3.4-20 shows that aquatic plant abundance in the 2-3 foot range of the lake was the highest in 2018, but little vegetation was observed greater than 8 feet deep in 2017 and 2018. Some of the greatest abundance of aquatic plants during 2007, 2010, and 2014 was found in waters of 8 to 14 feet.

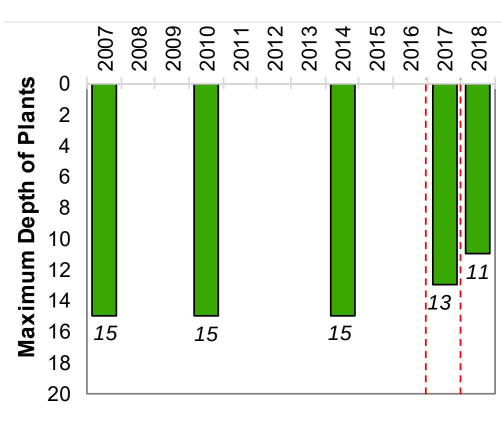


Figure 3.4-19. Maximum depth of plants from point-intercept surveys. Red dashed lines indicate western basin herbicide spot treatment.

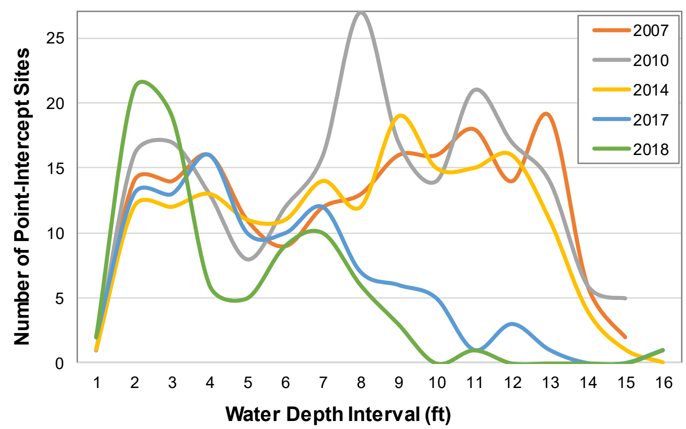


Figure 3.4-20. Depth distribution of aquatic plants from point-intercept surveys.

Riparian Stakeholder Survey Responses to Aquatic Vegetation within Lost Lake

As discussed in section 2.0, the riparian stakeholder survey asks many questions pertaining to perception of the lake and how those that own property on the system believe it may have changed over the years. The return rate of the survey was just below 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 LLPRD 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 LLPRD has to help understand district stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

Figures 3.4-21 and 3.4-22 display the responses of members of Lost Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, natively impacts the enjoyment of Lost Lake, a plurality of stakeholder survey respondents (47%) indicated *sometimes*, 34% indicated *often*, 10% indicated *rarely* or *never*, and 9% indicated *always* (Figure 3.4-21).

When asked if they believe aquatic plant control is needed on Lost Lake, 87% of respondents indicated *definitely yes* or *probably yes*, 10% indicated *unsure*, and 3% indicated *probably no* (Figure 3.4-22). The presence of AIS within Lost Lake is well-known knowledge for the stakeholders so while aquatic plants do not generally impact user's enjoyment of the lake, stakeholders believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in Lost Lake is discussed within the Implementation Plan Section (Section 5.0).

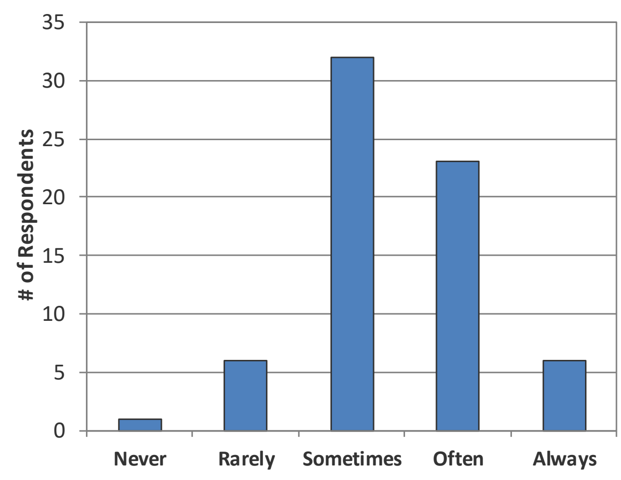


Figure 3.4-21. Riparian stakeholder survey response Question #23. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Lost Lake?

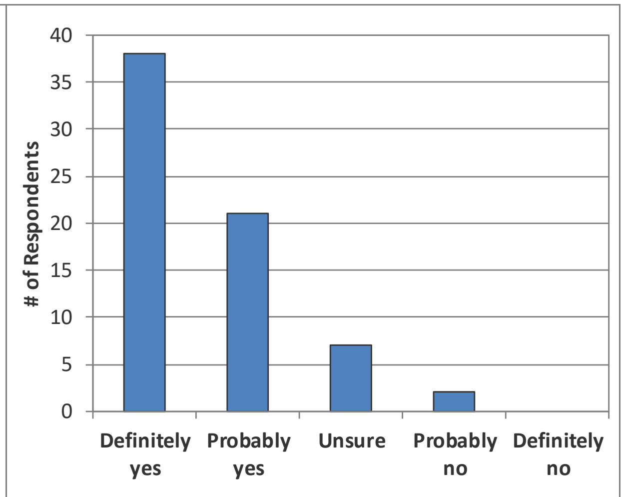
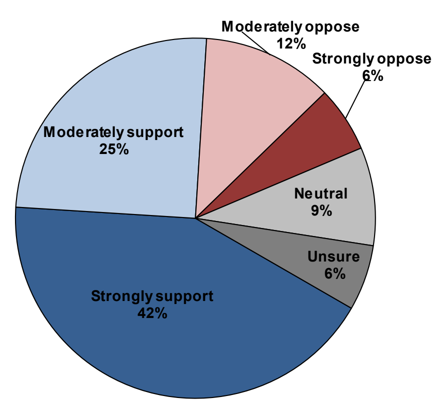


Figure 3.4-22. Riparian stakeholder survey response Question #24. Do you believe aquatic plant control is needed on Lost Lake?

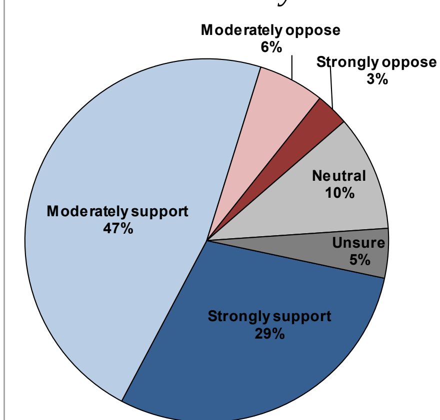
The planning committee wanted to understand the stakeholders' perceptions on the use of various active management techniques (Figure 3.4-23). 67% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of responsibly using herbicides on Lost Lake, whereas 18% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). 76% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of responsibly conducting hand-harvesting with divers, whereas 9% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). Only 1% 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 Lost Lake?

Herbicide Control



Hand-Removal by Divers



Do Not Manage Plants

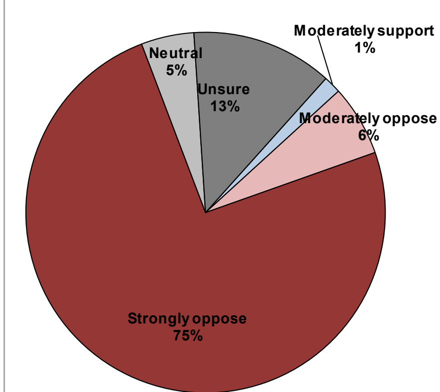


Figure 3.4-23. Select survey responses from the LLPRD Riparian stakeholder survey. Additional questions and response charts may be found in Appendix B.

An herbicide spot treatment of CLP occurred on Lost Lake in 2017 and 2018. The riparian stakeholder survey was distributed after the 2017 treatment was conducted, but before the 2018 treatment. Figure 3.4-24 displays the responses of the Lost Lake stakeholders and how they felt about the treatment that occurred in 2017. Approximately 62% of riparian respondents indicated that they *completely support* the herbicide treatment that occurred on Lost Lake in 2017, 19% indicated they *moderately support* the treatment, 9% indicated they were *unsure/neutral*, 7% indicated they *moderately oppose* the treatment, and 3% indicated they *completely oppose* the treatment.

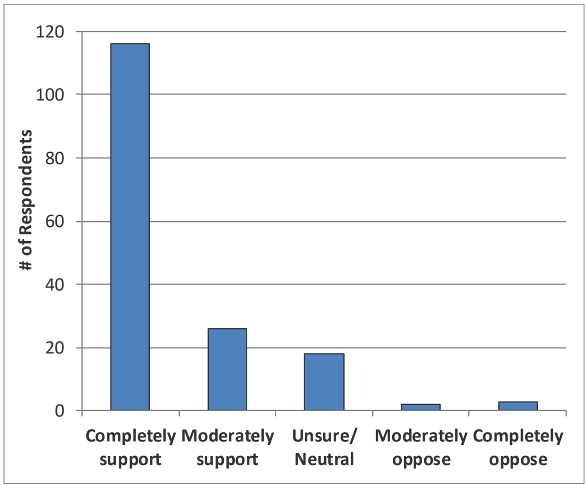


Figure 3.4-24. Riparian stakeholder survey response Question #27. How do you feel about the use of herbicides to treat CLP in 2017?

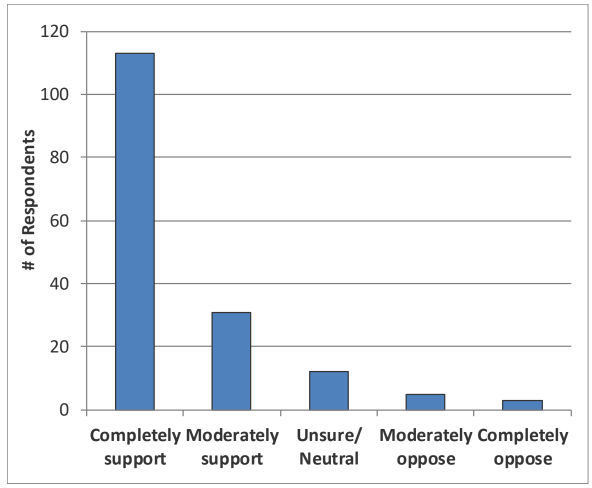


Figure 3.4-25. Riparian stakeholder survey response Question #28. What is your level of support or opposition for future aquatic herbicide use to target CLP?

When asked what their level of support or opposition for future aquatic herbicide use to target CLP in Lost Lake was, the majority of riparian respondents, 60%, indicated they *completely support* the future use, 22% indicated they *moderately support* future use, 9% indicated they were *unsure/neutral*, 6% indicated they *moderately oppose* future use, and 3% indicated they *completely oppose* the future use of aquatic herbicides (Figure 3.4-25). All the riparian 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 of native species such as fish, insects, etc., and that the future impacts are unknown (Question 29, Appendix B).

CLP Management Strategy

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Not all of the turions produced in one year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Traditionally a control strategy for an established CLP population includes 5-7 years of treatments of the same area to deplete the existing turion bank within the sediment (Jones et al 2012, Johnson et al. 2012). In practice, it is unclear how many years CLP turions can remain viable and therefore the number of consecutive years treatments are required is unknown.

Johnson et al. (2012) investigated 9 midwestern lakes with established CLP populations that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first 2 years of the control program, but continued reductions were observed following all five years of the project. These lakes contained CLP for numerous years before the herbicide whole-lake treatment program began, likely containing a robust turion bank in the sediment. When treatments ceased after five years, CLP populations continued to be present indicating that five years was insufficient to fully exhaust the sediment turions. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species. Because CLP has only been present in Lost Lake for a few years, some theorize that the turion base may be small and if a control program is initiated at this time, may not require as many successive treatments as a more established population would.

Endothall Toxicology

The aquatic herbicide endothall has been used in a spot-treatment use pattern in Lost Lake to target and control curly-leaf pondweed. Endothall is an aquatic herbicide that is applied as either a dipotassium salt or an amine salt. These active ingredients break down following application to endothall acid, the form that acts as an herbicide (Netherland 2009). Amine salt forms of endothall (Hydrothol®) can be highly toxic to aquatic invertebrate and fish so it is recommended that they not be used in areas where fish are considered an important resource (e.g. agriculture irrigation channels). The dipotassium salt form of endothall (Aquathol® K) has been shown to have a very low to no toxicity to fish and other invertebrates (WDNR PUBL-WT-970 2012). The 2017 and 2018 herbicide treatment on Lost Lake used the dipotassium salt from of endothall at a concentration of 2.0 ppm active ingredient (ai). The maximum application rate of the herbicide is 5.0 ppm ai.

It is important to note that US EPA registration of aquatic herbicides requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). Since endothall spot treatments occurred on Lost Lake, the toxicological analyses of the herbicide conducted as part of the EPA registration process are transferable to Lost Lake. Endothall has been a registered herbicide since 1960 and has been re-registered periodically including the latest re-registration occurring in 2017.

As outlined within the WDNR's Chemical Fact Sheet on Endothall (WDNR PUBL-WT-970 2012), an indirect effect of the treatment that needs to be considered is that the removal of vegetation caused by the herbicide treatment may result in temporary habitat loss at a vulnerable time of year for some fish and invertebrate species. Fish species that spawn in late spring or early summer may be impacted as water temperatures and spawning locations often overlap, and vital nursery areas for emerged fry could become susceptible. Yellow perch and muskellunge are examples of species that could potentially be affected by early season herbicide applications, as the treatments could eliminate spawning substrate or nursery areas for the emerged fry.

On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications, mechanical harvesting, or hand-harvesting. While the Implementation Plan will discuss these specific management actions as they relate to Lost Lake, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's aquatic plant population and the lake's fishery.

During management discussions, conversation regarding risk assessment of the various management actions were prominent. Onterra provided extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* (Draft Dec2018) to serve as an objective baseline for the LLPRD to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Lost Lake Ecosystem. These chapters are included as Appendix G.

Herbicide applications targeting curly-leaf pondweed typically occur before water temperatures greatly exceed 60°F, as endothall uptake rates have been shown to be higher at these water temperatures (Dr. Cody Gray, personal comm.). This timing also corresponds to the period before viable turion formation is likely to occur on CLP, which is important for the overall goal of the management strategy (i.e. control CLP before turions are produced). Conducting herbicide treatments earlier in the growing season are also thought to be more protective of the native plant community. Specific to lakes in the ceded territory, the timing of the treatment would be postponed until after the spring open-water Native American spear harvest has concluded and if possible, when downstream wild rice populations are anticipated to have advanced past the growth stage that is most sensitive to endothall treatment.

3.5 Aquatic Invasive Species in Lost Lake

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

Table 3.5-1. AIS present within Lost Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	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 11 aquatic invasive species that Lost Lake stakeholders believe are in Lost Lake. Only the species present in Lost Lake 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. More information on these invasive species or any other AIS can be found at the following links:

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

Aquatic Animals

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell. 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.

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).

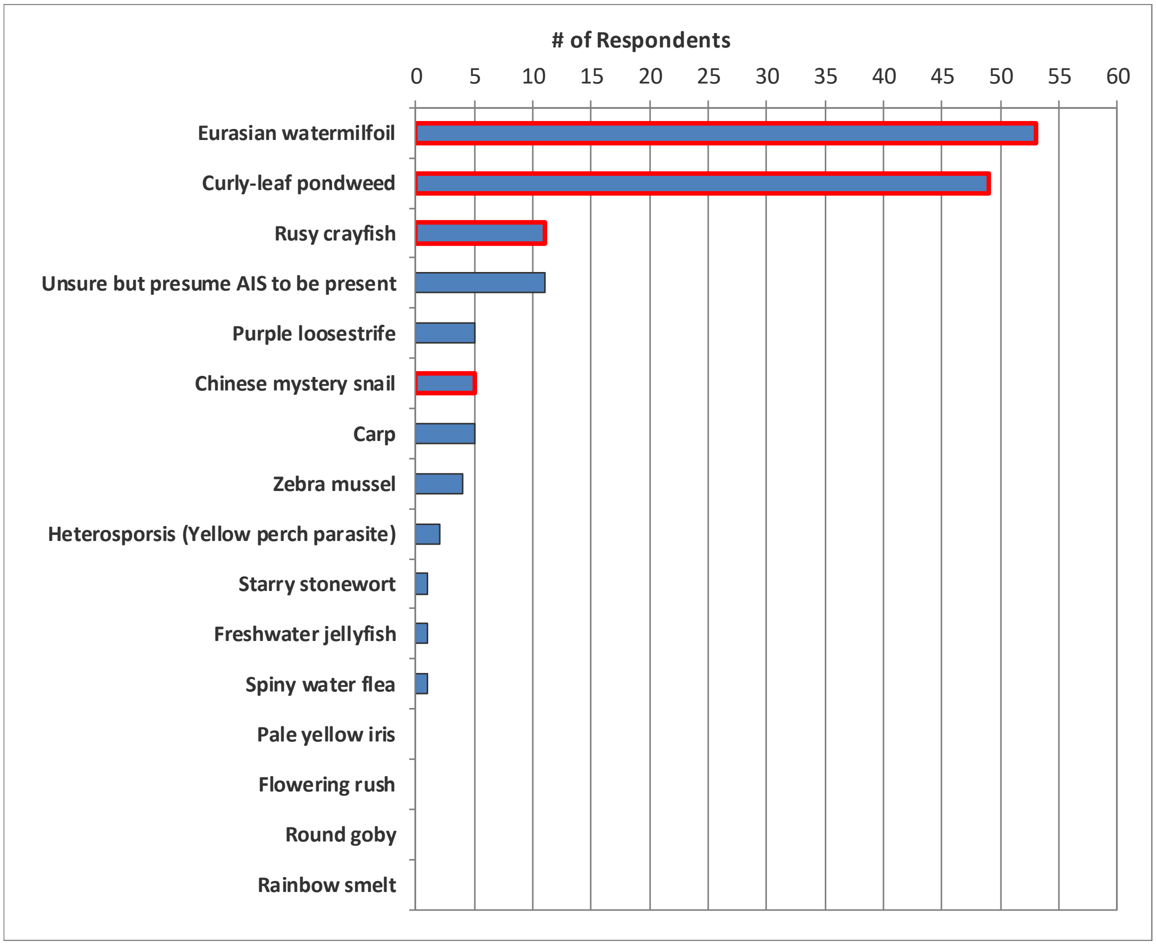


Figure 3.5-1. Riparian stakeholder survey response Question #20. Which aquatic invasive species do you believe are in Lost Lake? Bars outlined in red are species confirmed to be present in Lost Lake.

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Lost Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2017 & GLIFWC 2017).

Aquatic plant communities are an important component of a healthy ecosystem and provides important structural habitat for fish. Active management through the use of herbicide treatment has occurred in recent years in Lost Lake to target the non-native plant species curly-leaf pondweed. Understanding the impact aquatic plant management, including the use of herbicides, has on a fishery warrants further discussion.

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 Lost 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.

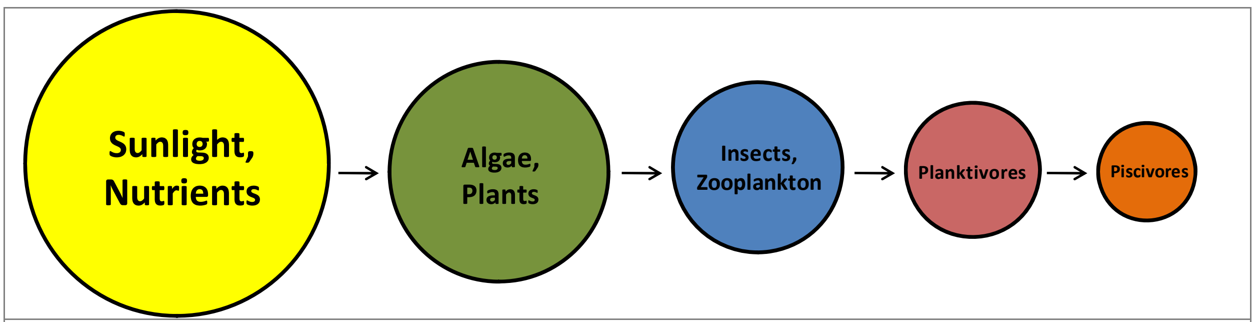


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Lost Lake is a lower eutrophic state, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Lost Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past surveys of Lost Lake include white sucker (*Catostomus commersonii*), burbot (*Lota lota*), creek chub (*Semotilus atromaculatus*), silver redhorse (*Moxostoma anisurum*), golden shiner (*Notemigonus crysoleucas*), common shiner (*Luxilus cornutus*) and bluntnose minnow (*Pimephales notatus*).

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

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

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

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

The other commonly used sampling method is electroshocking (Photograph 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. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark and recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Fish Stocking

Photograph 3.6-2. Fingerling Muskellunge.

To assist in meeting fisheries management goals, the WDNR may permit the stocking of 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. Lost Lake has been stocked from 1972 to 2017 with largemouth bass, walleye and muskellunge (Tables 3.6-2, 3.6-3 and 3.6-4). Historically, walleye were stocked fairly regularly from 1974 to 2012. Population estimates (PE) calculated during 1998 and 2011 showed 0.9 adults/acre for both years in Lost Lake. The WDNR's 2011 Fisheries Information Sheet is included as Appendix E. The average PE of walleye for Vilas County from WDNR survey records spanning 1990 through 2017 is 4.1 adults/acre. Minimal evidence of natural reproduction was found during recruitment surveys by the WDNR. Considering Lost Lake is a shallow, highly vegetated, and productive lake with strong panfish populations, the weak natural reproduction of walleye may be a combination of habitat limitations and the fish community (Boehm personal comm.). Additionally, walleye stocking has not been a viable alternative for Lost Lake. The 2011 PE showed very few walleye under 15" indicating not only weak natural reproduction but also stocking prior to 2011 was not sustainable as the fish stocked were not being observed during the survey (Boehm personal comm.). With this information considered, stocking of walleye by the WDNR ceased after 2012. The LLPRD continued their walleye stocking effort which typically occurs in odds years with 1,500 fingerling walleye.

Table 3.6-2. Stocking data available for largemouth bass in Lost Lake (1974-1999).

Year	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Fingerling	4,210	3
1988	Fingerling	3,302	2
1990	Fingerling	2,870	4
1997	Large Fingerling	360	3.4
1999	Large Fingerling	212	4.8

Table 3.6-3. Stocking data available for walleye in Lost Lake (1974-2017).

Lake	Year	Source	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Lost	1974	DNR	Unspecified	Fingerling	11,150	3
Lost	1975	DNR	Unspecified	Fingerling	13,000	3
Lost	1978	DNR	Unspecified	Fingerling	25,000	2
Lost	1981	DNR	Unspecified	Fingerling	20,000	5
Lost	1982	DNR	Unspecified	Fingerling	25,000	3
Lost	1984	DNR	Unspecified	Fingerling	24,955	2
Lost	1986	DNR	Unspecified	Fingerling	25,000	2
Lost	1988	DNR	Unspecified	Fingerling	25,000	2
Lost	1989	DNR	Unspecified	Fingerling	10,094	4
Lost	1990	DNR	Unspecified	Fingerling	25,200	3
Lost	1991	DNR	Unspecified	Fingerling	12,688	3
Lost	1992	DNR	Unspecified	Fingerling	6,902	3
Lost	1994	DNR	Unspecified	Fingerling	13,650	3
Lost	1998	DNR	Unspecified	Small Fingerling	54,400	1.5
Lost	2002	DNR	Mississippi Headwaters	Small Fingerling	27,200	7.1
Lost	2004	DNR	Mississippi Headwaters	Small Fingerling	27,200	1.3
Lost	2006	DNR	Mississippi Headwaters	Small Fingerling	19,040	1.4
Lost	2007	Lost Lake Community Club	Mississippi Headwaters	Fingerling	1,500	4.5
Lost	2008	DNR	Mississippi Headwaters	Small Fingerling	19,040	1.6
Lost	2009	Lost Lake Community Club	Upper Mississippi	Fingerling	1,500	4.5
Lost	2010	DNR	Mississippi Headwaters	Small Fingerling	19,040	1.4
Lost	2011	Lost Lake Community Club	Upper Mississippi	Fingerling	1,500	4.5
Lost	2012	DNR	Mississippi Headwaters	Small Fingerling	19,039	1.6
Lost	2013	Lost Lake District	Upper Mississippi	Fingerling	1,500	4.5
Lost	2015	Lost Lake District	Upper Mississippi	Fingerling	1,500	4.5
Lost	2017	Lost Lake District	Upper Mississippi	Fingerling	1,500	4.5

Table 3.6-3. Stocking data available for muskellunge in Lost Lake (1974-2016).

Lake	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Lost	1972	Muskellunge	Unspecified	Fingerling	1,400	12.33
Lost	1976	Muskellunge	Unspecified	Fingerling	550	9
Lost	1979	Muskellunge	Unspecified	Fingerling	1,107	10
Lost	1983	Muskellunge	Unspecified	Fingerling	1,090	9
Lost	1985	Muskellunge	Unspecified	Fingerling	1,113	9
Lost	1987	Muskellunge	Unspecified	Fingerling	3,189	11.5
Lost	1989	Muskellunge	Unspecified	Fingerling	550	11
Lost	1991	Muskellunge	Unspecified	Fingerling	500	11
Lost	1992	Muskellunge	Unspecified	Fingerling	500	11
Lost	1993	Muskellunge	Unspecified	Fingerling	1,000	10
Lost	1995	Muskellunge	Unspecified	Fingerling	729	11.9
Lost	1999	Muskellunge	Unspecified	Large Fingerling	500	11.6
Lost	2001	Muskellunge	Unspecified	Large Fingerling	544	10.2
Lost	2003	Muskellunge	Unspecified	Large Fingerling	544	10.5
Lost	2005	Muskellunge	Unspecified	Large Fingerling	544	10.6
Lost	2007	Muskellunge	Upper Wisconsin	Large Fingerling	363	12.1
Lost	2009	Muskellunge	Upper Wisconsin River	Large Fingerling	537	10.5
Lost	2011	Muskellunge	Upper Wisconsin River	Large Fingerling	543	9.3
Lost	2013	Muskellunge	Upper Wisconsin River	Large Fingerling	544	11.35
Lost	2014	Muskellunge	Upper Wisconsin River	Large Fingerling	542	9.4
Lost	2016	Muskellunge	Upper Wisconsin River	Large Fingerling	542	10.3

Fishing Activity

Based on data collected from the riparian stakeholder survey (Appendix B), fishing was the second-most important reason for owning property on or near Lost Lake (Question #15). Figure 3.6-2 displays the fish that Lost Lake stakeholders enjoy catching the most, with crappie, muskellunge and bluegill/sunfish 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 55% of respondents who fish Lost Lake believe the quality of fishing has remained the same or gotten worse since they started fishing the lake (Figure 3.6-4).

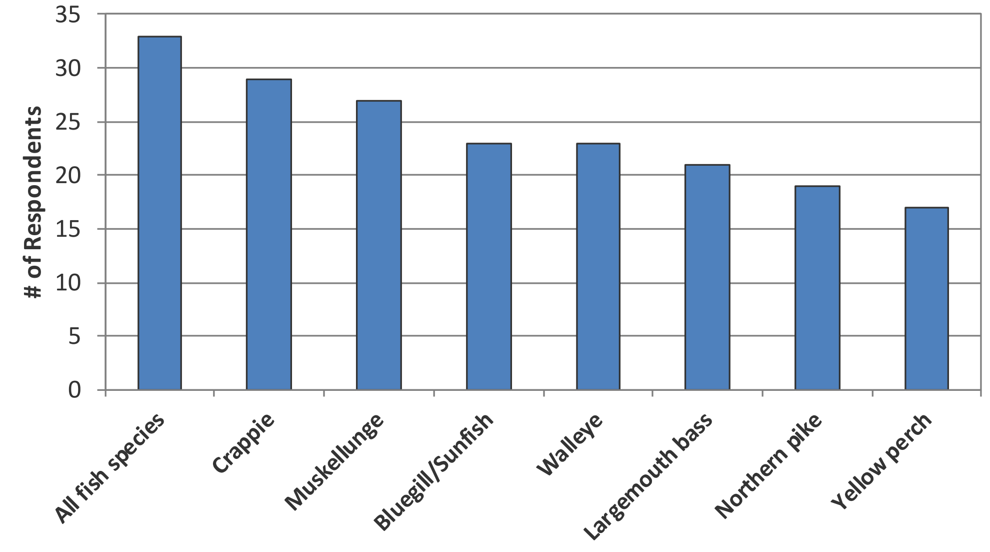


Figure 3.6-2. Riparian stakeholder survey response Question #9. What species of fish do you like to catch on Lost Lake?

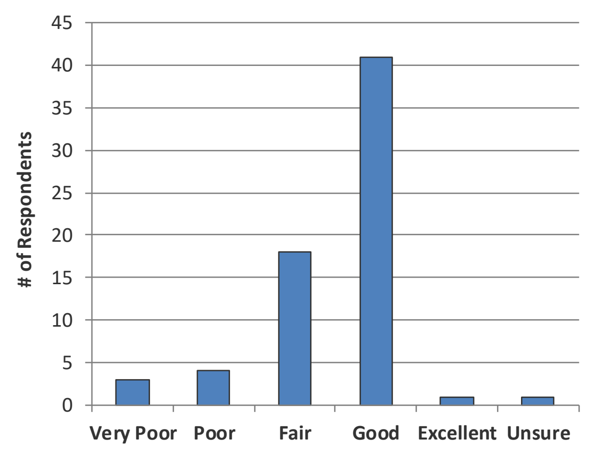


Figure 3.6-3. Riparian stakeholder survey response Question #10. How would you describe the current quality of fishing on Lost Lake?

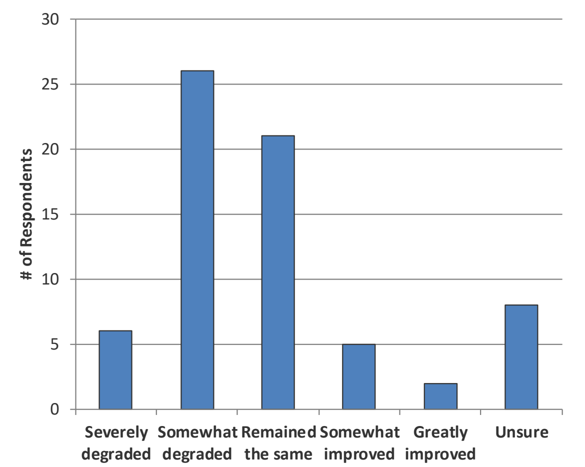


Figure 3.6-4. Riparian stakeholder survey response Question #11. How has the quality of fishing changed on Lost Lake since you started fishing the lake?

Lost 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). Lost Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings 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 represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. 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 than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

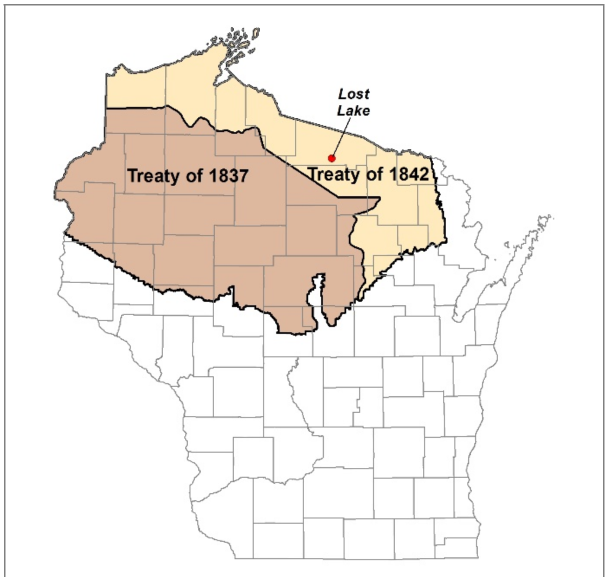


Figure 3.6-5. Location of Lost Lake within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Tribal members may 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. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Tribal harvest in Lost Lake has been minimal with just three walleye harvested in 2012, one in 2017 and no historic muskellunge harvest.

Lost Lake Fish Habitat

Substrate Composition

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

Substrate and habitat are critical to fish species that do not provide parental care to their eggs. Northern pike is one species that does not provide parental care to its eggs (Becker 1983). Northern pike broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye are another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn and care for their eggs in muck as well.

According to the point-intercept survey conducted by Onterra in 2017, 79% of the substrate sampled in the littoral zone of Lost Lake were soft sediments, 17% was composed of sand and 5% were composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006). A fall 2017 survey documented 101 pieces of coarse woody along the shores of Lost Lake, resulting in a ratio of approximately 21 pieces per mile of shoreline.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore. The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

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

Fish cribs are a fish habitat structure that is placed on the lakebed. Installing fish cribs may be cheaper than fish sticks; however some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structure in a lake does not require a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

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

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

Regulations

Regulations for Lost Lake gamefish species, as of April 2018, are displayed in Table 3.6-5. Lost Lake falls into the northern bass management zone in Wisconsin and thus smallmouth bass may not be harvested (catch and release only) from May 5, to June 15, 2018. A walleye regulation that restricts the harvest of 20”-24” fish is in place for Lost Lake. The purpose of this regulation is to limit the harvest of large female walleye so the reproductive potential for the species is maximized. 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 3.6-5. WDNR fishing regulations for Lost Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
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 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with one line per person with no more than three trolled lines per boat.

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree. However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-7. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

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

Figure 3.6-7. 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/)

4.0 SUMMARY AND CONCLUSIONS

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

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

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

Almost 30% of the Lost Lake's shoreline is in *urbanized* or *developed-unnatural* condition. These are the shoreland types that provide the least nutrient buffering capabilities and provide almost no habitat value for aquatic and terrestrial wildlife. This is offset by 50% of the lake's shoreline being *natural/undeveloped* or *developed-natural*, the shoreline condition that provides the most habitat value and nutrient buffering capacity. About one third mile of Lost Lake's shoreline is owned by the State of Wisconsin and is in a natural condition. The health of the Lost Lake ecosystem would be improved by increasing natural shorelines.

The water quality data from Lost Lake indicate that the lake is on average in good to excellent condition. The data do not reveal any trends over time, but do indicate large swings in the data. For instance, water clarity was over 4 feet less than the average in 2017, which is hypothesized to be related to high precipitation especially earlier in the growing season. Unfortunately, no water quality data exist between 2010 to 2017, a period when aquatic plant populations have been shown to generally decline.

A lake's water quality is largely a reflection of its drainage basin, or watershed. Lost Lake's watershed is comprised of land cover types that export minimal amounts of phosphorus to the lake. Based on the land cover date, the watershed model predicted Lost Lake to have lower phosphorus values than are present in the lake. This suggests that another source, likely from internal nutrient loading, is creating a more productive lake than would be expected from external watershed phosphorus loading alone. Although internal phosphorus loading likely occurs annually to some extent in Lost Lake, historical data indicates that in 1997, 1999, 2004, and 2017 the magnitude of phosphorus increase was significantly greater.

A concerning reduction in the overall plant community of Lost Lake has been documented in recent years. Aquatic plant point-intercept surveys have been completed on Lost Lake in 2007, 2010, 2014, 2017, and 2018. While there are gaps in the data, it generically appears that a number of plants declined from 2010 to 2014, with some declining to zero. Further declines were observed from 2014 to 2017. Declines in aquatic plant abundance are often associated with declines in water clarity. Water transparency data from 1993 to 2007 indicated a mean summer Secchi disk value of 7.5 feet. In 2010 and 2017, the mean summer Secchi disk values were 5.1 and 4.6, respectively. No data are available between 2010 and 2017. Continued water quality and aquatic plant monitoring are important to understanding the condition of Lost Lake.

Aquatic invasive plant species are present in Lost Lake, including two submersed species, Eurasian watermilfoil and curly-leaf pondweed. The population of Eurasian watermilfoil has remained relatively low but widely distributed in Lost Lake since initial reports of detection in 2013, and therefore is not currently the target of active management. The recent addition of curly-leaf pondweed (2014) has been more problematic in Lost Lake, reaching levels in the western bay that inhibit traditional recreational use of the lake as well as potentially impacting the way the ecosystem functions. After a wait-and-see approach in 2015 and 2016, the LLPRD enacted a control program towards the curly-leaf pondweed population within the western bay in 2017 and 2018. It is presumed that multiple years of successive herbicide treatments will be required in this location to decrease curly-leaf pondweed densities; the LLPRD is committed to continue this strategy in 2019 and 2020. The LLPRD has also developed a longer-term strategy that outlines a threshold for potential further management that attempts to balance tolerance of curly-leaf pondweed while continuing to manage a reduced curly-leaf pondweed population within lake. The LLPRD understands that this balance is a difficulty many lake groups struggle with.

With herbicide control strategies being implemented during the spring of 2017 and 2018, the impacts of these control actions on the already struggling aquatic plant community has been discussed. While the lake-wide herbicide concentrations within Lost Lake confirm that the treatment impacts are largely contained to the basin of the control action, rebound of select native plants within the western basin may be impeded. If future monitoring indicates the aquatic plant community of Lost Lake is increasing but not in the western basin, the LLPRD may consider postponing active management towards curly-leaf pondweed.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the LLPRD Planning Committee and ecologist/planners from Onterra. It represents the path the LLPRD 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 Lost Lake stakeholders as portrayed by the members of the Planning Committee, the returned riparian 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.

While the LLPRD 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 LLPRD 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: Manage Existing and Prevent Further Aquatic Invasive Species Infestations within Lost Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at critical public access locations
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	Currently the LLPRD monitors the public boat landings using training provided by the Clean Boats Clean Waters program. Lost Lake is a 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 Lost Lake. 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. Inspections at the Long Lake landing have exceeded 200 hours annually since 2012 through a paid effort and the LLPRD intends to continue the inspection efforts at this level. This program has been historically sustained through a streamline CBCW grant program with partnership from Vilas County. However, the Vilas County Program

	with UW-Oshkosh has been recently been dissolved by the county; therefore, the LLPRD is searching for a new source of labor.
Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate annual professional monitoring of AIS, particularly CLP
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	An Early Season AIS Survey would be completed annually during June when CLP is at its peak growth, allowing for a true assessment of the amount of this exotic within the lake. 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 CLP 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. Continued monitoring of EWM populations would occur semi-annually (as needed), following similar protocols as discussed above for CLP but occurring towards the end of the growing season. If large colonies of dense (*dominant, highly dominant*, or *surface matting*) EWM is documented in the lake, the development of an EWM management goal may be considered.
Action Steps:	
	See description above as this is an established program.

Management Action:	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3years, Community Mapping every 10 years
Facilitator:	Board of Directors
Description:	For lakes conducting active management, a whole-lake point-intercept surveys should be conducted at a minimum once every 3 years. This will allow an understanding of the submergent aquatic plant community dynamics within the Lost Lake. This will also allow an understanding of changes in the EWM population for determination if active management should be considered, particularly if EWM populations exceed 15% of the littoral zone as measured by the point-intercept survey.

	In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Lost Lake, a community mapping survey would be conducted approximately every 10 years. The community mapping survey has been conducted on Lost Lake approximately every 6-7 years (2004, 2010, 2017) in the past as part of each lake management planning project update.
Action Steps:	
	See description above as this is an established program.

Management Action:	Conduct CLP population management using herbicide spot treatments
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	As discussed within the Non-Native Plants in Lost Lake subsection of the Aquatic Plant Section (3.4), the LLPRD have conducted two years of consecutive herbicide treatments on the largest area of CLP population in Lost Lake. The LLPRD anticipates multiple additional treatments of this area before significant gains in CLP reduction will occur. On nearby Little Saint Germain Lake, an established population within No Fish Bay was targeted for approximately 10 consecutive years. In the last 3 years, the CLP population of No Fish Bay has only comprised of a small number of individual plants. In practice, it is unclear how many years CLP turions can remain viable and therefore the number of consecutive years treatments are required is unknown. Because CLP has only been present in Lost Lake for a few years, some theorize that the turion base may be small and if a control program is initiated at this time, may not require as many successive treatments as a more established population would. Therefore, the LLPRD would set a threshold (i.e. trigger) to help guide future management decisions. The trigger may be subject to modification based upon changing understanding of this form of plant management. With two years of treatment occurring to date, the LLPRD is planning on targeting the same location for another two years (2019-2020) and has secured a WDNR AIS-Established Population Control Grant to assist with funding. Prior to the treatment each year, a sub-sample point-intercept survey (Figure 5.0-1, left frame) would occur as a surrogate understanding of turion sprouting. In 2017 and 2018, 84% and 46% of sub-sample points contained CLP, respectively. Along with providing an understanding of the overall control program, the data will be used as a trigger for implementing the management strategy. In 2021 and beyond, CLP treatment would be considered that spring if the sub-sample data yield greater than 30%. It is

hoped that this will allow a balance of CLP tolerance while continuing to manage a reduced CLP population within lake. The WDNR would evaluate each year's justification for treatment and make annual permit decisions based upon the data collected and the evolution of best management practices. The LLPRD will involve the WDNR in discussions regarding changes to the ongoing management strategy.

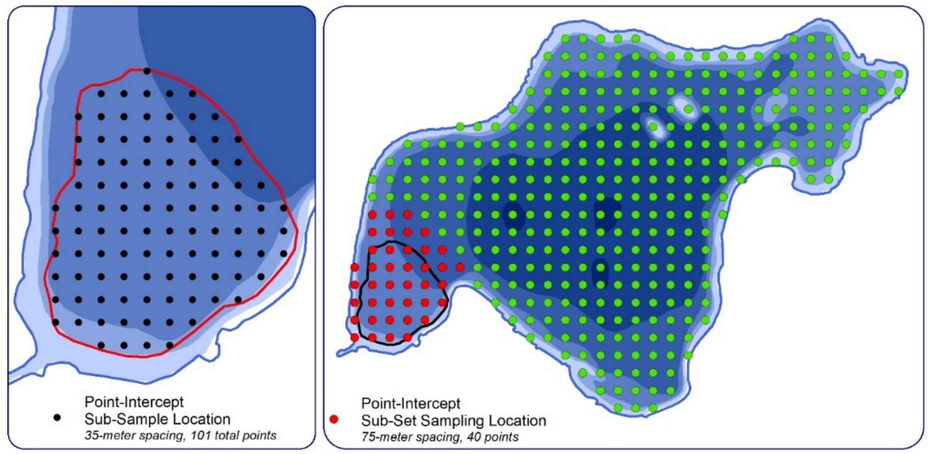


Figure 5.0-1. Lost Lake quantitative monitoring plan.

The condition of the native plant community is also a concern of the LLPRD. Because many native aquatic plants are not actively growing at the time of the spring pre-treatment survey, a separate point intercept dataset would be used to assess the native aquatic plant community in response to the herbicide treatment. Whole-lake point intercept surveys were conducted on Lost Lake in 2007, 2010, 2014, 2017, and 2018. A subset of these data comprises 40 points with a resolution of 75 meters in the western bay that is within and around the herbicide application area (Figure 5.0-1, right inset).

As occurred in 2017 and 2018, the application would occur before water temperatures greatly exceed 60°F, as endothall uptake rates have been shown to be higher at these water temperatures (Dr. Cody Gray, personal comm.) Considerations would also be given to completing the application after the Lac du Flambeau Band of Lake Superior Chippewa Indians has finished their spring open-water spear harvest.

The impacts of precipitation events prior to and during the treatment will continue to be monitored, particularly as longer residence time may justify a decrease in application rate down to 1.5 ppm ai compared with 2.0 ppm ai targeted in 2017 and 2018.

The WDNR has indicated their preference for the LLPRD to consider mechanical harvesting as an alternative management strategy to herbicide spot treatment. The Lac du Flambeau Tribal Natural Resource Department maintains opposition to herbicide treatment on an affected wild rice waterbody and fishery within ceded territory.

Action Steps:	
	See description above

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality of Lost Lake 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. Volunteer water quality monitoring should be completed annually by Lost 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 LLPRD 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. 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. As a part of the program the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer. It also must be noted that the CLMN program may be changing in the near future, as enrollment in the program is currently capped. If there is not an ability for the LLPRD to participate in the advanced CLMN program, they are open to considering self-funding the analysis of these samples on an annual or semi-annual basis.	
Action Steps:		
	1.	Contact Sandra Wickman (715.365.8951) to enroll in the CLMN program.
	2.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and and report results to district members during annual meeting.

3.	CLMN volunteer and/or LLPRD would facilitate new volunteer(s) as needed

Management Action:	Ensure water quality of upstream lakes within Lost Lake's watershed are being monitored
Timeframe:	Initiate in 2019
Facilitator:	Board of Directors
Description:	As discussed within the Watershed Section (3.2), approximately 47% of Lost Lake's total watershed is composed of Stella Lake's subwatershed, 27% of Found Lake's subwatershed, and 26% of its own direct watershed. Ensuring that water quality monitoring is occurring in Found Lake and Stella Lake may allow earlier detection of trends than may impact Lost Lake. Found Lake has an active lake association and currently monitors water clarity through the CLMN program. The Stella Lake District is currently inactive and has not conducted water quality monitoring since 2005. The LLPRD would set a goal to collect Secchi disk transparency on Stella Lake following CLMN protocols.
Action Steps:	
1.	Communicate with Found Lake Association and Stella Lake District to ensure water quality parameters are being monitored.
2.	If gaps in water quality monitoring are identified, trained CLMN volunteer from Lost Lake collect Secchi disk following CLMN program. Data would be entered into SWIMS.

Management Goal 3: Increase LLPRD'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:	The LLPRD maintains an active email distribution network and an updated website for communication: www.townofstgermain.org/lk_dist_lost.html 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 LLPRD 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 • Shoreline habitat restoration and protection • Fireworks and other environmental education • Create opportunities to serve on LLPRD board of directors • Develop better communication with lake property owners • Boating safety (promote existing guidelines, Vilas County Courtesy Code)
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Continue LLPRD's involvement with other entities that have responsibilities in managing (management units) Lost Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the LLPRD 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 St. Germain Lakes Committee	Chairman (Ted Ritter Tritter3@frontier.com)	Lost Lake falls within the Town of St. Germain and has representation on this committee	LLPRD representative attend committee meetings	Committee was formed to pool resources from the town's 5 main lake organizations and involving the township government opportunities.
Vilas County Lakes & Rivers Association	President (Tom Ewing. tomewingjr@aol.com)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed. May check website (http://www.vclra.us/home) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County AIS Coordinator	Invasive Species Coordinator (Cathy Higley – 715.479.3738)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: 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 (Steve Gilbert– 715-356-5211 ext. 229)	Manages the fishery of Lost 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.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	LLPRD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management 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 years, an updated stakeholder survey would be distributed to the Lost 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 Lost Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Initiate 2018
Facilitator:	Board of Directors or possible coordinator
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. Numerous properties within the Town of Saint Germain have been restored over the past 10 years, allowing a large set of demonstration sites for riparians to view and understand what they may look like on their property. As discussed within the Shoreland Conditional Section (3.2), riparian participation in past restoration programs, even those with no financial responsibility from the landowner, were low. A number of factors were cited, including the fact that a grass roots effort

	originating from the district may get more buy-in that a project partially being led by the WDNR. The LLPRD has discussed shoreline restoration at numerous past meetings, including showing some of the preliminary results of the studies occurring along its shorelines. The LLPRD Board of Directors believes its constituents are concerned about perceived overreach of property rights and policing of shorelines when the topic is discussed. The LLPRD will continue to provide information to district members on shoreland restoration, including with assistance from the Vilas County Lakes & Rivers Association. 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:	
	See description above

<u>Management Action:</u>	Coordinate with WDNR and private landowners to expand coarse woody habitat in Lost Lake
Timeframe:	Initiate 2018
Facilitator:	Board of Directors or possible coordinator
Description:	LLPRD stakeholders must realize the complexities and capabilities of Lost Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a

	variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.
	
	The LLPRD would also like to work with Vilas County and WDNR to determine if a coarse woody habitat improvement project (i.e. fish sticks) would be applicable state-owned conservation lands near the boat landing. This could serve as a demonstration site on Lost Lake to recruit additional buy-in for private lands. The LLPRD would then further 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 Steve Gilbert (WDNR Fisheries Biologist) to gather information on initiating and conducting coarse woody habitat projects.

Management Action:	Develop a fisheries management plan for Lost Lake
Timeframe:	Initiate in 2019
Facilitator:	Board of Directors
Description:	The LLPRD would like the WDNR fisheries biologist to lead them through the creation of a written strategy for managing the fisheries of Lost Lake. The LLPRD would encourage an open visioning session where a bidirectional flow of information and perspectives can take place. This will allow managers to understand user preferences to balance with ecosystem capability. With a formally defined strategy being in place, measurable objectives can be set to determine if the strategy is succeeding.
Action Steps:	
	See description above

Management Action:	Investigate requesting transfer of ownership of the Lost Lake dam
Timeframe:	Initiate in 2019
Facilitator:	Board of Directors
Description:	Currently, the water control structure that influences Lost Lake's water levels is owned by Vilas County. Through an agreement, the dam is operated by the LLPRD, including routine maintenance. The LLPRD would initiate a feasibility study on whether or not they should request Vilas County to transfer ownership of the dam to the district. This would secure the fate of the dam with the LLPRD, as they are the primary stakeholder its operation impacts.
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 Lost Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

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

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

Watershed Analysis

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

Acoustic Survey

During the mid- to late-summer 2017, Onterra systematically collected continuous, advanced sonar data across Lost Lake. The resulting data was electronically sent to a Minnesota-based firm (Navico) for initial processing. The acoustic data collected during the lake management planning project was analyzed for bathymetry, submersed aquatic vegetation bio-volumes, and substrate analysis models.

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Lost Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Lost Lake (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

AIS Mapping Surveys

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

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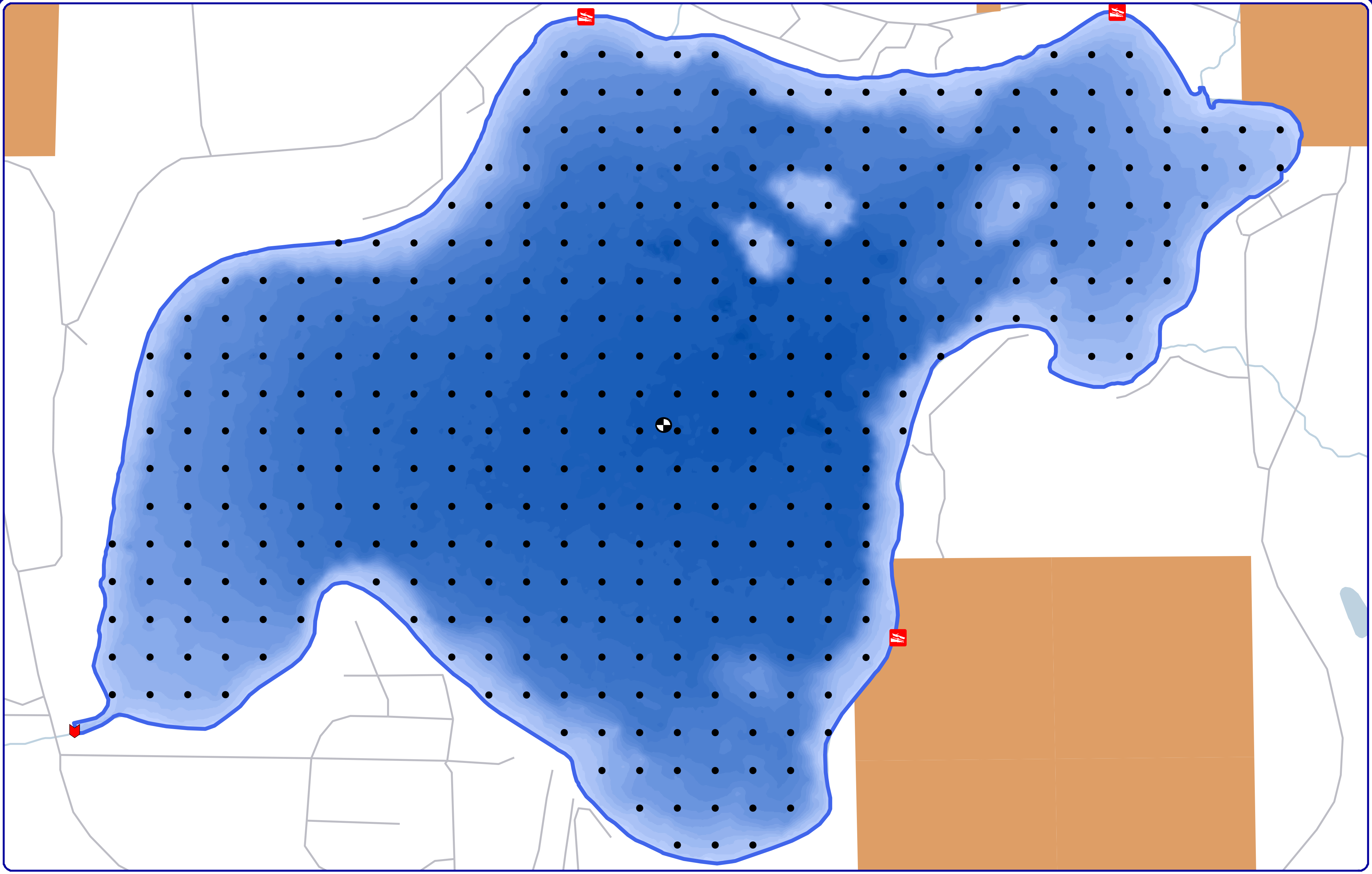
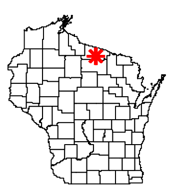
Zhang, C. and K.J. Boyle. 2010. The Effect of an Aquatic Invasive Species (EWM) on Lakefront Property Values. Ecological Economics 70:394-404.




Project Location in Wisconsin

N
W
E
S

850
Feet

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

Sources:
Roads and Hydro: WDNR
Map Date: April 16, 2018
Filename: *Map1_Lost_Location.mxd*

Legend

Lost Lake ~ 539 acres
WDNR Definition

WDNR Managed Lands

Point-intercept Sample Location
75 meter points

Public Access

Dam

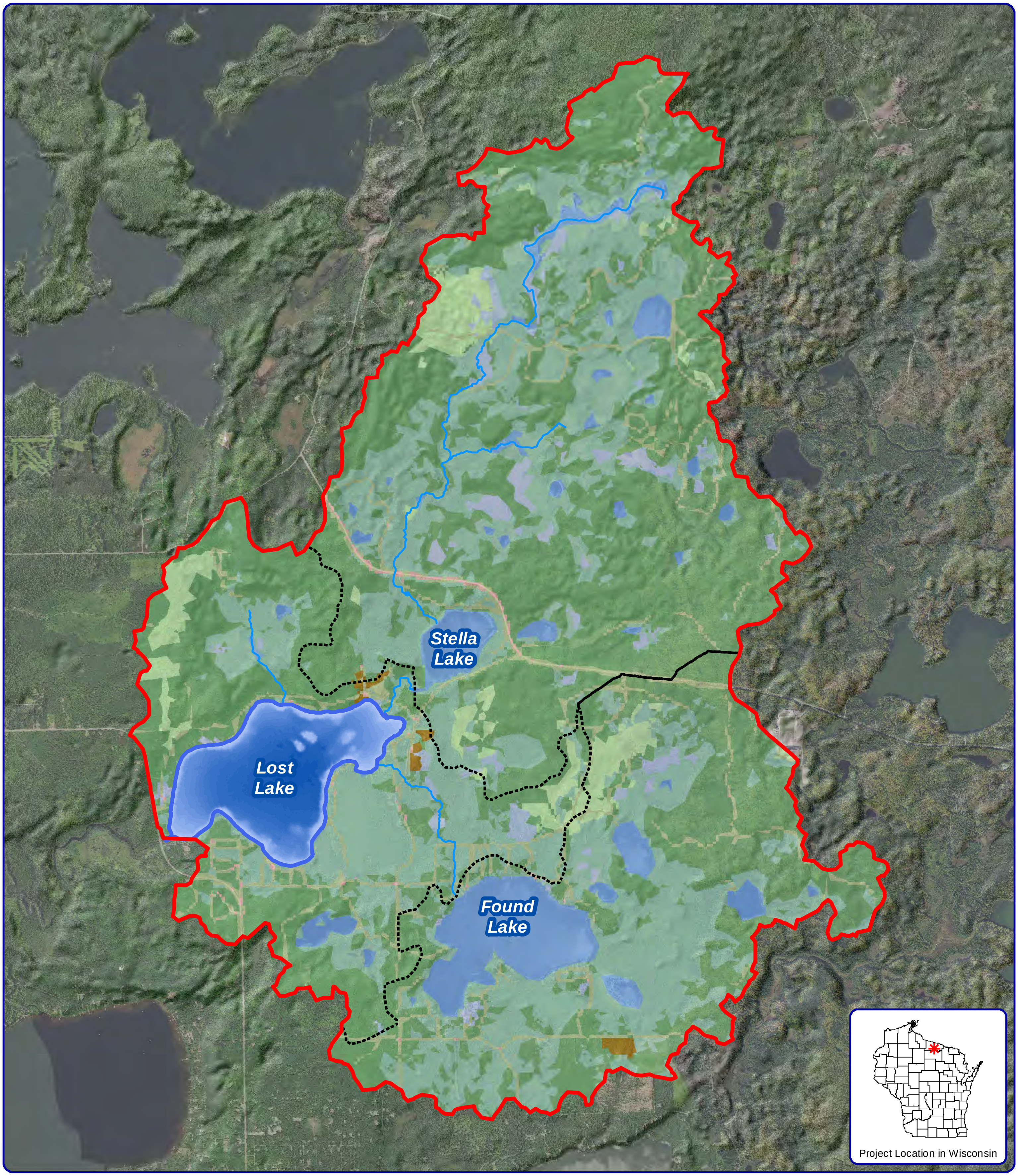
Water Quality Sampling Location

Map 1

Lost Lake

Vilas County, Wisconsin

Project Location
& Lake Boundaries



N
W E
S

4,200

Feet

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

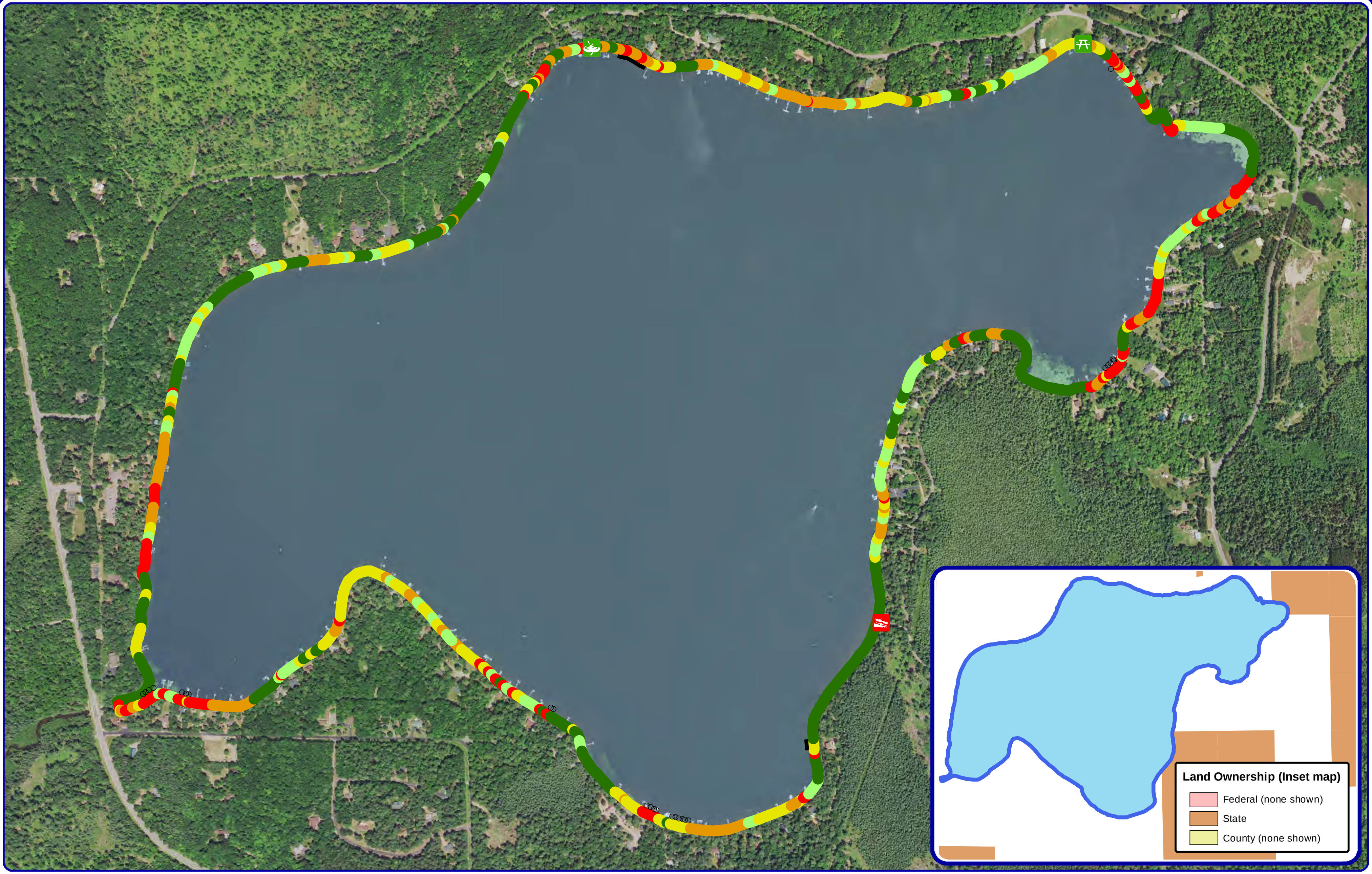
Sources:
Hydro: WDNR
Bathymetry: Onterra 2017
Orthophotography: NAIP 2015
Land Cover: NLCD 2011
Watershed Boundaries: Onterra 2017
Map Date: December 4, 2017
Filename: Map2_Lost_WS.mxd

Legend

- Forest
- Forested Wetlands
- Wetlands
- Open Water
- Rural Open Space
- Pasture/Grass
- Row Crops
- Rural Residential
- Lost Lake Watershed Boundary
- Subwatershed Boundary
- River/Stream

Map 2
Lost Lake
Vilas County, Wisconsin

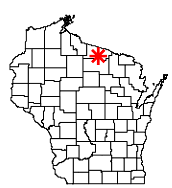
Watershed Boundaries & Land Cover Types



N
W E
S
900
Feet

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

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Shoreline Assessment: Onterra, 2017
Map Date: November 2, 2017
Filename: Map3_Lost_ShorelandCondition_2017.mxd



Project Location in Wisconsin

Legend

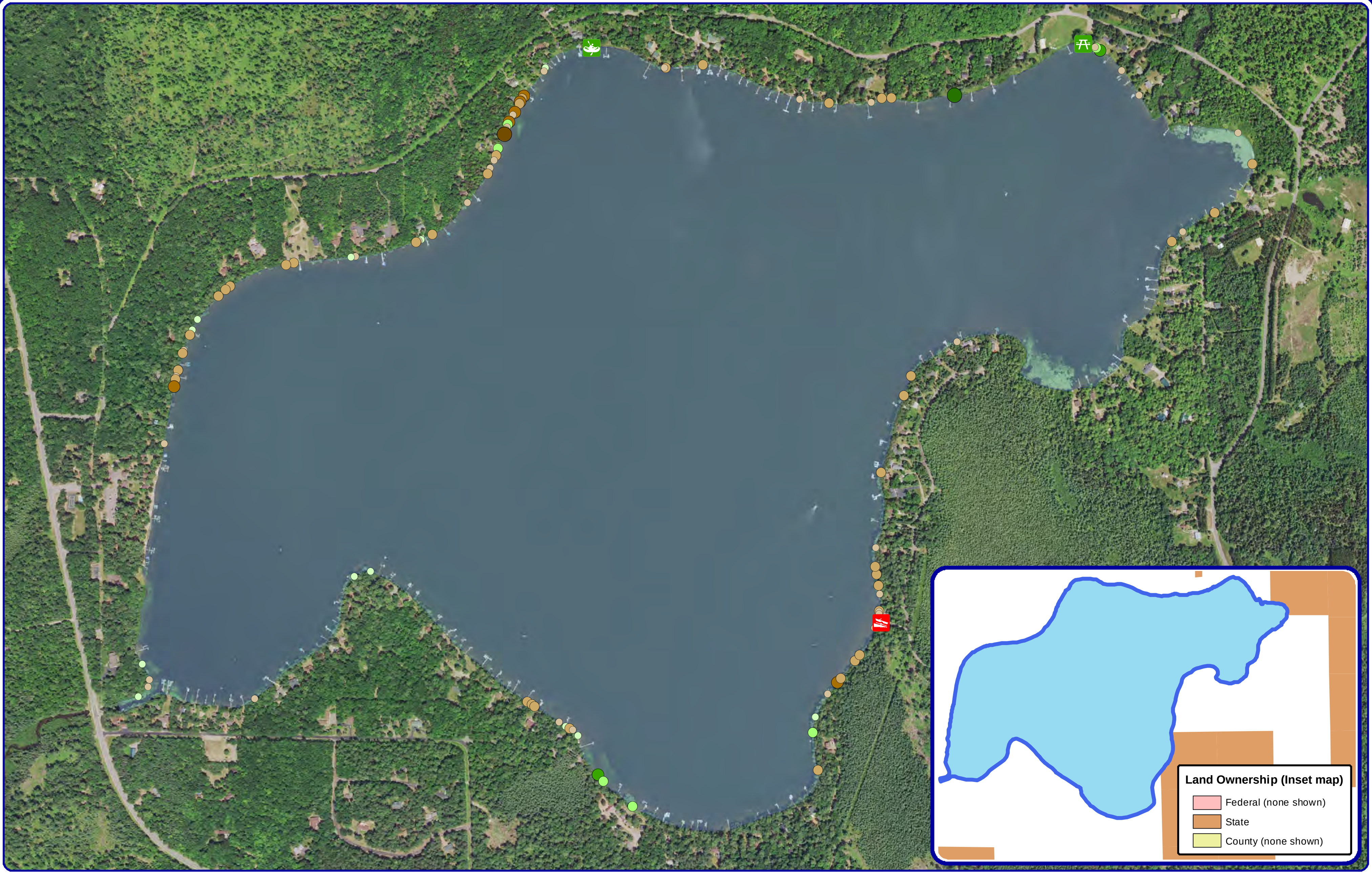
- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall
- Rip-Rap
- Wood/Masonary/Metal

Map 3

Lost Lake
Vilas County, Wisconsin

2017 Shoreland Condition



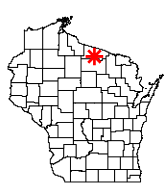
N
W E
S

900

Feet

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

Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Coarse Woody Habitat Survey: Onterra, 2017
Map Date: November 2, 2017
Filename: Map4_Lost_CWH_2017.mxd



Project Location in Wisconsin

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches (none)
Minimal Branches	Minimal Branches	Minimal Branches (none)
Moderate Branches	Moderate Branches	Moderate Branches (none)
Full Canopy	Full Canopy	Full Canopy (none)

Map 4

Lost Lake

Vilas County, Wisconsin

Coarse Woody Habitat

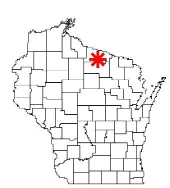
N W E S

950

Feet

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

Sources:
Aquatic Plants: Onterra, 2017
Orthophotography: NAIP, 2017
Map date: October 23, 2017
Filename: Map6_Lost_Comm_2017.mxd



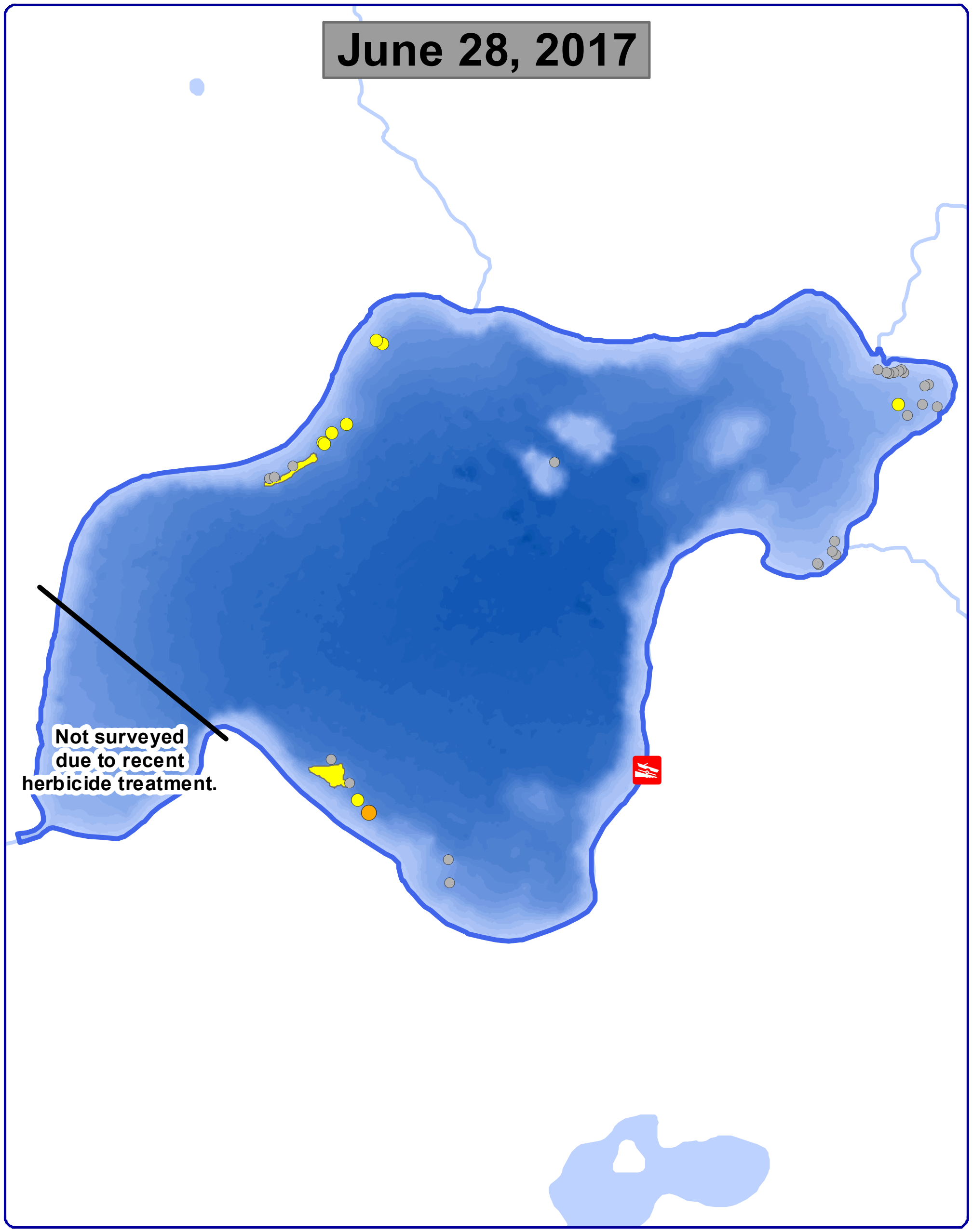
Extent of large map shown in red.

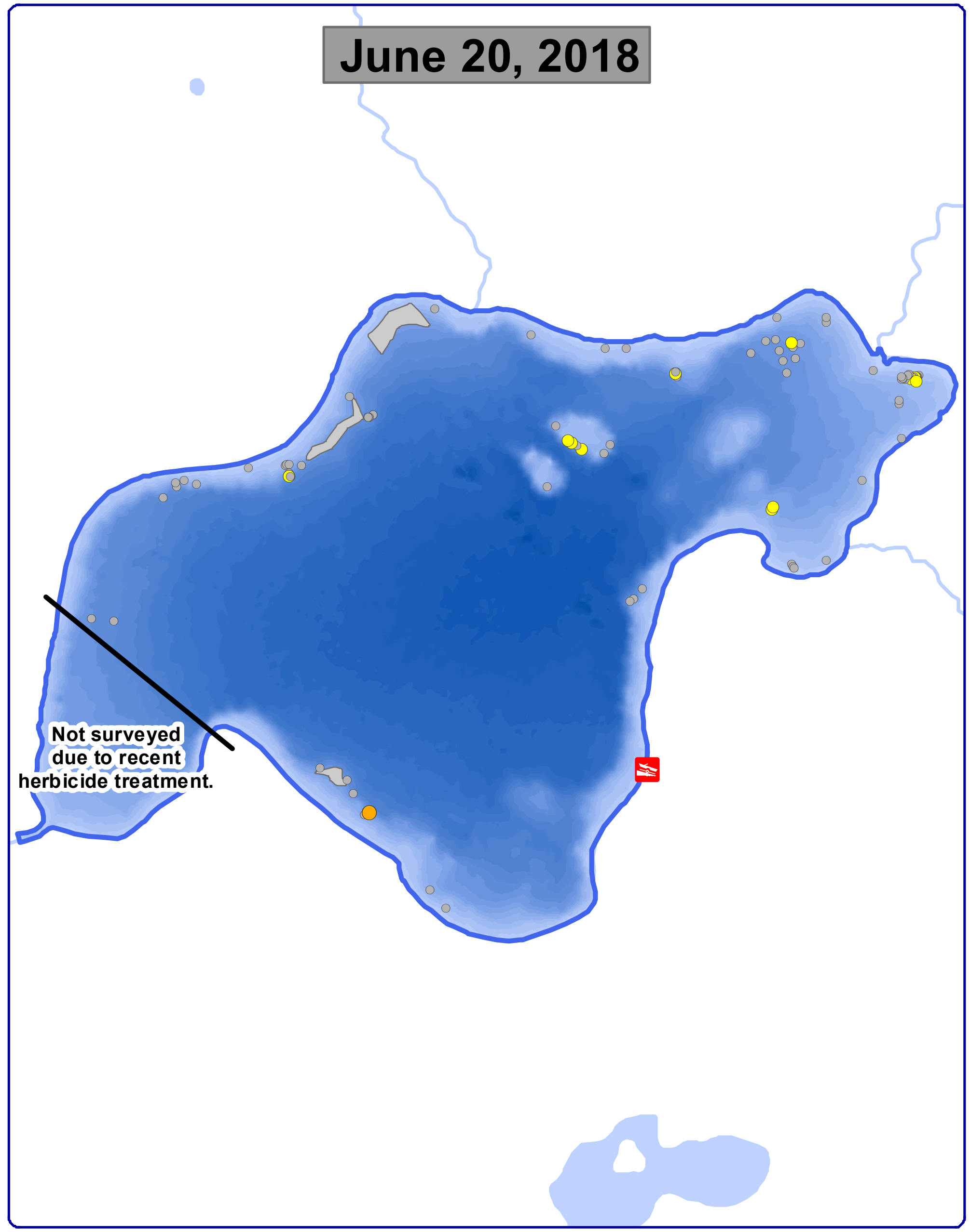
Legend

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

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

Map 5
Lost Lake
Vilas County, Wisconsin
Aquatic Plant Communities

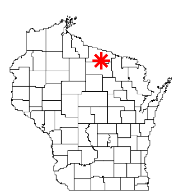




200
Feet

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

Sources:
Roads & Hydro: WDNR
Aquatic Plants: Onterra, 2017-2018
Bathymetry: Onterra, 2017
Map date: November 13, 2018 - EJH



Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant *(none found)*
- Surface Matting *(none found)*
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 6

Lost Lake

Vilas County, Wisconsin

Late-June 2017-2018
CLP Survey Results