Loon Lake

Shawano County, Wisconsin

Comprehensive Management Plan

June 2018

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

Loon Lake Planning Committee

Damian Drewek	Randy Perra	Mary Claire Lucck
Larry Philbrick	Lloyd Knope	Byron Wendt
Dick Koeller		

DRAFT

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1.0 INTRODUCTION

According to the 1967 recording sonar WDNR Lake Survey Map, Loon Lake is 305 acres. The WDNR website indicates the lake is 327 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program (NAIP)* collected in June 2015. Based upon heads-up digitizing the water level from that photo, the lake was determined to be 327 acres. Loon Lake, Shawano County, is a drainage lake with a maximum depth of 20.6 feet and a mean depth of 8 feet. This eutrophic lake has a relatively large watershed when compared to the size of the lake. Loon Lake contains 40 native plant species, of which wild celery is the most common plant. Three exotic plant species are known to exist in Loon Lake.

Loon Lake Wescott Management District (LLWMD) is the local citizen-based organization leading the management of Loon Lake. The group has worked for years to protect and enhance the lake and has utilized WDNR grant funds to conduct lake management planning activities, acquire land for conservation purposes, and control invasive plant species.

Field Survey Notes

Loon Lake has red, stained water and an abundance of bladderwort species. The northwestern portion of the lake is lined with water-willow making for beautiful scenery.

Photograph 1.0-1 Loon Lake, Shawano County

Lake at a Glance – Loon Lake

Morphology	
Acreage	327
Maximum Depth (ft)	20.6
Mean Depth (ft)	8
Shoreline Complexity	1.8
Vegetation	
Number of Native Species	40
Threatened/Special Concern Species	-
Exotic Plant Species	Pale-yellow iris, Eurasian watermilfoil, Curly-leaf pondweed
Simpson's Diversity	0.91
Average Conservatism	6.4
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.9
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	35:1

2.0 STAKEHOLDER PARTICIPATION

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

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

Kick-off Meeting

On July 23, 2016, a project kick-off meeting was held at Camp Tekakwitha to introduce the project to the general public. The meeting was announced through a mailing and personal contact by LLWMD board members. The approximately 94 attendees observed a presentation given by Eddie Heath, an aquatic ecologist with Onterra. Mr. Heath's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I

On July 27, 2017, Mr. Eddie Heath of Onterra met with six members of the Loon Lake Planning Committee for nearly 3 hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including Eurasian watermilfoil treatment results as well as treatment strategies, aquatic plant inventories, water quality analysis, shoreland conditions, coarse woody habitats, and watershed modeling were presented and discussed.

Planning Committee Meeting II

On November 14, 2017, Mr. Eddie Heath met with four members of the Planning Committee over teleconference to begin developing management goals and actions for the Loon Lake management plan. Prior to the meeting, a draft outline of the Implementation Plan Section was created and served as the framework for the meeting.

Project Wrap-up Meeting

Scheduled for July 21st 2018.

Management Plan Review and Adoption Process

A preliminary draft of the Comprehensive Lake Management Plan was provided to the Planning Committee and the Board of Directors in mid-May, 2018.

In June 2018, an official first draft of the LLWMD's Comprehensive Management Plan was supplied to the WDNR, Shawano County, and LLWMD's Planning Committee for official review.

Stakeholder Survey

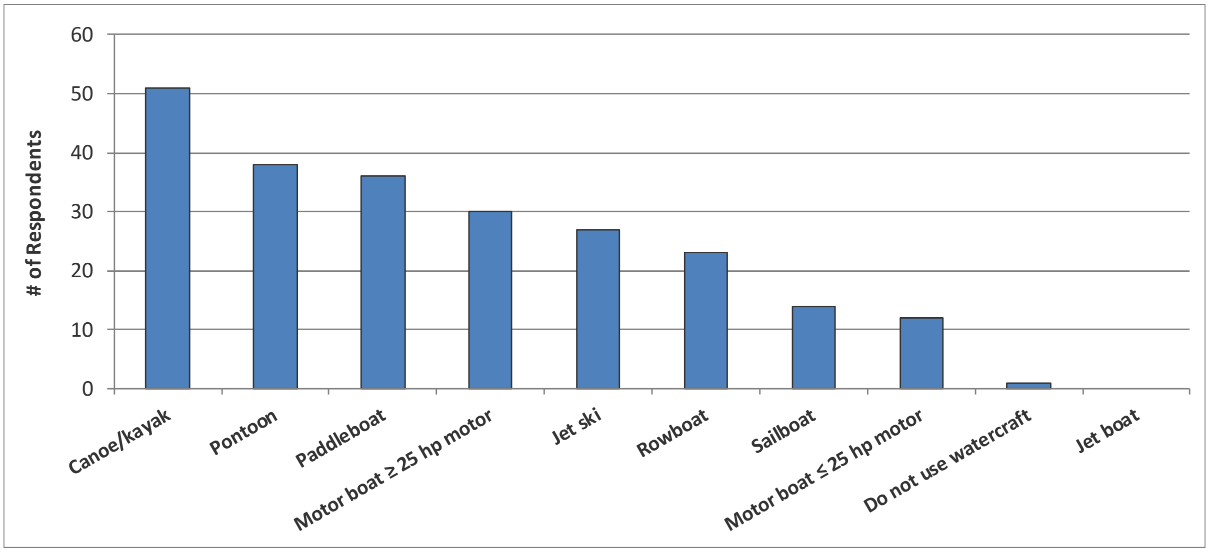
As a part of this project, a stakeholder survey was distributed to riparian property owners and trailer park residents around Loon Lake. The survey was designed by Onterra staff and the LLWMD planning committee and reviewed by a WDNR social scientist. During October 2016, the eight-page, 35-question survey was posted online through Survey Monkey for property owners to answer electronically and in June 2017 the survey was posted for trailer park residents. 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 LLWMD volunteer for analysis. Forty-four percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Loon Lake. The majority of stakeholder respondents (48%) live on the lake during the summer months only, while 24% are year-round residents, 2% visit on weekends through the year, 1% have a resort property, and 1% have a rental property. Seventy-seven percent of stakeholder respondents have owned their property for over 15 years, and 45% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a canoe/kayak, pontoon, paddleboat, large motor boat, jet ski, or a combination of those vessels on Loon Lake (Question 12). Row boat and sail boats were also popular options. As seen on Question 15, the top recreational activity on the lake is relaxing/entertaining.

A concern of stakeholder respondents noted throughout the survey (see Questions 21-22 and survey comments – Appendix B) was aquatic invasive species introduction, watercraft traffic or unsafe watercraft practices, and changing water levels in Loon Lake.

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



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

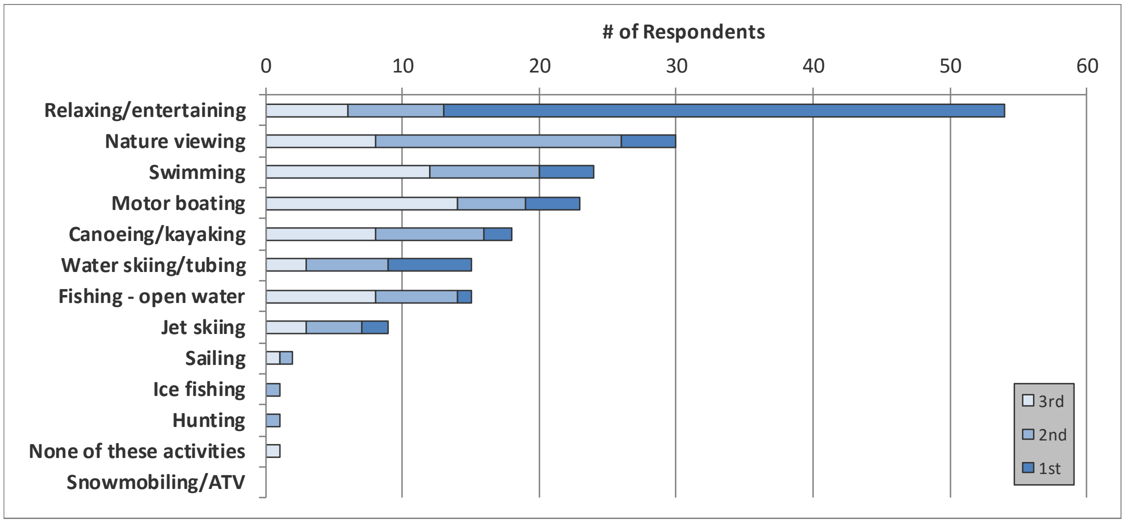
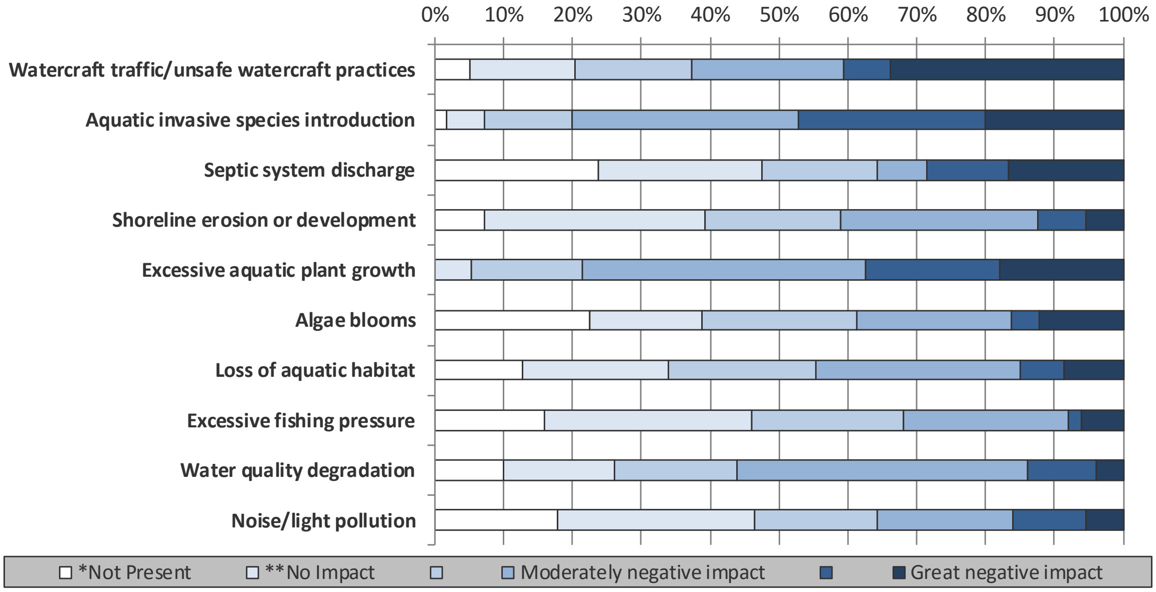


Figure 2.0-1. Select survey responses from the Loon Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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



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

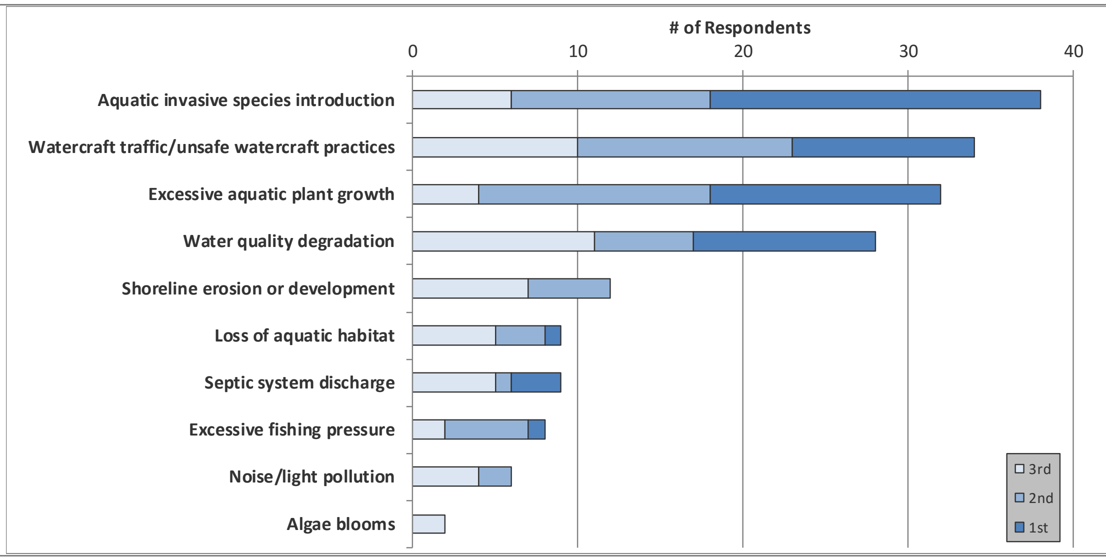


Figure 2.0-2. Select survey responses from the Loon Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Loon 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 Loon 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, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading*

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Loon 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, Loon Lake is classified as a shallow lowland drainage lake (category 4 on Figure 3.1-1).

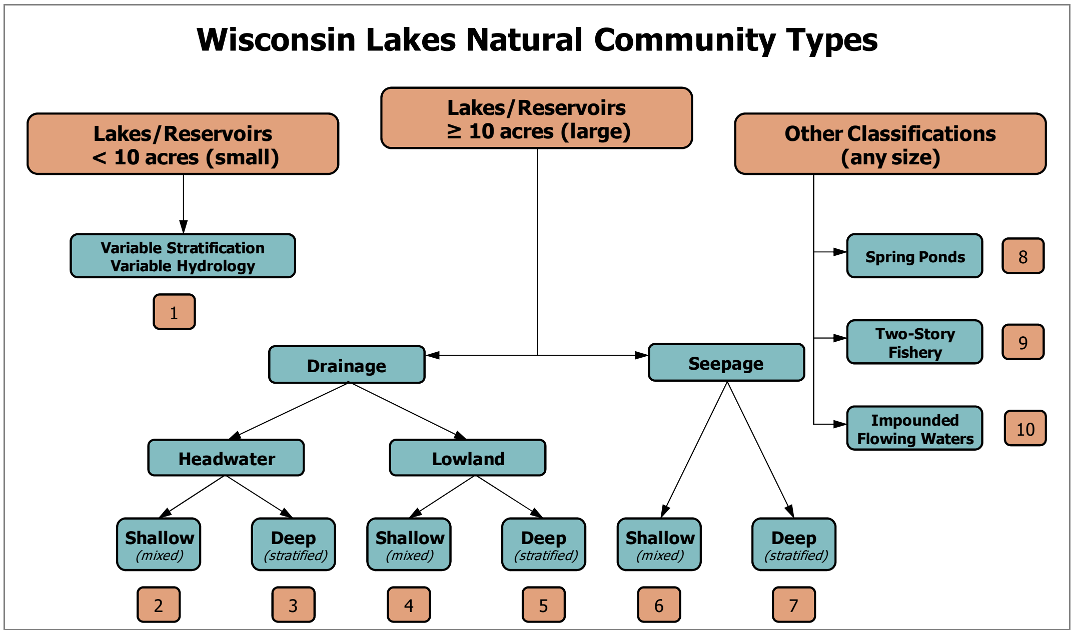


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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

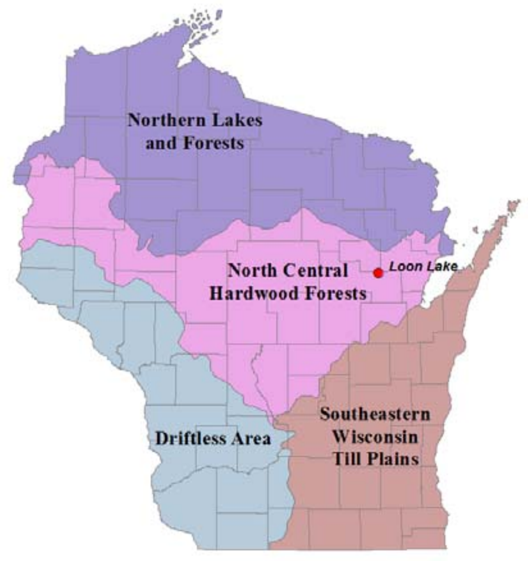


Figure 3.1-2. Location of Loon Lake within the ecoregions of Wisconsin. After Nichols 1999.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Loon 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.

Loon Lake Water Quality Analysis

Loon Lake Long-term Trends

Near-surface total phosphorus data from Loon Lake are available from 2002 and 2003 and annually from 2010 to 2016 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 14.8 µg/L in 2003 to 34.8 µg/L in 2015; however, the low average concentration observed in 2003 is represented by only one sample and may not be indicative of the true summer average for that year. The overall weighted summer average total phosphorus concentration is 26 µg/L and falls into the *good* category for Wisconsin's shallow lowland drainage lakes and indicates that Loon Lake's phosphorus concentrations are slightly lower than the median concentration of other shallow lowland drainage lakes in the state and lower than the median concentration for all lake types within the NCHF ecoregion. The 2016 summer total phosphorus concentration was below the weighted average, with an average concentration of 23 µg/L.

Chlorophyll-*a* concentration data are available from Loon Lake for the same time periods as total phosphorus data (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 0.4 µg/L in 2002 to 11.7 µg/L in 2011; however, the low average concentration observed in 2002 is represented by only one sample and may not be indicative of the summer average for that year. The weighted summer total chlorophyll-*a* concentration is 8 µg/L and falls within the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's shallow lowland drainage lakes. The weighted summer average chlorophyll-*a* concentration falls below the median concentrations for shallow lowland drainage lakes in Wisconsin and all lake types within the NCHF ecoregion. The 2016 summer chlorophyll-*a* concentration was below the weighted average, with an average concentration of 4 µg/L.

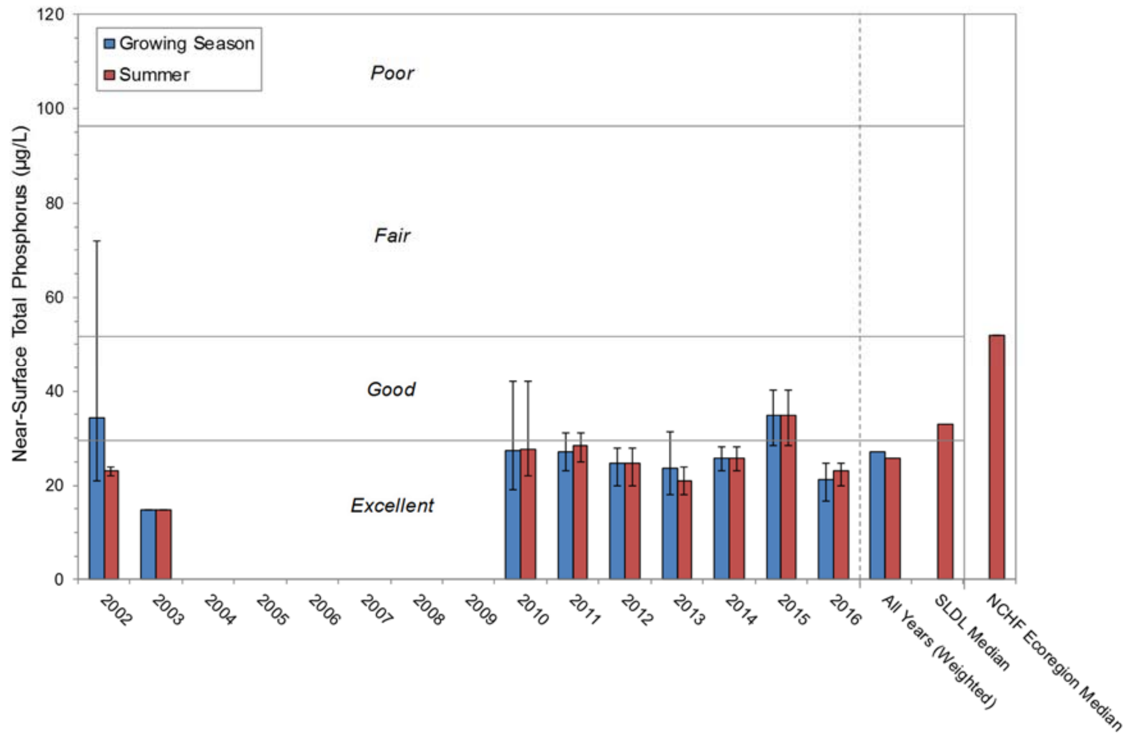


Figure 3.1-3. Loon Lake, state-wide shallow lowland drainage lakes, and North Central Hardwood Forests (NCHF) total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

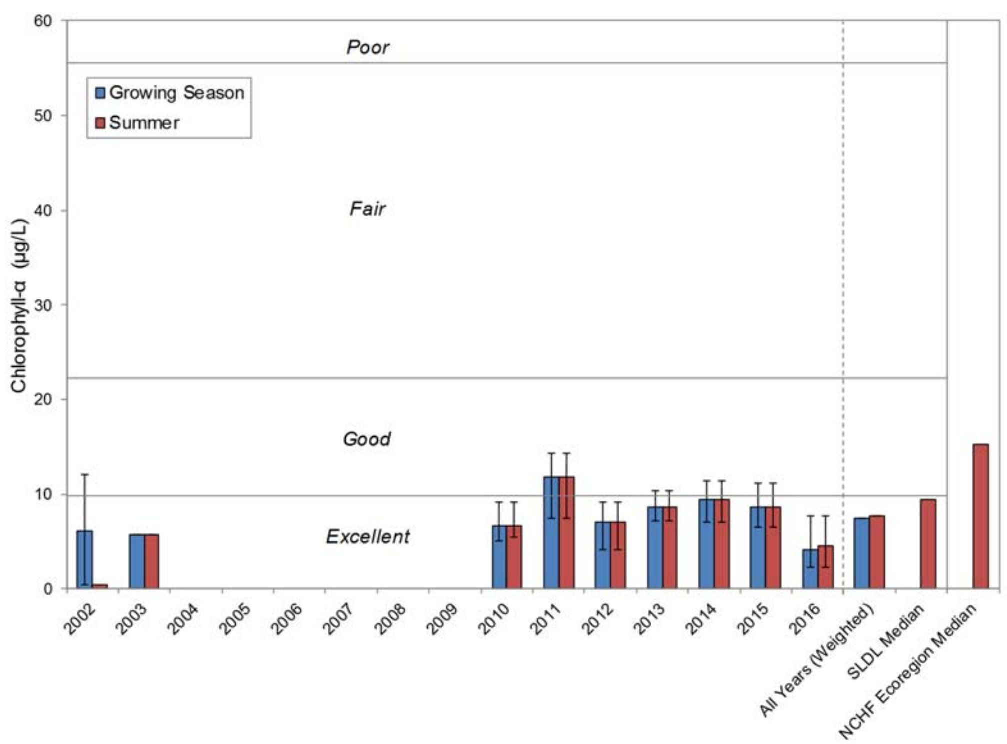


Figure 3.1-4. Loon Lake, state-wide shallow lowland drainage lakes, and North Central Hardwood Forests (NCHF) chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Annual Secchi disk transparency data are available from Loon Lake from 1990 to 2016 (Figure 3.1-5). Average summer Secchi disk depths ranged from 3.5 feet in 2011 to 8.1 feet in 1999. The weighted summer average Secchi disk depth is 5.5 feet, which falls into the *excellent* category for Secchi disk depth in Wisconsin's shallow lowland drainage lakes. The weighted average summer Secchi disk depth is the same as the median value (5.6 feet) for shallow lowland drainage lakes in Wisconsin and is slightly deeper than the median value for all lake types within the NCHF ecoregion. Loon Lake has similar water clarity to the majority of other shallow lowland drainage lakes in Wisconsin and slightly higher water clarity than all lakes within the NCHF ecoregion.

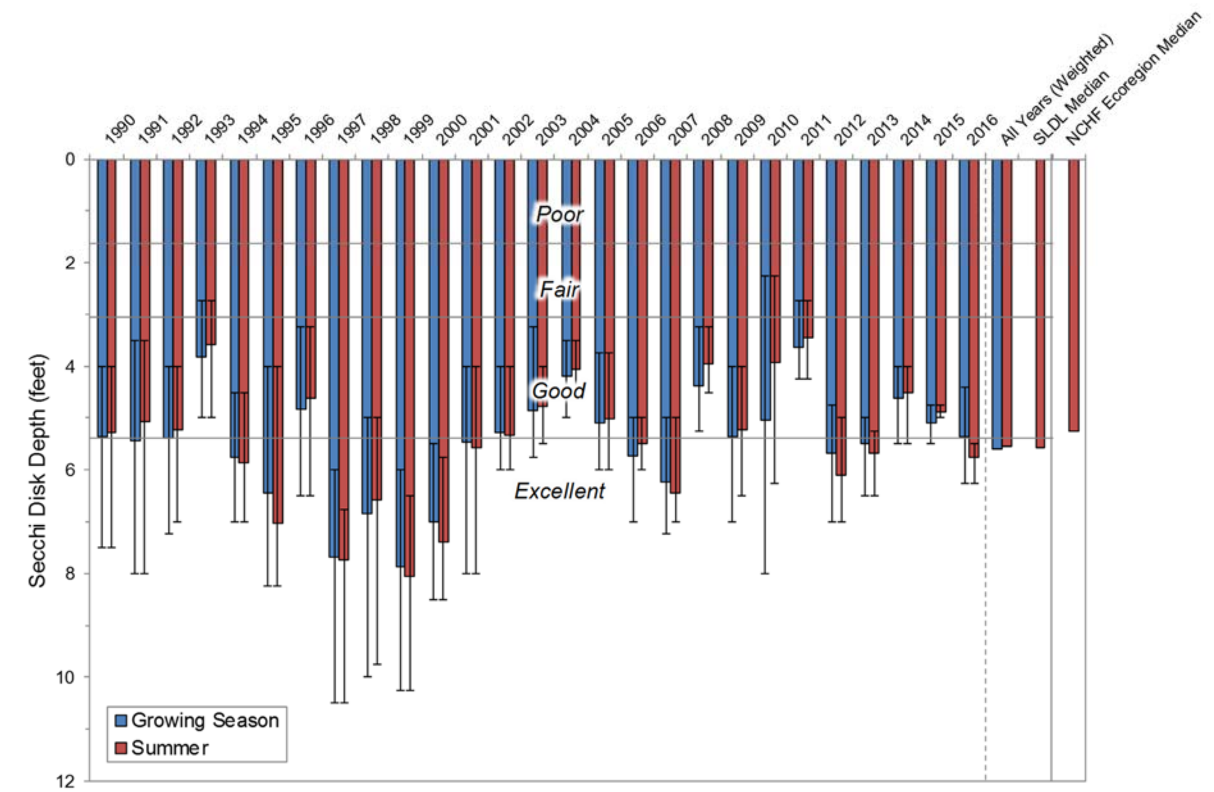


Figure 3.1-5. Loon Lake, state-wide shallow lowland lakes, and North Central Hardwood Forests (NCHF) Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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

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 Loon Lake in 2016 averaged 60 SU (standard units) indicating the lake's water is *tea colored* and that the lake's water clarity is primarily influenced by dissolved components in the water.

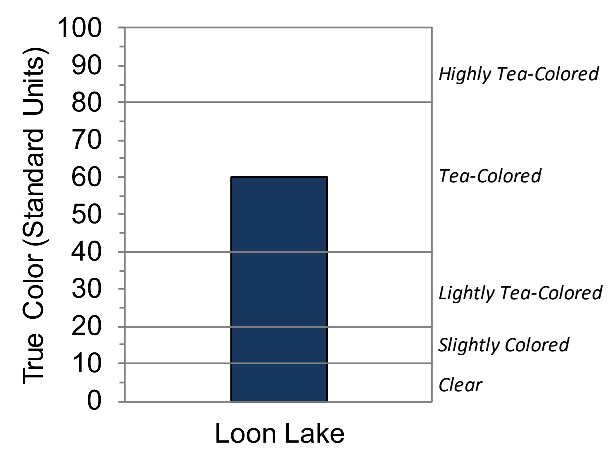


Figure 3.1-6. Loon Lake true color value.

As stated previously, Secchi disk depth has been measured annually from 1990-2017. Figure 3.1-7 displays the annual sum of precipitation, growing season mean Secchi disk transparency, and average summer Secchi disk transparency from 1990-2017. During years of high precipitation, Secchi disk depth decreases in Loon Lake. Years of low precipitation have better Secchi disk transparency in the lake. This relationship is likely a result of an influx of dissolved organic compounds, causing the brown colored water, entering the lake from the extensive wetlands in Loon Lake's watershed during wet years. The absence of these dissolved compounds during dry years causes the Secchi disk transparency to be higher. The correlation of annual precipitation and growing season mean Secchi disk depth is statistically significant ($R^2 = 0.2108$). It should be noted that this relationship could be broken down following many consistently wet years as wetlands in the watershed are flushed of these compounds. The relationship could also be broken down when a very wet year follows many consistently dry years, resulting in larger than usual amounts of organic acids and dissolved compounds being flushed into the lake during the wet year. In summary this means that during wet years the lake will tend to have more of a brown color with lower water clarity while during dry years the water will be less stained and have better water clarity.

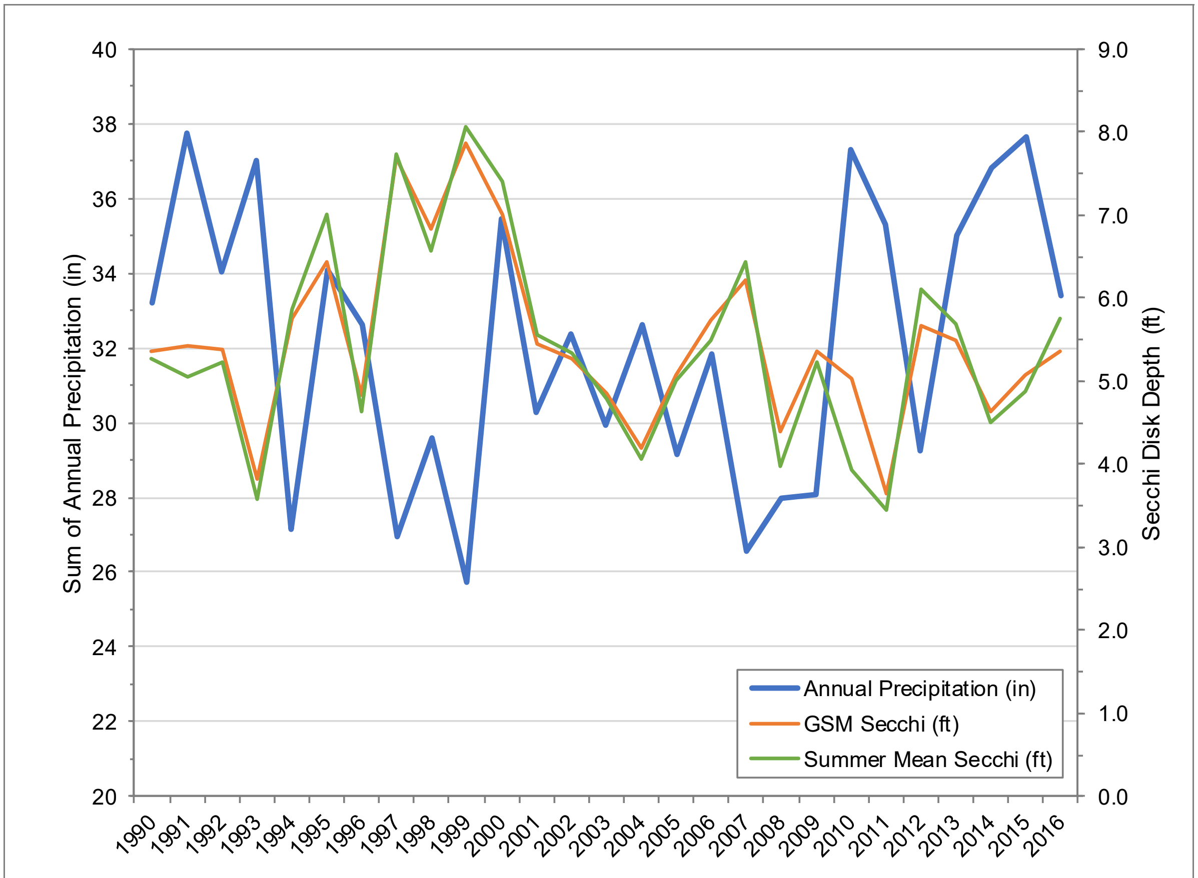


Figure 3.1-7. Loon Lake sum of annual precipitation and Secchi disk depths. Annual precipitation from Midwest Regional Climate Center, Shawano 2 SSW station.

Limiting Plant Nutrient of Loon Lake

Using midsummer nitrogen and phosphorus concentrations from Loon Lake, a nitrogen:phosphorus ratio of 33:1 was calculated. This finding indicates that Loon Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

Loon Lake Trophic State

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

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Loon Lake indicate the lake is at present in a low eutrophic state (Figure 3.1-8). Loon Lake's productivity is slightly lower when compared to both other shallow lowland drainage lakes in Wisconsin and other lakes within the NCHF ecoregion. In the sub-section describing long-term trends it was noted that the low mean phosphorus concentration in 2003 and low mean chlorophyll-

a value in 2002 may have been the result of only one sample having been collected. The TSI plot shows that the Secchi TSI is similar to other years and confirms that the low phosphorus and chlorophyll-*a* values are the result of only a single sample being collected. In fact, the single samples in both years were collected in June when the lowest concentrations of the summer often occur.

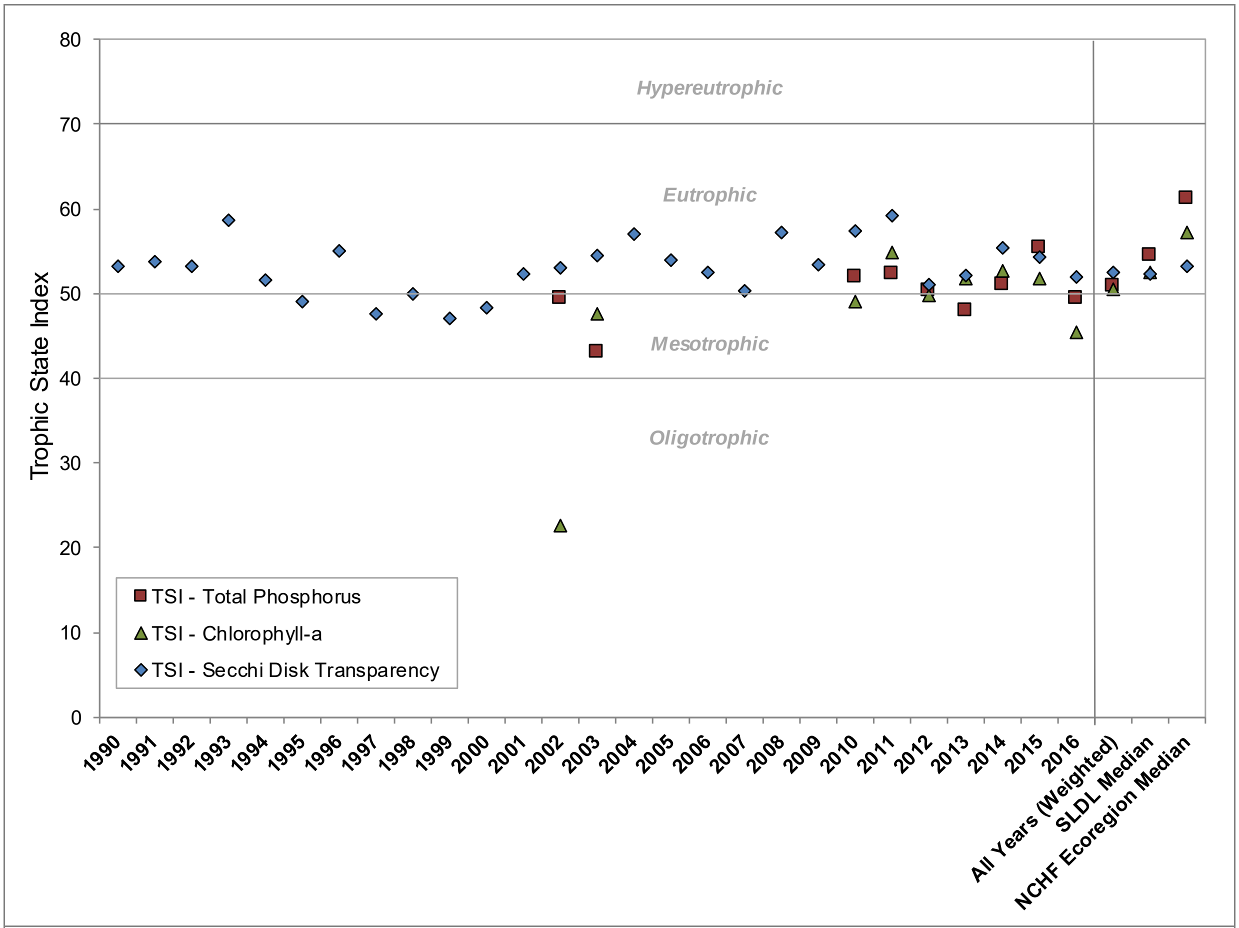


Figure 3.1-8. Loon Lake, state-wide shallow lowland drainage lakes, and North Central Hardwood Forests (NCHF) Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Loon Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Loon Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-9. These data indicate that Loon Lake stratifies during the summer, but only the water near the bottom becomes anoxic. The data also indicates that there was sufficient oxygen throughout the water column under the ice to support the fishery during late-winter sampling.

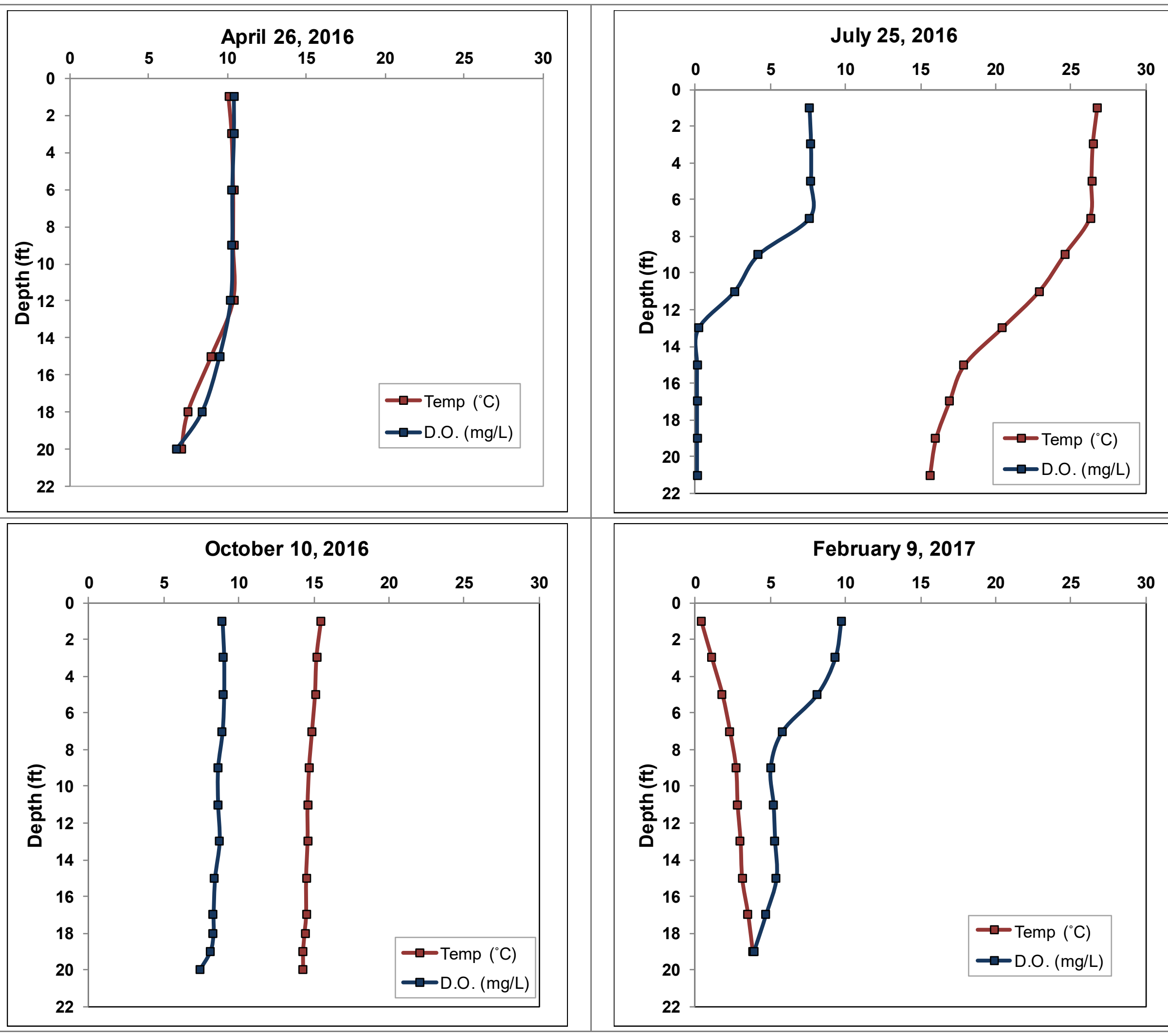


Figure 3.1-9. Loon Lake dissolved oxygen and temperature profiles. June and August 2016 collections completed by the Citizens Lake Monitoring Network.

Additional Water Quality Data Collected at Loon 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 Loon 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.

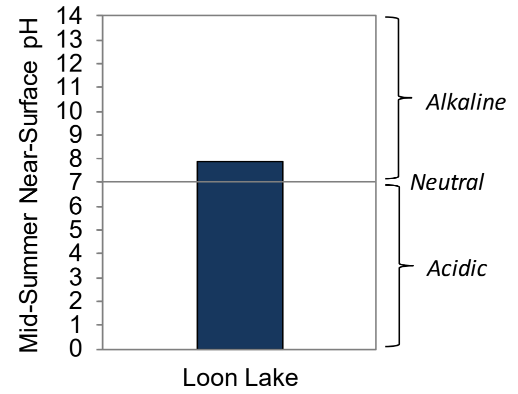


Figure 3.1-10. Loon Lake mid-summer near-surface pH value.

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 Loon Lake was found to be near neutral with a value of 7.9, and falls within the normal range for Wisconsin Lakes (Figure 3.1-10).

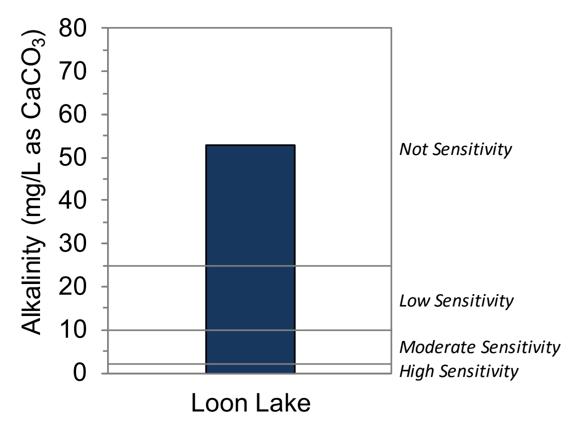


Figure 3.1-11. Loon Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 Loon Lake was measured at 53 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitivity to acid rain (Figure 3.1-11).

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 Loon Lake's pH of 7.9 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 Loon Lake was found to be 12.3 mg/L, falling just inside the optimal range for zebra mussels (Figure 3.1-12).

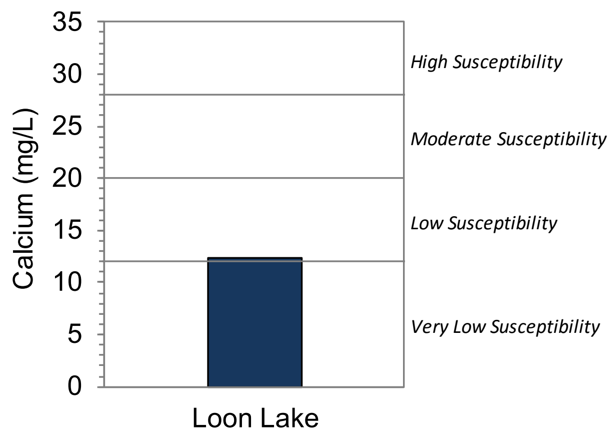


Figure 3.1-12. Loon Lake spring calcium concentrations and zebra mussel susceptibility. Samples collected from the near-surface.

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

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Loon Lake was considered borderline suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Loon 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 2016 surveys.

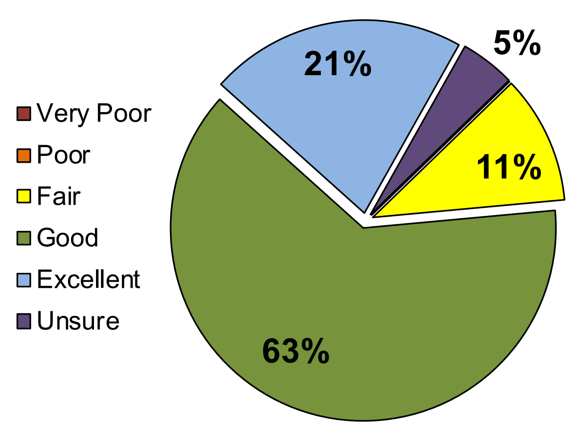
Stakeholder Survey Responses to Loon Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Of the 151 surveys distributed, 67 (44%) 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 respondent's perceptions of water quality in Loon Lake but cannot be stated with statistical confidence.

Figure 3.1-13 displays the responses of members of Loon Lake stakeholder respondents to questions regarding water quality and how it has changed over their years visiting Loon Lake. When asked how they would describe the current water quality of Loon Lake, 63% of respondents indicated *good*, 21% indicated *excellent*, 11% indicated *fair*, and 5% indicated they were *unsure*.

When asked how they believe the current water quality has changed since they first visited the lake 26%, indicated it has *remained the same*, 25% indicated it has *somewhat improved*, 23%, indicated it has *somewhat degraded*, 18% indicated it has *greatly improved*, 6% indicated they were *unsure*, and 2% indicated it has *severely degraded* (Figure 3.1-13). Historical data indicate that the water quality has not been degrading over time in Loon Lake. The proportion of stakeholder respondents who indicated Loon Lake's water quality has somewhat or severely degraded may be taking into account Eurasian watermilfoil growth in the lake or may have observed increases in aquatic plant abundance within the lake. Concerns over disappearing tree cover on Loon Lake's island, discussed further in the aquatic plant section, may also impact the perception of stakeholders who indicated that Loon Lake's water quality has been degraded.

16. How would you describe the current water quality of Loon Lake?



17. How has the current water quality changed since you first visited the lake?

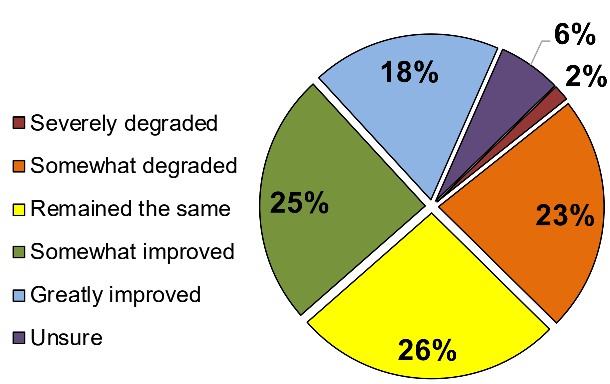


Figure 3.1-13. Loon Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Loon Lake Watershed Assessment

Loon Lake's total watershed encompasses an area of approximately 11,831 acres (18.5 square miles) across Shawano, Menominee, and Oconto counties, yielding a watershed to lake area ratio of 35:1 (Map 2). In other words, approximately 35 acres of land drain to every one acre of Loon Lake. According to WiLMS modeling, the lake's water is completely replaced approximately every 87 days (residence time) or 4.2 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. Both Rice and Lulu lakes drain into Loon Lake; however, phosphorus data are only available from Lulu Lake. While the phosphorus load from Lulu Lake can be estimated using measured phosphorus concentrations, phosphorus originating from the Rice Lake subwatershed is estimated by WiLMS based on land cover composition. For modeling purposes, the lake's watershed was divided into two main subwatersheds, Loon Lake's direct watershed and Lulu Lake's subwatershed (Map 2). Approximately 93% of Loon Lake's watershed is composed of its direct watershed and 7% is composed of the Lulu Lake subwatershed (Figure 3.2-1).

Approximately 44% of Loon Lake's direct watershed is composed of wetlands (forested and non-forested), 43% is composed of forest, 8% is composed of pasture/grass, 3% is composed of Loon Lake's surface, and 2% is composed of row crop agriculture (Figure 3.2-1). The remaining portions are composed of rural residential areas and medium density urban areas. Similarly, Lulu Lake's subwatershed is dominated by forest, pasture/grass, and forested and non-forested wetlands.

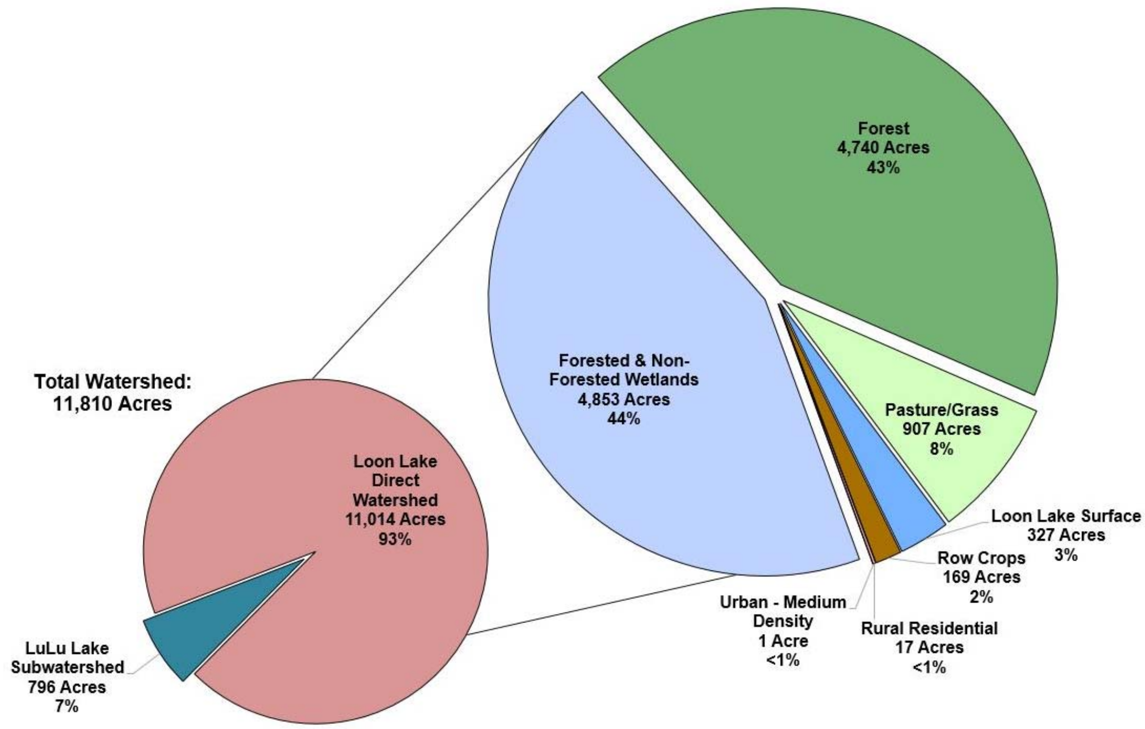


Figure 3.2-1. Loon Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the landcover described above, WiLMS was utilized to estimate the annual potential phosphorus load from Loon Lake's direct watershed and the estimated outflow from Lulu Lake's subwatershed. It was estimated that approximately 1,351 pounds of phosphorus is delivered to Loon 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 2016 stakeholder survey of riparian property owners, and indicates that approximately 12 pounds, or roughly 1% of the annual phosphorus load is attributed to septic systems.

Of the estimated 1,355 pounds being delivered annually to Loon Lake, 97% is estimated to originate from its direct watershed (Figure 3.2-2). Within the direct watershed, 32% is estimated to originate from forested and non-forested wetlands, 28% from forest, 18% from pasture/grass, 11% from row crop agriculture, 7% through direct atmospheric deposition into the lake, and <1% from rural residential areas. Approximately 3% of the annual phosphorus load is estimated to originate from the Lulu Lake subwatershed (Figure 3.2-2).

Using predictive equations, WiLMS estimates that based on the potential annual phosphorus load, Loon Lake should have a growing season mean total phosphorus concentration of approximately 31 µg/L. This predicted concentration is relatively similar to the measured growing season mean total phosphorus concentration of 27.1 µg/L. This indicates the lake's watershed and phosphorus inputs were modeled fairly accurately, although the slightly higher estimated phosphorus concentration indicates that the estimated annual phosphorus load of 1,355 pounds is slightly over estimated. Overall, the watershed modeling indicates that measured phosphorus concentrations in Loon Lake are near expected levels based on the lake's watershed size and land cover composition.

There are no indications that significant sources of unaccounted phosphorus are being loaded to the lake.

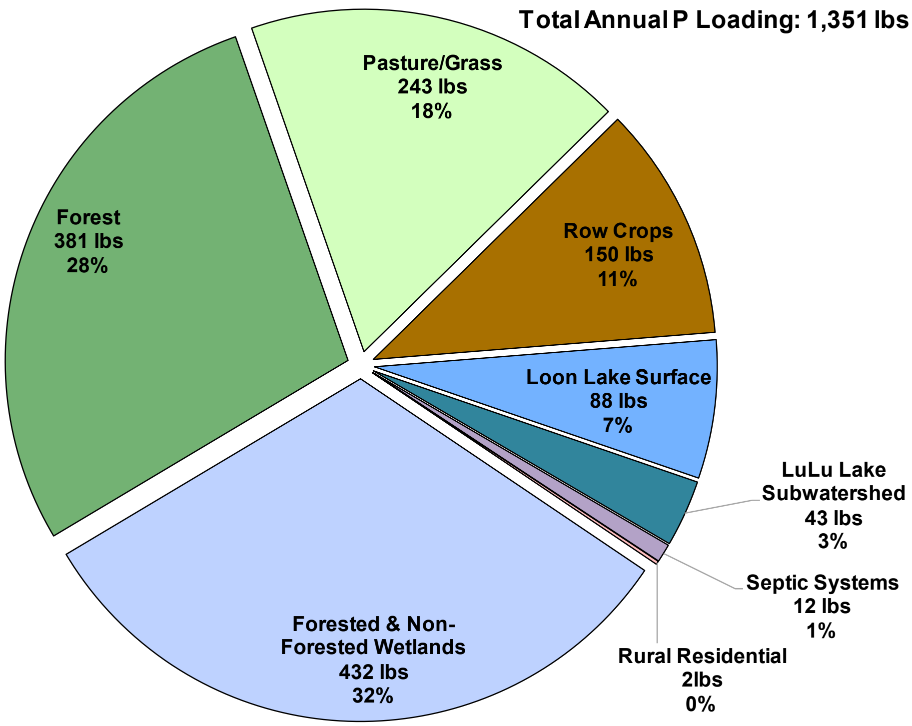


Figure 3.2-2. Loon Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

<u>Wisconsin-NR 115: Wisconsin's Shoreland Protection Program</u>

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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 in many macroinvertebrates found in these areas, who themselves are feeding upon algae and periphyton growing on the wood surface. Newbrey et al. (2005) found that some fish species prefer different complexity of branching on coarse woody habitat, though in general some degree of branching is preferred over coarse woody habitat that has no branching.

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

National Lakes Assessment

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

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

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

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

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.3-2. Example of a biolog restoration site.

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

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

Cost

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

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

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

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).
- Planting area of upland buffer zone 2- 35' x 35' areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq. ft and 2 shrubs/100 sq. ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5' x 35' areas.
- Plant spacing for the aquatic zone would be 3 feet.

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

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

Loon Lake Shoreland Zone Condition

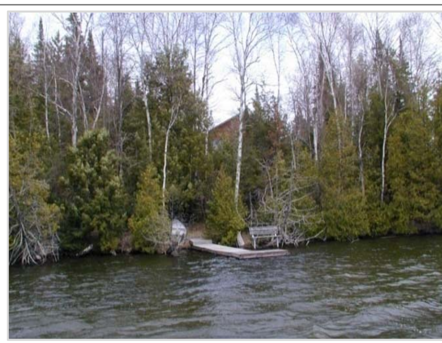
Shoreland Development

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

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

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

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



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

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

Figure 3.3-1. Shoreland assessment category descriptions.

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

Loon Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.1 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 1.2 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Loon Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

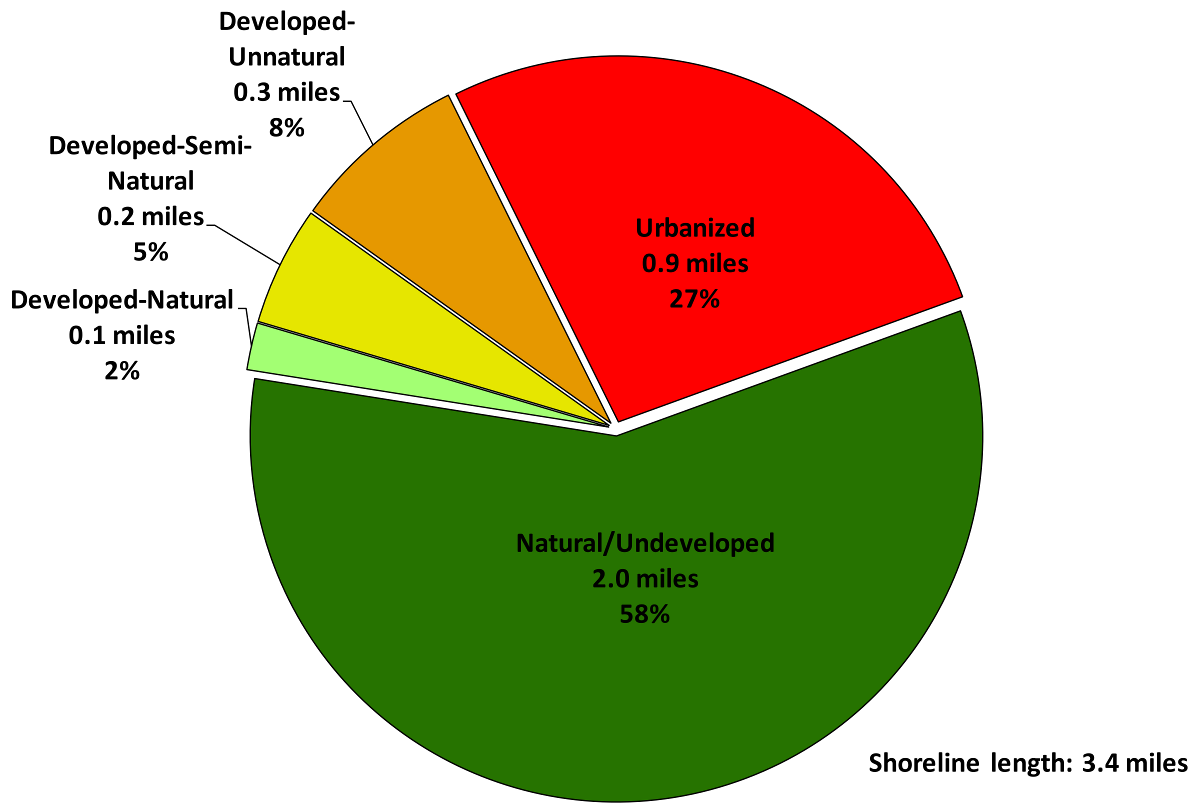


Figure 3.3-2. Loon Lake shoreland categories and total lengths. Based upon an Fall 2016 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

As part of the shoreland condition assessment, Loon 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, 22 total pieces of coarse woody habitat were observed along 3.4 miles of shoreline (Map 4), which gives Loon Lake a coarse woody habitat to shoreline mile ratio of 6:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Of the 22 total pieces of coarse woody habitat observed during the survey, 16 pieces were 2-8 inches in diameters, 6 were 8 inches in diameter or greater, and no clusters of pieces of coarse woody habitat were found.

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 Loon 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 98 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 Loon Lake fell well below the 25th percentile of these 98 lakes (Figure 3.3-3).

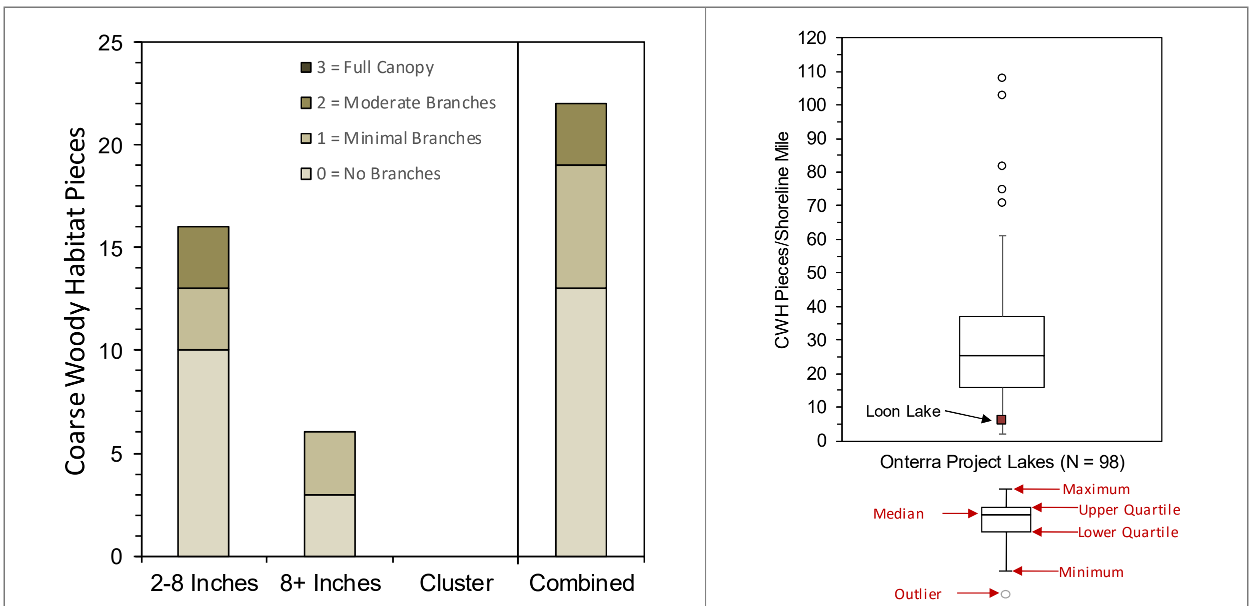


Figure 3.3-3. Loon Lake coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of the Loon coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

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 Loon 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 Loon 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

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

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width. Please note that the use of powered cutters may require a mechanical harvesting permit to be issued by the WDNR.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from \$85 to \$150. Power-cutters range in cost from \$1,200 to \$11,000.

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

Photograph 3.4-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

Photograph 3.4-4. Granular herbicide application.

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

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

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

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

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

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

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian 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.

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Loon Lake in 2016. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Loon 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 Loon Lake to be compared to other lakes within the region and state.

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

Species Diversity

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

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

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

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

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

The Simpson's Diversity Index value from Loon Lake is compared to data collected by Onterra and the WDNR Science Services on 85 lakes withn the North Central Hardwood Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

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

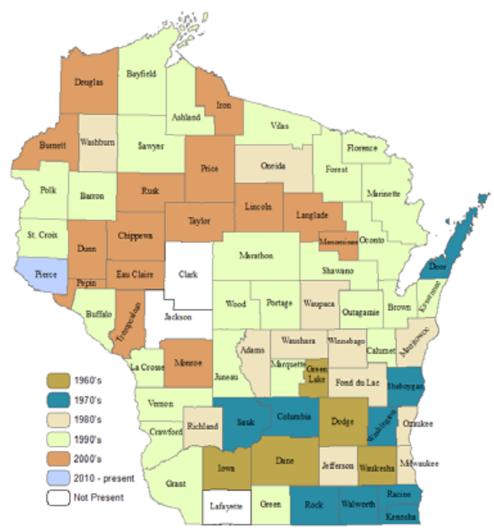


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian watermilfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

Aquatic Plant Survey Results

During the aquatic plant surveys completed on Loon Lake in 2016, a total of 43 species of plants were located in Loon Lake, three of which are considered non-native, invasive species: Eurasian watermilfoil, curly-leaf pondweed and pale-yellow iris (Table 3.4-1). Point-intercept surveys have been completed on Loon Lake from 2006-2016 and those changes in species' abundance are discussed later in this section. On June 13, 2016, an Early-Season AIS Survey was completed on Loon Lake that focused on locating and mapping curly-leaf pondweed at peak biomass as well as mapping early occurrences of Eurasian watermilfoil. This meander-based, visual survey located three occurrences of curly-leaf pondweed (Map 5). Eurasian watermilfoil was also found to be throughout Loon Lake during this survey. Both non-native species will be discussed more in depth within the Non-Native Aquatic Plants Section because of their ability to negatively impact lake ecology, recreation, and aesthetics.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Loon Lake on August 1 and 2, 2016 by Onterra. 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. On August 2, 2016, Onterra ecologists completed an acoustic survey on Loon Lake. The 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. Data pertaining to Loon Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey revealed that Loon Lake's average substrate hardness ranges from hard to moderately hard with deeper areas containing softer, more flocculent sediments (Figure 3.4-2 and Map 6). On average, the softest substrates (muck, marl) are found within 14 to 21 feet of water. The greatest transition between hard and softer substrates is found between 12 and 15 feet of water, with hardness declining rapidly with depth. Figure 3.4-2 illustrates the spatial distribution of substrate hardness in Loon 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.

Table 3.4-1. Aquatic plant species located on Loon Lake during August 2016 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Decodon verticillatus*	Water-willow	7	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris pseudacorus	Pale-yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A	I
	Schoenoplectus pungens	Three-square rush	5	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Sparganium eurycarpum	Common bur-reed	5	I
	Spartina pectinata	Prairie cord grass	5	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium acaule*	Short-stemmed bur-reed	8	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Najas guadalupensis	Southern naiad	7	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	I
	Stuckenia pectinata	Sago pondweed	3	I
	Utricularia gibba	Creeping bladderwort	9	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia resupinata	Northeastern bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
FF	*Lemna trisulca*	Forked duckweed	6	X

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

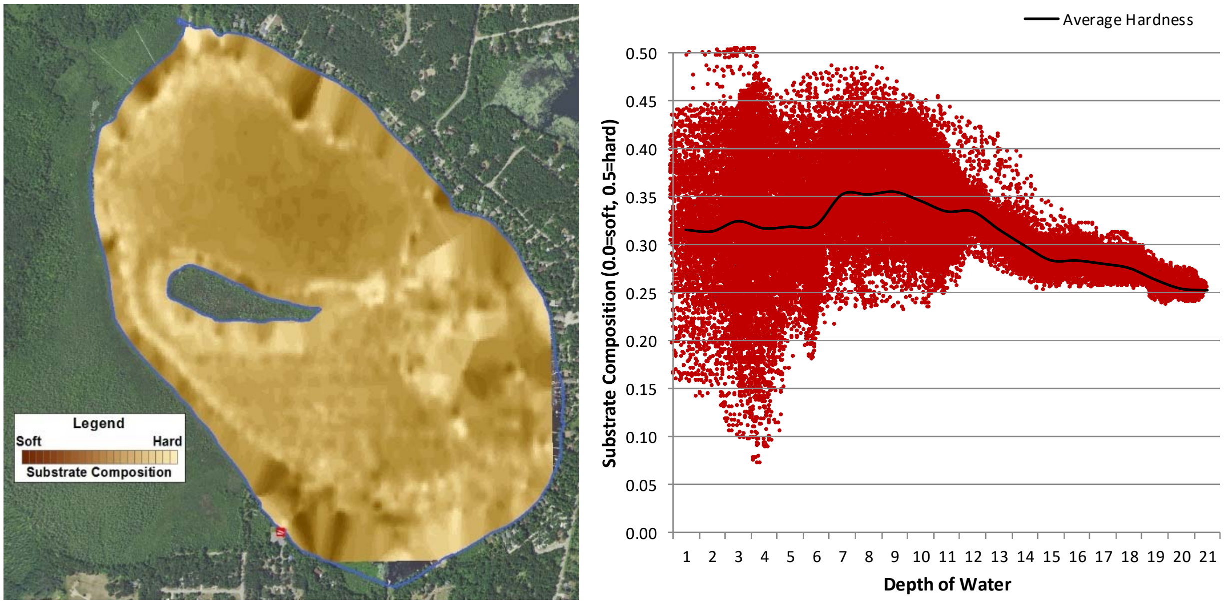


Figure 3.4-2. Loon Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Created using data from August 2016 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 3.4-3 and Map 7. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2016 whole-lake point-intercept survey and acoustic survey found aquatic plants growing to a maximum depth of 10 feet. Overall, the 2016 acoustic survey indicates that approximately 52% of Loon Lake contains aquatic vegetation (Figure 3.4-3). The remaining area of the lake is too deep and does not receive adequate light to support aquatic plant growth.

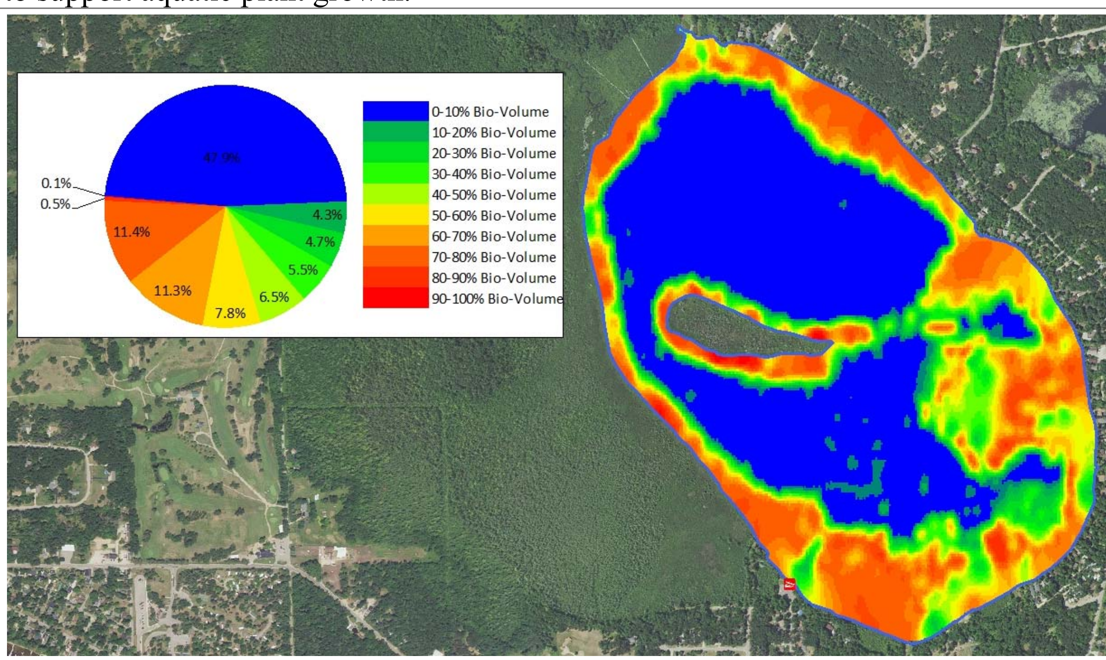


Figure 3.4-3. Loon Lake 2016 aquatic plant bio-volume. Created using data from August 2016 acoustic survey.

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 202 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2016, approximately 78% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 14% of the 202 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 28% had a TRF rating of 2, and 36% had a TRF rating of 3 (Figure 3.4-4). The TRF data indicates that where aquatic plants are present in Loon Lake, they were relatively dense.

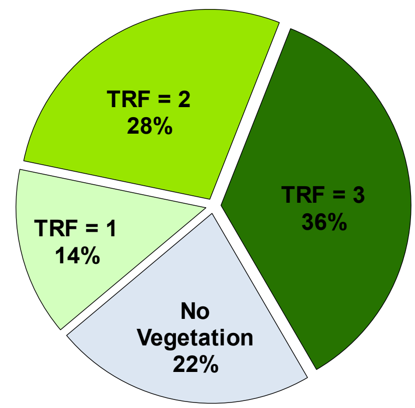


Figure 3.4-4. Loon Lake 2016 aquatic vegetation total rake fullness (TRF) ratings within littoral areas. Created from data collected during the 2016 whole-lake aquatic plant point-intercept survey.

Of the 43 aquatic plant species located in Loon Lake in 2016, 27 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 16 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 these 27 species, wild celery was the most frequently encountered, followed by slender naiad, stoneworts, and muskgrasses (Figure 3.4-5).

Wild celery, also known as tape or eel grass, was the most frequently encountered aquatic plant species with a littoral frequency of occurrence of 55% during the 2016 point-intercept survey (Figure 3.4-5). 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 Loon Lake, wild celery was most abundant between 2 and 6 feet of water.

Slender naiad, the second-most frequently encountered aquatic plant in 2016 with a littoral frequency of occurrence of 36% (Figure 3.4-5), is a submersed, annual plant that produces numerous seeds. 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 Loon Lake, slender naiad was prevalent across all depths.

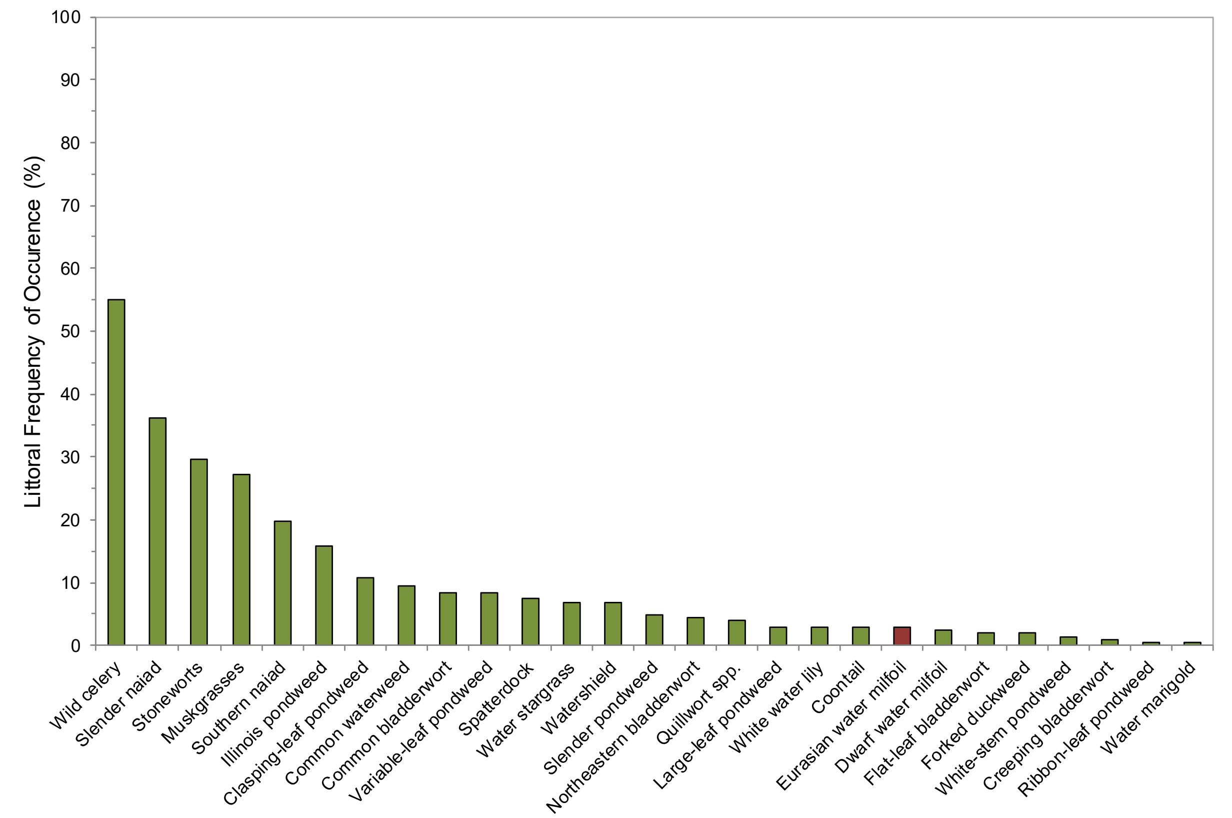


Figure 3.4-5. 2016 Littoral frequency of occurrence of aquatic plant species in Loon Lake. Created using data 2016 whole-lake aquatic plant point-intercept survey. While curly-leaf pondweed is present within the lake, it went undetected during the 2016 whole-lake point-intercept survey.

Stoneworts, the third-most frequently encountered aquatic plant in Loon Lake, are a genus of macroalgae. The stems and branches of these plants are often bright green and semi-transparent. These plants were found growing in large beds along the bottom in Loon Lake, where they are not likely seen from the surface. The fine, whorled branches of stoneworts provide excellent habitat for aquatic invertebrates and provide foraging and cover areas for fish. Stoneworts were found to be most dominant from 4 to 8 feet.

Photograph 3.4-5. The aquatic macroalgae muskgrasses (*Chara* spp.). Photo credit Onterra.

Muskgrasses, like stoneworts, are a genus of macroalgae (Photograph 3.4-5). In 2016, muskgrasses were the fourth-most frequently encountered aquatic plant and had a littoral frequency of occurrence of approximately 27% (Figure 3.4-5). Dominance of the aquatic plant community by muskgrasses is common and these macroalgae have been found to more competitive against vascular plants (e.g. pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel and Kufel 2002; Wetzel 2001). Muskgrasses 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). In Loon Lake, muskgrasses were abundant from 2 to 6 feet.

Aquatic plant point-intercept datasets are also available from 2006-2015 in Loon Lake, and the methodology and sampling locations were the same as the survey completed in 2016. The datasets from 2006 to 2016 can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or in species' abundance have occurred over this time period. Comparison between these ten surveys indicates that the littoral frequency of occurrence of all vegetation within Loon Lake has significantly changed every year except from 2013-2014. There were significant decreases in littoral frequency of occurrence five years and significant increases four years. These changes could be attributed to many factors but as previously mentioned in the Water Quality section, while water quality has remained excellent through much of Loon Lake's history, years with a lot of rain can increase run off into the lake, lowering Secchi disk readings, causing less light penetration, and an increase in phosphorus and chlorophyll-*a*. There could be an increase in tannins leaching out of detritus causing the water color to be perceived as more stained or darker, due to the higher precipitation. This increase in tannins could also be affecting the water clarity, further affecting the growth of aquatic plants.

Figure 3.4-6 displays the aquatic plant littoral frequency of occurrence and total rake fullness for Loon Lake from 2007-2016. Total rake fullness was not recorded in 2006. Total rake fullness was quite variable over the time period, but overall, plants are present around most of Loon Lake but, besides 2016, they are not overly dense where they are present. The variability between littoral frequency of occurrence, mentioned above, can be very clearly seen in Figure 3.4-6. All years had at least 50% littoral frequency of occurrence except for 2011. 2010 and 2011 had much higher precipitation levels than previous and later years, most likely causing this lower littoral frequency of occurrence seen in 2011.

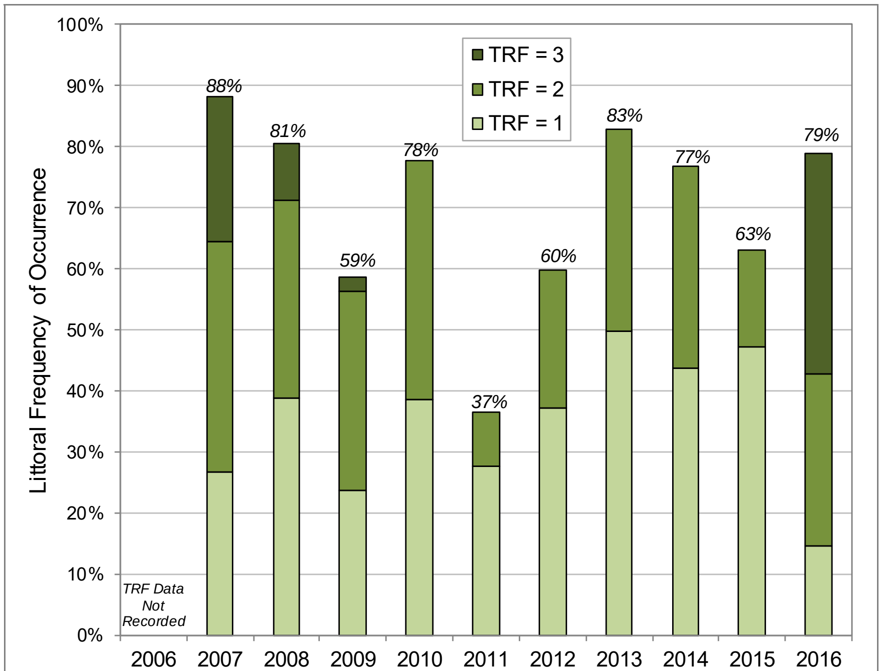


Figure 3.4-6. Aquatic plant frequency of occurrence and total rake fullness (TRF) ratings in Loon Lake from the 2006 to 2016 surveys. All years were significantly different except for the change from 2013 to 2014. (Chi-square α = 0.05). N = 365.

Figure 3.4-7 displays the littoral frequency of occurrence of aquatic plant species from 2006 to 2016 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% in one of the ten surveys are displayed. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of muskgrasses (*Chara* spp.) and stoneworts (*Nitella* spp.), slender naiad (*Najas flexilis*) and southern naiad (*Najas guadalupensis*), and small pondweed (*Potamogeton pusillus*) and slender pondweed (*Potamogeton berchtoldii*) were combined for this analysis. In total, seven aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2010 and 2016 (Figure 3.4-7). Watershield, coontail and forked duckweed saw a significant decrease from 2006 to 2016 while white water lily and dwarf watermilfoil saw a significant increase over the same time period. Eurasian watermilfoil, common bladderwort, spatterdock, creeping bladderwort, muskgrasses and stoneworts, slender and southern naiad, wild celery, common waterweed, Illinois pondweed, variable-leaf pondweed, clasping-leaf pondweed, water stargrass, and stiff pondweed all saw significant increases and decreased over the ten-year period. Large-leaf pondweed and needle spikerush saw no significant changes from 2006 to 2016.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants. Eurasian watermilfoil and curly-leaf pondweed have been treated in Loon Lake beginning in 2005. As will be discussed within the Non-Native Aquatic Plant section, there have been small-scale and large-scale herbicide treatments on Loon Lake. The lake was treated from 2005 to 2010, 2012-2013, and 2016 with no treatments in 2011, 2014 or 2015. This combination of herbicide treatments as well as changes in precipitation and run-off are most likely the factors affecting the changes in aquatic plants within Loon Lake. Ongoing collection of aquatic plant data from Wisconsin's lakes shows that aquatic plant populations have the capacity to fluctuate widely on an interannual basis under natural conditions. It cannot be said for certain if the changes are interannual variations, ecological changes, or a product of the herbicide treatments because it is most likely a combination of all three factors. Having a species-rich plant community like that found in Loon Lake is important as when conditions are unfavorable for some species, other species can fill in to fulfill their ecological role.

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 40 native aquatic plant species were located in Loon Lake during the 2016 surveys, 26 were directly encountered on the rake during the point-intercept survey. Loon Lake's native aquatic plant species richness in 2016 exceeded the 75th percentile value for lakes within the North Central Hardwood Forests (NCHF) ecoregion and for lakes throughout Wisconsin (Figure 3.4-8). The species richness recorded in 2016 (26) was also higher than that recorded during the 2011 (25), 2012 (25), and 2015 (22) point-intercept surveys but lower than 2006-2010 and 2014.

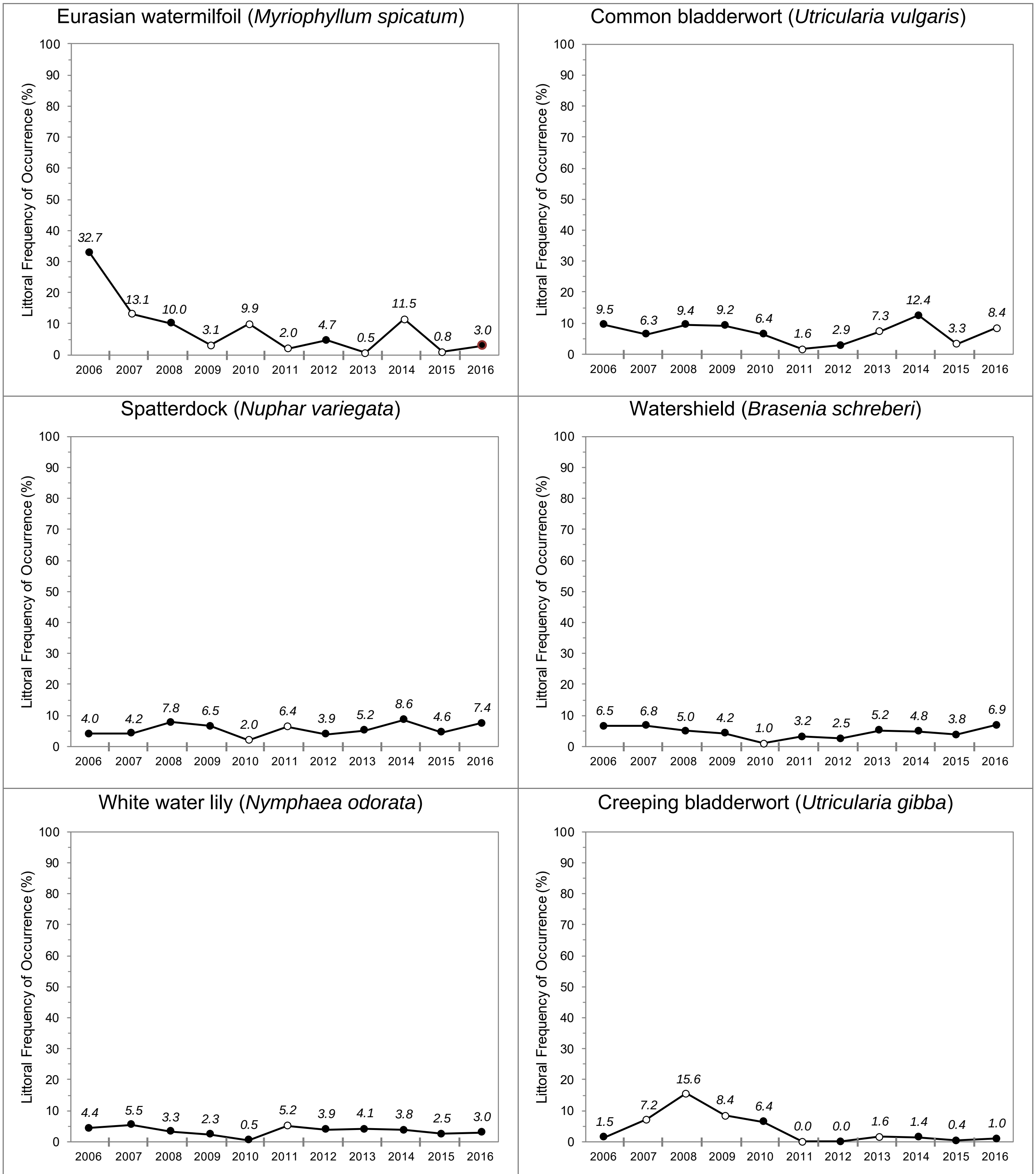


Figure 3.4-7. Littoral frequency of occurrence of select native aquatic plant species in Loon Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the ten surveys. Created using data from WDNR 2006-2015 (N = 365) and Onterra 2016 (N = 365) whole-lake point-intercept surveys.

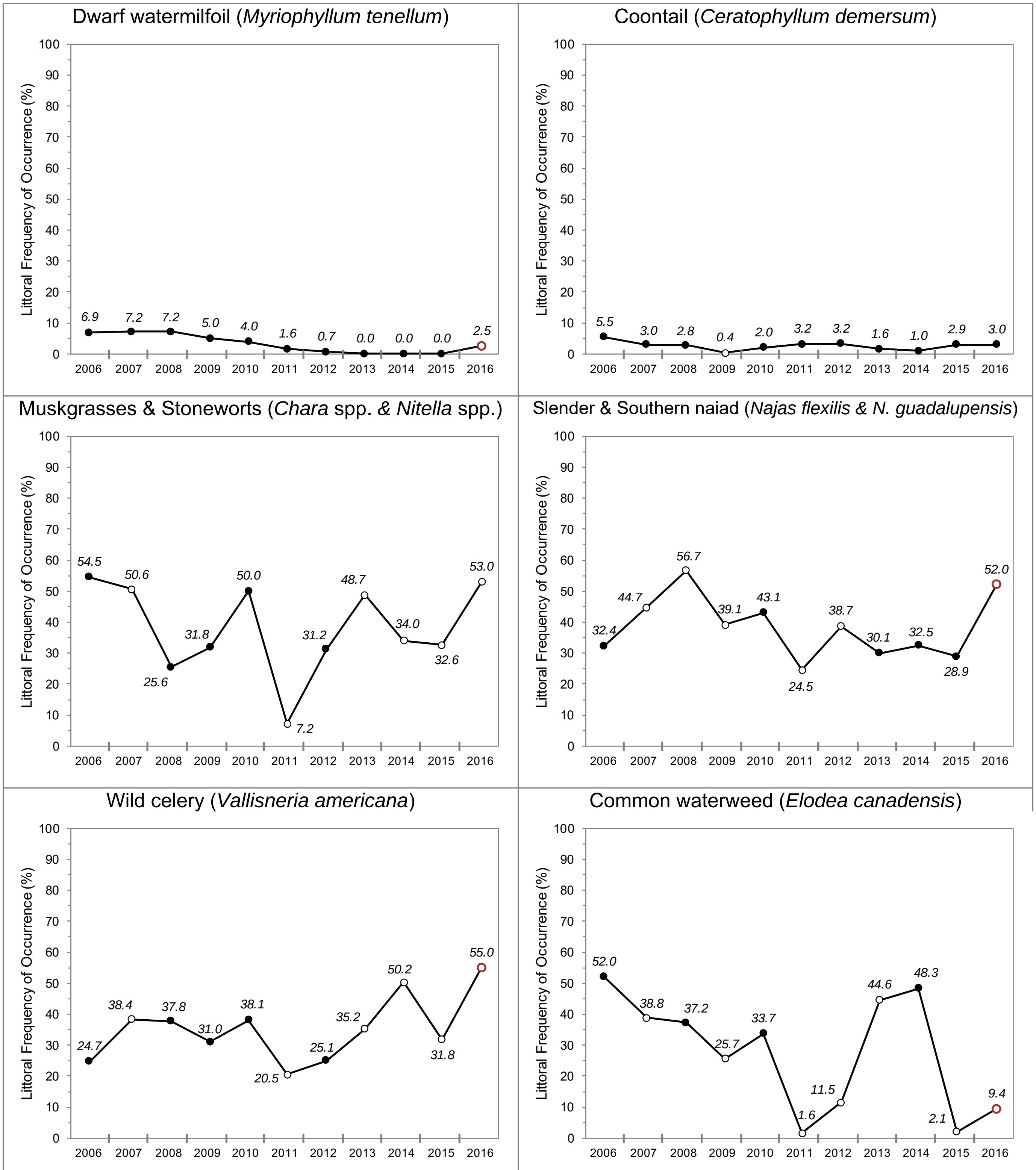


Figure 3.4-7 continued. Littoral frequency of occurrence of select native aquatic plant species in Loon Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the ten surveys. Created using data from WDNR 2006-2015 (N = 365) and Onterra 2016 (N = 365) whole-lake point-intercept surveys.

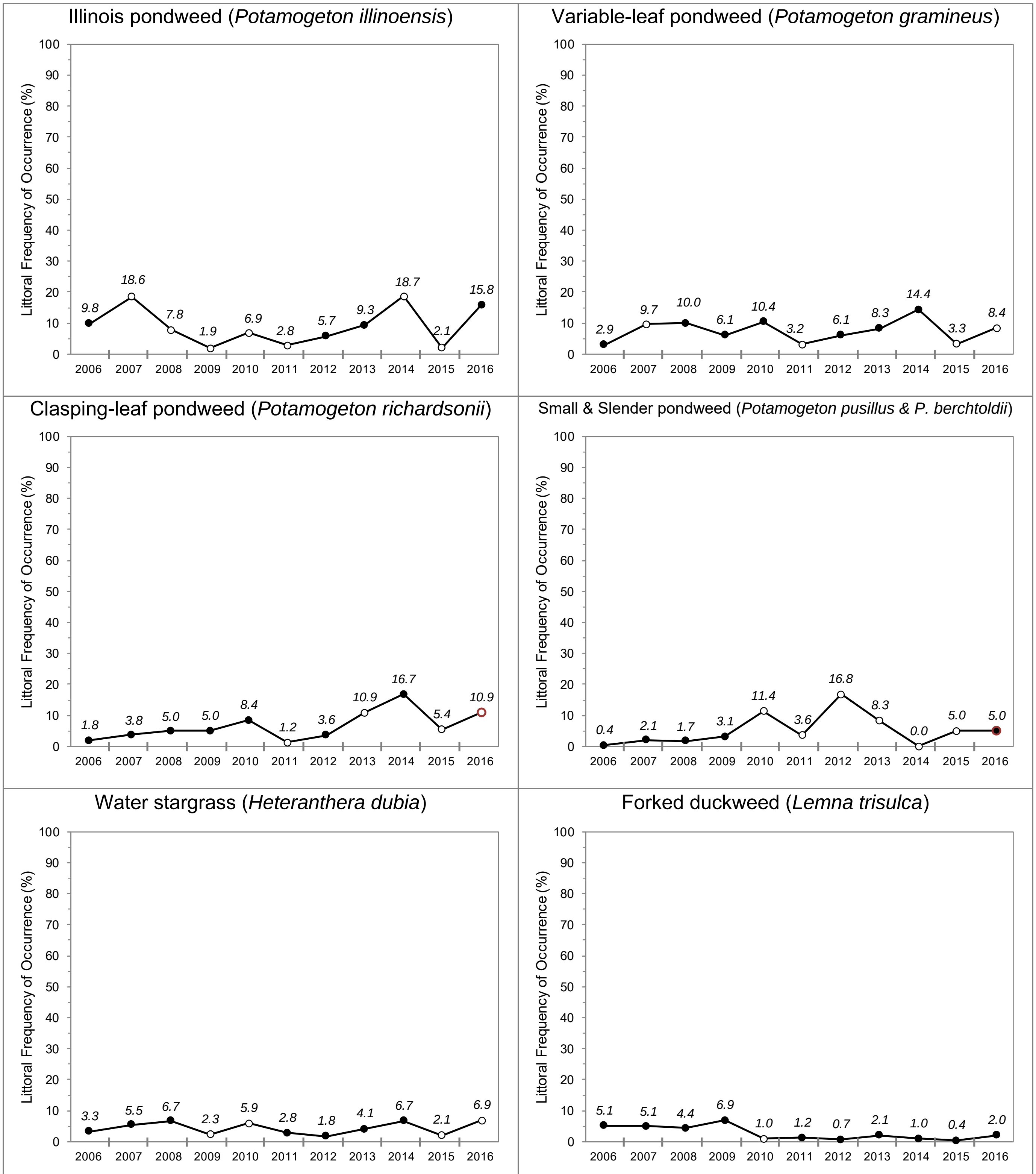


Figure 3.4-7 continued. Littoral frequency of occurrence of select native aquatic plant species in Loon Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the ten surveys. Created using data from WDNR 2006-2015 (N = 365) and Onterra 2016 (N = 365) whole-lake point-intercept surveys.

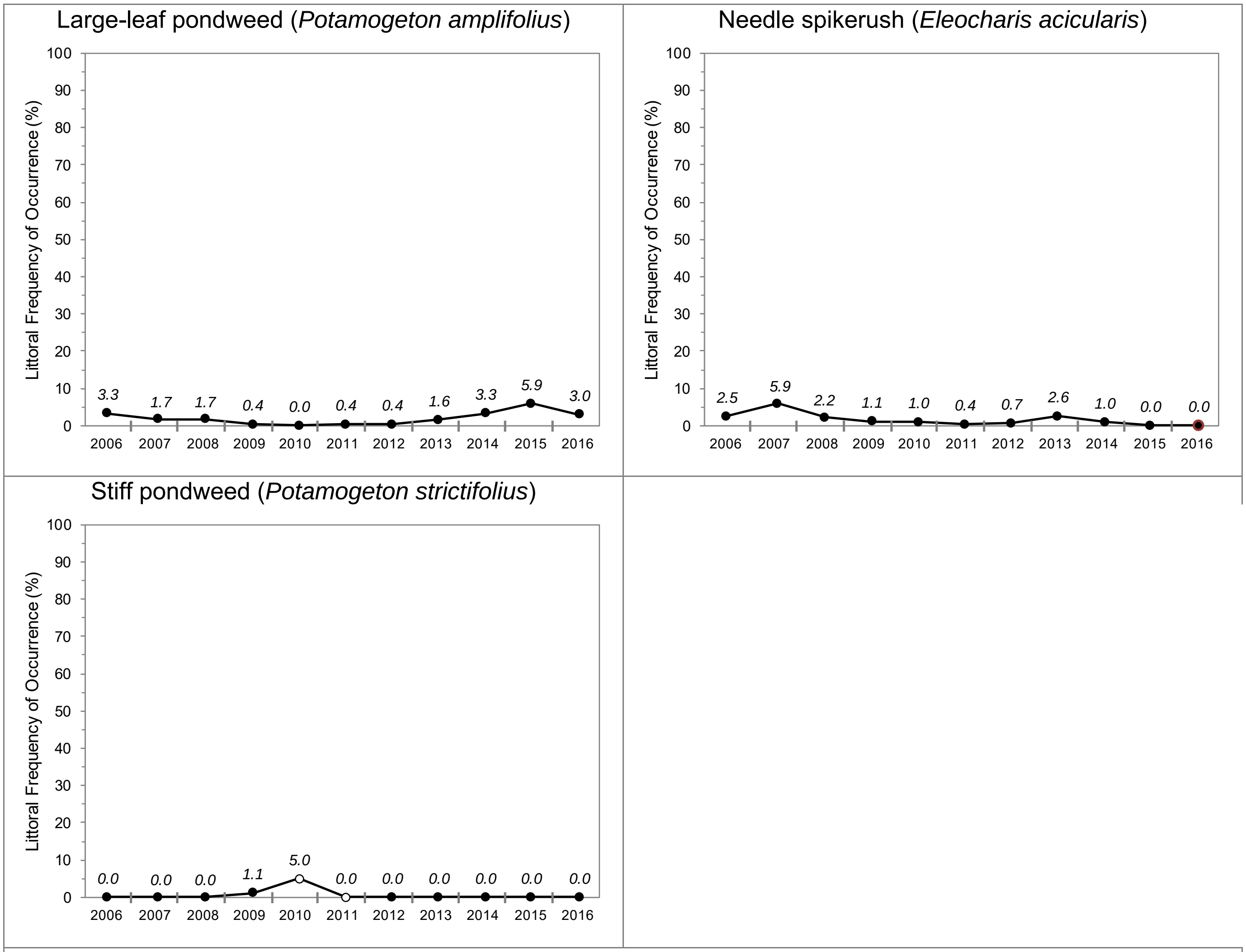


Figure 3.4-7 continued. Littoral frequency of occurrence of select native aquatic plant species in Loon Lake from 2006-2016. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2010 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the ten surveys. Created using data from WDNR 2006-2015 (N = 365) and Onterra 2016 (N = 365) whole-lake point-intercept surveys.

The average conservatism of the 27 native aquatic plants recorded on the rake in 2016 was 6.8, falling above the 75th percentile value for lakes within NCHF ecoregion and for lakes throughout Wisconsin (Figure 3.4-9). This indicates that Loon Lake has a high number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NCHF ecoregion. Average conservatism in 2016 was higher when compared to the average conservatism values recorded in 2009, and 2011-2015.

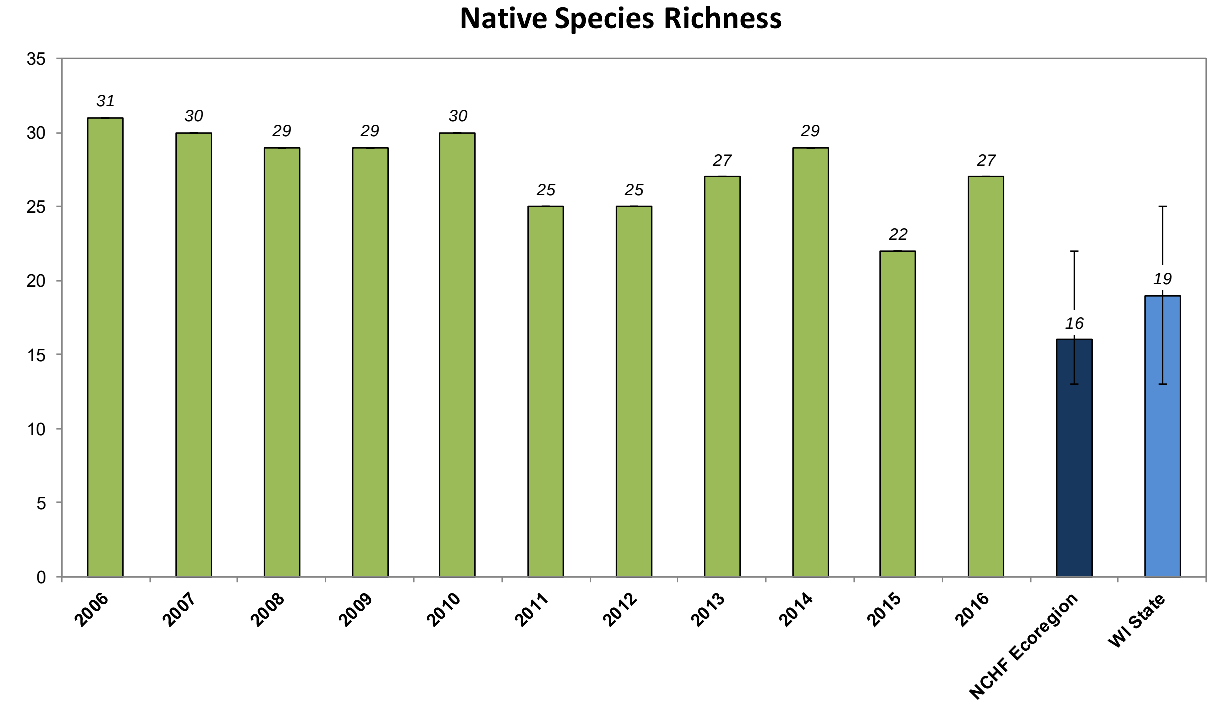


Figure 3.4-8. Loon Lake native species richness. Created using data from the 2006-2016 surveys.

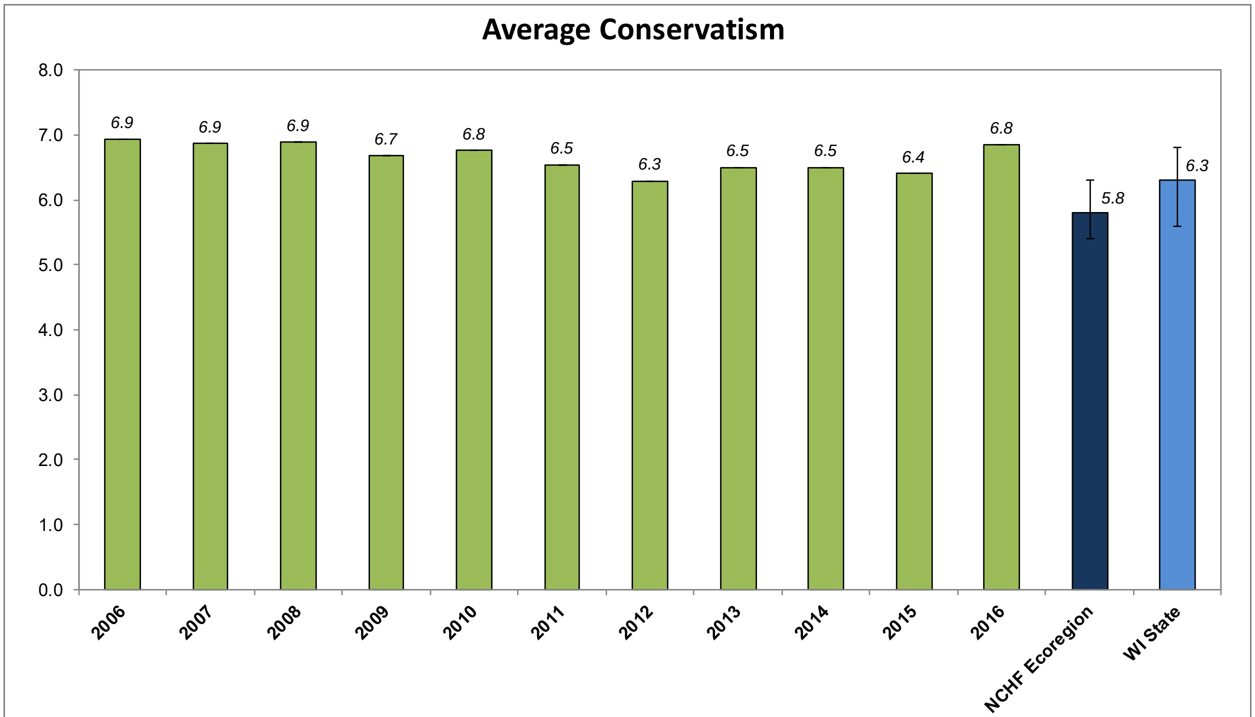


Figure 3.4-9. Loon Lake Average Conservatism. Created using data from the 2006-2016 surveys.

Using Loon Lake's 2016 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 35.6, exceeding the 75th percentile values for lakes within the NCHF ecoregion and the state (Figure 3.4-10). This indicates that Loon Lake's aquatic plant community is of higher quality in terms of species richness and community composition than the majority of lakes within the ecoregion and the state. Given that native species richness and average conservatism were higher in 2016 when compared to 2009 and 2011-2015, the 2016 Floristic Quality Index value was also higher than those calculated for those years.

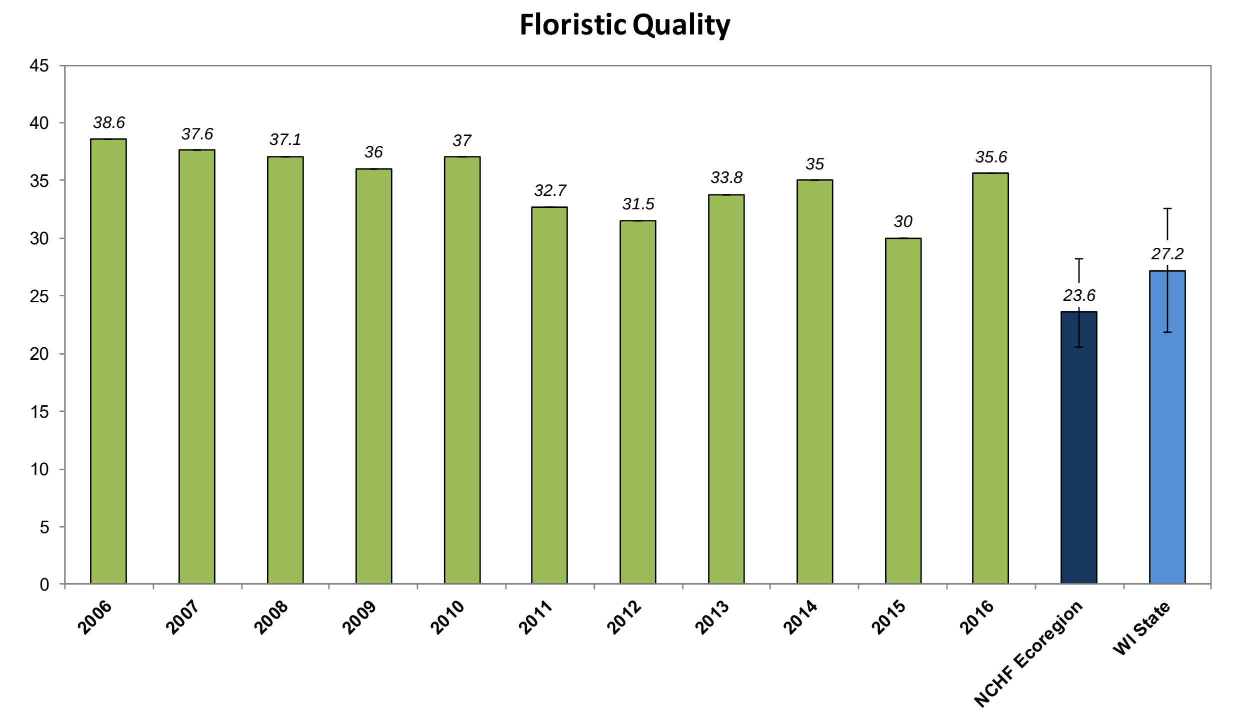


Figure 3.4-10. Loon Lake Floristic Quality Analysis. Created using data from the 2006-2016 surveys.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Loon Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 85 lakes within the NCHF ecoregion (Figure 3.4-11). Using the data collected from the 2006 through 2016 point-intercept surveys, Loon Lake's aquatic plant community is shown to have relatively high species diversity. Simpson's Diversity Index values were all higher than the median (0.84) for the ecoregion with only three years, 2011, 2012 and 2015, falling at or below the 75^{th} percentile for the ecoregion.

While Loon Lake contains a high number of aquatic plant species, about half (54%) of the plant community is comprised of just four species. Another 11% of the aquatic plant community is made up of 13 species, meaning that the lake is quite diverse but still dominated by a few species. One way to visualize the diversity of Loon Lake is to look at the relative occurrence of aquatic plant species. Figure 3.4-12 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey and illustrates the relatively uneven distribution of aquatic plant species within the 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).

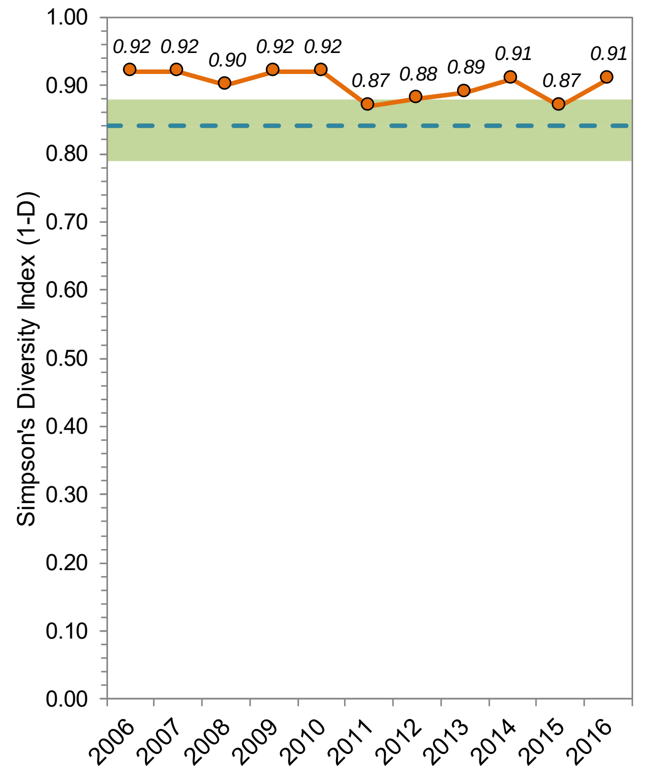


Figure 3.4-11. Loon Lake species diversity index. Created using data from the 2006-2016 aquatic plant surveys. Ecoregion data from 85 NCHF lakes collected by WDNR Science Services and Onterra.

For instance, while wild celery had a littoral frequency of occurrence of 55%, their relatively frequency of occurrence was 20%. Explained another way, if 100 plants were sampled from Loon Lake, 20 would be wild celery. Figure 3.4-12 illustrates that 54% of Loon Lake's aquatic plant community was comprised of just four species in 2016: wild celery, slender naiad, stoneworts, and muskgrasses. Generally, having a higher number of aquatic plant species (species richness), the dominance of the plant community by a few number of species results in lower species diversity. Within Loon Lake, this does not seem to be the case, 65% of the community is made of 17 different species.

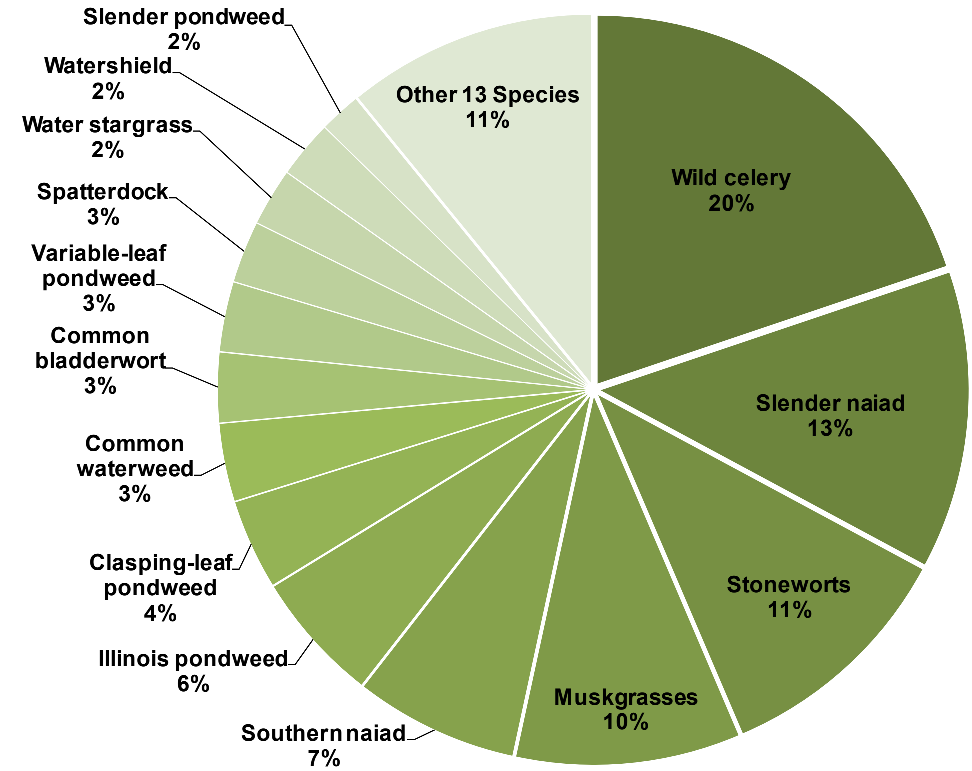


Figure 3.4-12. 2016 relative frequency of occurrence of aquatic plants in Loon Lake. Created using data from 2016 point-intercept survey.

The quality of Loon 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 2016 community map indicates that approximately 42.5 acres (13%) of the 327 acre-lake contain these types of plant communities (Table 3.4-2 and Map 8). 15 floating-leaf and emergent species were located on Loon 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.

Table 3.4-2. Loon Lake acres of plant community types. Created from August 2016 community mapping survey.

Plant Community	Acres
Emergent	1.8
Floating-leaf	40.5
Mixed Emergent & Floating-leaf	0.2
Total	42.5

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

(*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-native Plants in Loon Lake

Eurasian watermilfoil

Eurasian watermilfoil (EWM; Photograph 3.4-6) is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties. EWM is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, EWM has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it oftentimes does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. EWM can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. It is important to note that on many lakes, perhaps more often in northern Wisconsin, the EWM population remains low and may only cause localized nuisance conditions and not cause lake-wide ecological changes. A WDNR study of 397 lakes that had confirmed EWM populations, approximately 65% contained populations of 10% or less (Nault 2016).

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

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

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

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

EWM population. Within strategic planning meetings, the LLWMD Planning Committee discussed these two concepts and some of the information that surrounds them.

Impact Riparian Use

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

Impact Historic Ecosystem Function

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

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

Loon Lake HWM Management History

EWM was first documented in Loon Lake in 1998. Hybrid watermilfoil (*Myriophyllum spicatum* x *Myriophyllum sibiricum;* HWM) was also documented at the same time. Due to only being able to differentiate between the two species through genetics, EWM and HWM can be used synonymously for Loon Lake. Control actions directed at HWM have been ongoing since shortly after the discovery and confirmation of HWM in the lake in 1998 and have included biological control (weevils), mechanical control (harvesting) and chemical control (herbicide treatments). Biological and mechanical control efforts were proven to be largely unsuccessful in Loon Lake and control efforts have shifted largely towards chemical control through herbicide treatments on nearly an annual basis from 2003-2017.

In 2000, the LLWMD initiated active management strategies towards the HWM population. Following an assessment by EnviroScience, Loon Lake was found to have a robust native milfoil weevil (*Euhrychiopsis lecontei*) population. In 2001 and 2002, the LLWMD stocked a total of

24,500 milfoil weevils to combat the invasive milfoil population. The LLWMD abandoned this strategy after assessments yielded increased milfoil populations and declined weevil abundance.

In 2002 the LLWMD hired an herbicide applicator firm to initiate chemical control strategies towards the HWM population the following year. From 2003 to 2010, the HWM control strategy largely consisted of 2,4-D and/or endothall applications, sometimes multiple applications per year (Figure 3.4-13). Herbicide treatments were planned for the spring of 2011, but unexpectedly low HWM populations observed during a pretreatment survey postponed the management action.

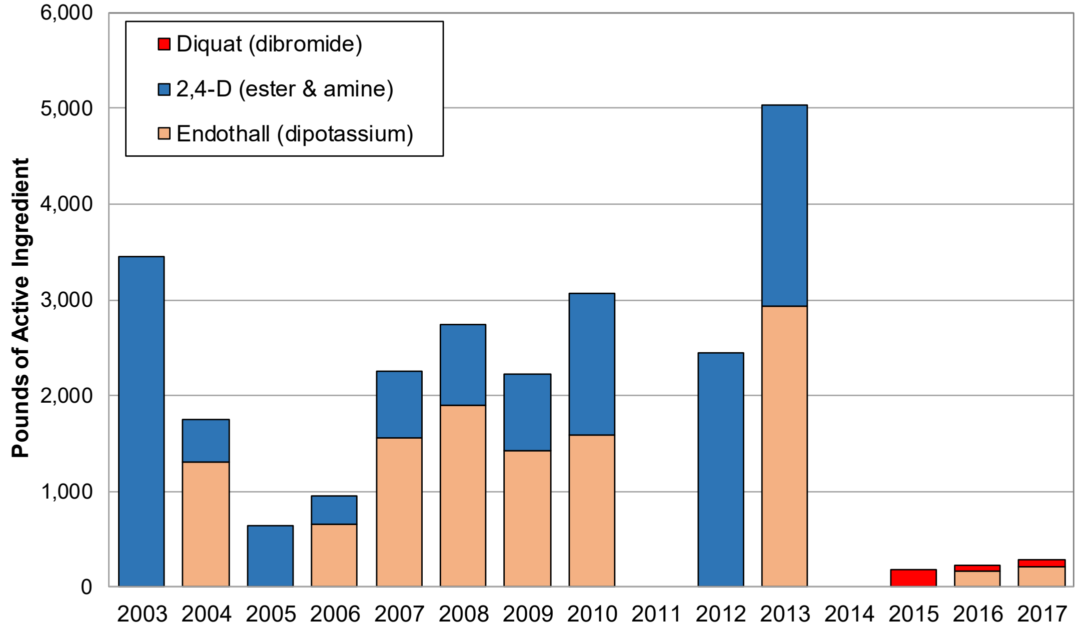


Figure 3.4-13. Herbicide Treatment History on Loon Lake.

Formal monitoring of the herbicide treatments generally yielded seasonal reductions in the HWM population with full rebound by the end of the summer occurring in most instances. In 2012, a large-scale (aka whole-lake) herbicide treatment strategy was planned for Loon Lake by John Skogerboe, US Army Engineer Research and Development Center (ERDC). From an ecological perspective, large-scale treatments are those where the herbicide may be applied to specific sites where milfoil is present, but when the herbicide dissipates from where it was applied and reaches equilibrium within the entire mixing volume of water of the lake, it is at a concentration that is sufficient to cause mortality to the target plant within that entire treated volume (Nault et al. 2012). A recent article by Nault et al. 2018 investigated 28 large-scale herbicide treatments in Wisconsin and found that "herbicide dissipation from the treatment sites into surrounding untreated waters was rapid (within 1 day) and lakewide low-concentration equilibriums were reached within the first few days after application." WDNR administrative code defines large-scale treatments as those that exceed 10% of the littoral zone (NR 107.04[3]). As spot treatments approach 10% of a lake's area, they are more likely to have large-scale impacts, which is why the WDNR has this check mechanism within the permitting process.

The 2012 large-scale treatment strategy targeted a lake-wide concentration of 2,4-D at 0.3 ppm acid equivalent (ae). This strategy provided similar control to past efforts, with upfront reductions followed by population rebound from survivorship. It was unclear why the 2012 large-scale strategy did not meet expectations, since the measured 2,4-D concentrations and exposure times from the lake would have been sufficient to cause invasive milfoil population control on other systems.

Lake managers suspected the HWM population within Loon Lake may have been more tolerant of the 2,4-D use-pattern than is present in other lakes. Small-scale laboratory aquaria tests conducted by Dr. Netherland at the Army Corps ERDC facility in Florida indicated that the Loon Lake genotype(s) studied were unusually more tolerant to herbicide than reference strains.

The concept of heterosis, or hybrid vigor, is important in regards to hybrid water milfoil management in Loon Lake. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid watermilfoil (HWM) typically has thicker stems, is a prolific flowerer, and grows much faster than pure-strain EWM (LaRue et al. 2012). These conditions likely contribute to this plant being particularly less susceptible to biological (Enviroscience personal comm.) and chemical control strategies (Glomski and Netherland 2010, Poovey et al. 2007, Nault et al. 2018). In a recent study of 28 large-scale 2,4-D amine treatments in Wisconsin (Nault et al. 2018), HWM initial control was less and the longevity was shorter than pure-strain EWM control projects. Therefore, it appears that potentially most strains of HWM, but not all, are more tolerant of auxin-mimic herbicide treatments (e.g. 2,4-D, triclopyr) than pure-strain EWM.

Another large-scale treatment took place on Loon Lake in 2013, this time embracing an emerging strategy using a combination of 2,4-D and endothall. An additive, potentially synergistic advantage occurs when combining 2,4-D and endothall. The simultaneous exposure to endothall and 2,4-D has been shown to provide increased control of invasive milfoil control in outdoor growth chamber studies (Madsen et. al 2010). A handful of HWM treatments in Wisconsin utilizing this strategy have been conducted to date with promising results of control and selectivity towards native plants.

The 2013 combination treatment had a 1-7 DAT mean concentration of 0.302 2,4-D acid equivalent (ae) and 0.347 ppm endothall ae (0.488 ppm active ingredient [ai]). The manufacturer of endothall (United Phosphorus, Inc [UPI]) recommends a combination treatment dosing of 2,4-D at 0.300 ppm ae and endothall between 0.53 and 0.71 ppm ae (0.75-1.0 ppm ai). The 2013 treatment strategy was below currently recommended target lake-wide concentrations; however, it was reported as being successful with some HWM rebound occurring late in the growing season, yielding 11.6% of the littoral zone by early autumn (Figure 3.4-14).

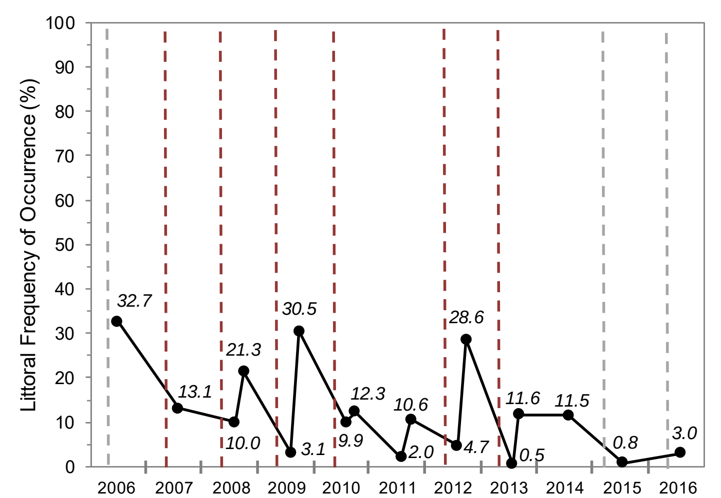


Figure 3.4-14. HWM Littoral Frequency of Occurrence from 2006-2016. Late-July 2006-2015 surveys conducted by WDNR. 2016 survey conducted by Onterra. Early autumn 2008-2013 surveys conducted by J. Skogerboe. Grey dashed line equals spot treatment (<2,000 lbs active ingredient), red dashed line equals whole-lake treatment.

No herbicide control actions took place in 2014 and the EWM population remained at 11.5% of the littoral zone. Understanding Concentration-Exposure Times (often referred to as CETs) is an important consideration for the use of aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Numerous past attempts at controlling the EWM population in this part of Loon Lake have failed, as herbicide dilution was too rapid to kill the EWM.

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

The small-scale diquat treatment in 2015 showed mixed results in the treatment area, although the EWM population lake-wide was reduced to under 1%. This lake-wide population reduction was likely caused by environmental conditions and not that year's herbicide management program. The long-term control of EWM targeted with diquat continues to be evaluated on many lakes across Wisconsin. As a contact herbicide, diquat does not move (translocate) through plant tissue. Therefore, only the exposed plant material is impacted by the herbicide. Concern exists whether this herbicide has the capacity to kill the entire plant or if the herbicide simply removes all the above ground biomass and the plant rebounds from unaffected root crowns. Diquat also has a high affinity for binding with organic particles. In shallow waters where the application equipment creates disturbance of the lake bottom, the diquat being applied will quickly bind to the suspended particles and be instantly unavailable to cause impacts to the target plants. In lakes with high organic material encrusted on the plant, this may also reduce the efficacy of the treatment.

It is theorized, but not proven, that a combination of endothall and diquat or 2,4-D may not require as long of an exposure time as either herbicide alone due to increased systematic impacts to the target plants particularly at cold water temperatures. The manufacturers of endothall (Aquathol® K, UPI), have shown that increased systemic activity of the endothall occur when water temperatures are colder (<60°F). Numerous spot treatment field trials of 2,4-D/endothall (soon to be commercially available under the Chinook® brand) and diquat/endothall (commercially available under the Aquastrike® brand) are occurring in Wisconsin.

The 2016 spot treatment targeted two areas with a combination of 2,4-D/endothall. The herbicide treatment fell short of meeting control expectations in 2016 on Loon Lake, likely due to insufficient herbicide concentration exposure time. Although there are a number of factors that can influence water movement in the lake, these data suggest that wind conditions around the time of the treatment may have increased water movement and herbicide dissipation following the application. The two locations were again proposed for treatment in 2017. Based on the emerging scientific information on endothall, it was proposed that the treatment occur before surface waters exceed 60-65°F if logistically possible. The LLWMD would like to put a condition on the application that it cannot occur when winds exceed 7 mph, and would prefer the application occur when winds are 0-5 mph. The 2017 treatments were met with a higher level of success. Further information regarding the current HWM control project can be found within the 2017 Loon AIS Monitoring and Control Report.

2017 HWM Peak Biomass Survey

On August 25, 2017, Onterra ecologists visited Loon Lake to complete the HWM Peak Biomass survey. This meander-based survey, which mimics the methodology used in the ESAIS survey, is completed late in the growing season (August/September) when HWM has reached its peak growth stage. Because HWM should be at or near its maximum density, the results of this survey provide an understanding of where HWM is in the lake and what its full impact on the ecology of the lake may be. As a result, these data are useful in determining the efficacy of control actions used during the summer months as well assisting in the next year's control planning.

Much of the HWM was found to be growing up to the waters' surface and was at times in flower. A total of 9.9 acres of colonized HWM were mapped during the late summer survey of which 7.0 acres were of a *highly scattered* density, 2.4 acres were of a *scattered* density, and an additional 0.4 acres were of a *dominant* density. The largest contiguous colonies of HWM were located mostly on the western side of the lake, however, low density occurrences were observed throughout many areas of the littoral zone (Map 9). The acreage estimates only take into account the HWM polygons, not HWM mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*).

Curly-leaf pondweed

Curly-leaf pondweed (*Potamogeton crispus*), another non-native exotic plant species commonly found in Wisconsin, was discovered within Loon Lake in 2012. The CLP population has remained low since 2012, with no large- or small-scale treatments focused on the CLP. During many of the HWM treatments, endothall was also used which can be used to control CLP. During the 2016 Early Season Aquatic Invasive Species (ESAIS) Survey only three *single or few* CLP plant occurrences were found (Map 5).

Photograph 3.4-7. Curly-leaf pondweed, a non-native, invasive aquatic plant. Photo credit Onterra.

Pale-yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Pale yellow iris was growing along the shore of Loon Lake (Map 8). At this time, the only means of controlling pale-yellow iris populations is continual hand removal and monitoring.

Stakeholder Survey Responses to Aquatic Vegetation within Loon Lake

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.4-13 and 3.4-14 display the responses of Loon Lake stakeholder survey respondents 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, negatively impacts the enjoyment of Loon Lake, 57% of stakeholder survey respondents indicated *sometimes*, 22% indicated *rarely*, 14% indicated *often*, and 6% indicated *never* (Figure 3.4-15).

When asked if they believe aquatic plant control is needed on Loon Lake, 44% of respondents indicated *probably yes*, 41% indicated *definitely yes*, 13% indicated that they were *unsure*, and 2% indicated *probably no* or *definitely no* (Figure 3.4-16). The presence of AIS within Loon Lake is well-known knowledge for stakeholder survey respondents, 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 Loon Lake is discussed within the Implementation Plan Section (Section 5.0).

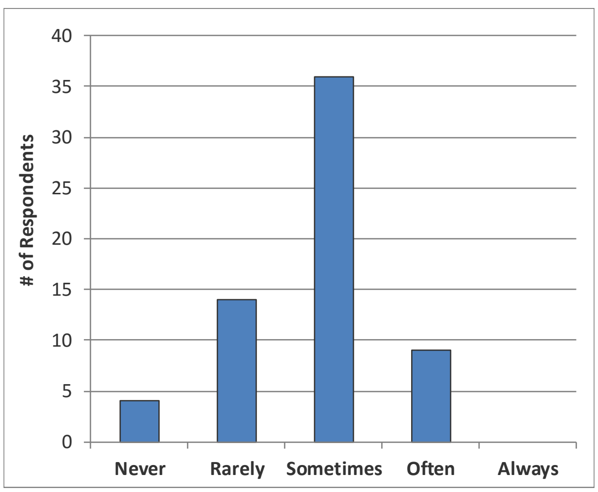


Figure 3.4-15. Stakeholder survey response Question #23. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Loon Lake?

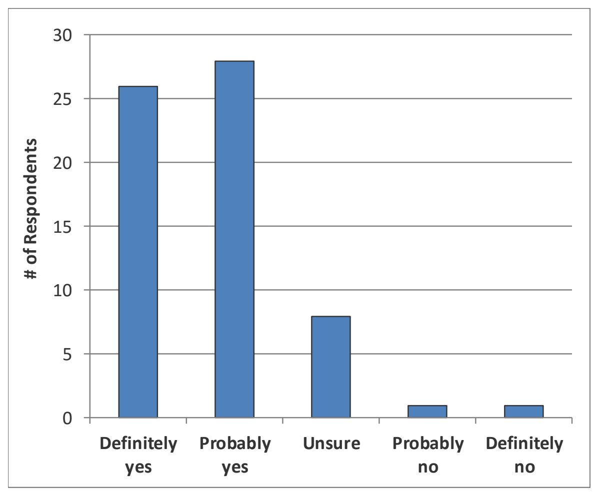


Figure 3.4-16. Stakeholder survey response Question #24. Do you believe aquatic plant control is needed on Loon Lake?

Concerns from Loon Lake stakeholder respondents regarding water levels and reductions in trees on the island in Loon Lake were introduced previously in Section 2.0 (Stakeholder Survey) and Section 3.1 (Water Quality). Figure 3.1-17 depicts aerial photographs of Loon Lake's island from 1938, 2005, 2013, and 2015. While the area of the island does not appear to be decreasing, it does appear that tree cover is decreasing. The trees may likely be dying from increasing water levels; however, water level data is not available for the time periods shown in Figure 3.4-17.

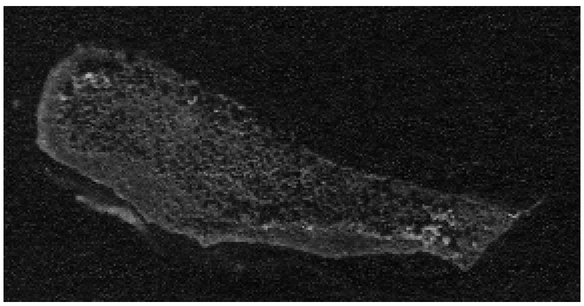
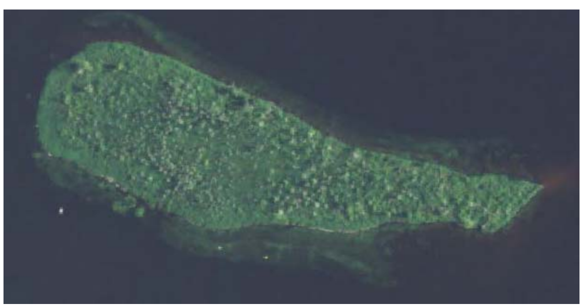
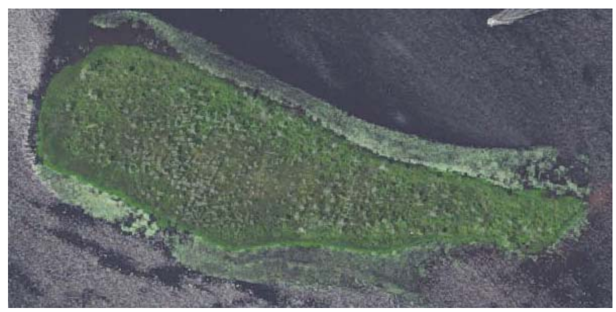
1938	2005
	
2013	**2015**
	

Figure 3.4-17. Historical photographs of Loon Lake's island. 1938 aerial photograph from Wisconsin State Cartographer's Office Historical Aerial Image Finder (WHAIFinder). 2005, 2013, and 2015 aerial photograph from the National Agriculture Imagery Program (NAIP).

3.5 Aquatic Invasive Species in Loon Lake

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Loon Lake within the anonymous 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 Loon 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
	Pale-yellow iris	*Iris pseudacorus*	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

Figure 3.5-1 displays the 11 aquatic invasive species that Loon Lake stakeholder respondents believe are in Loon Lake. Only the species present in Loon Lake are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholder respondents 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

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).

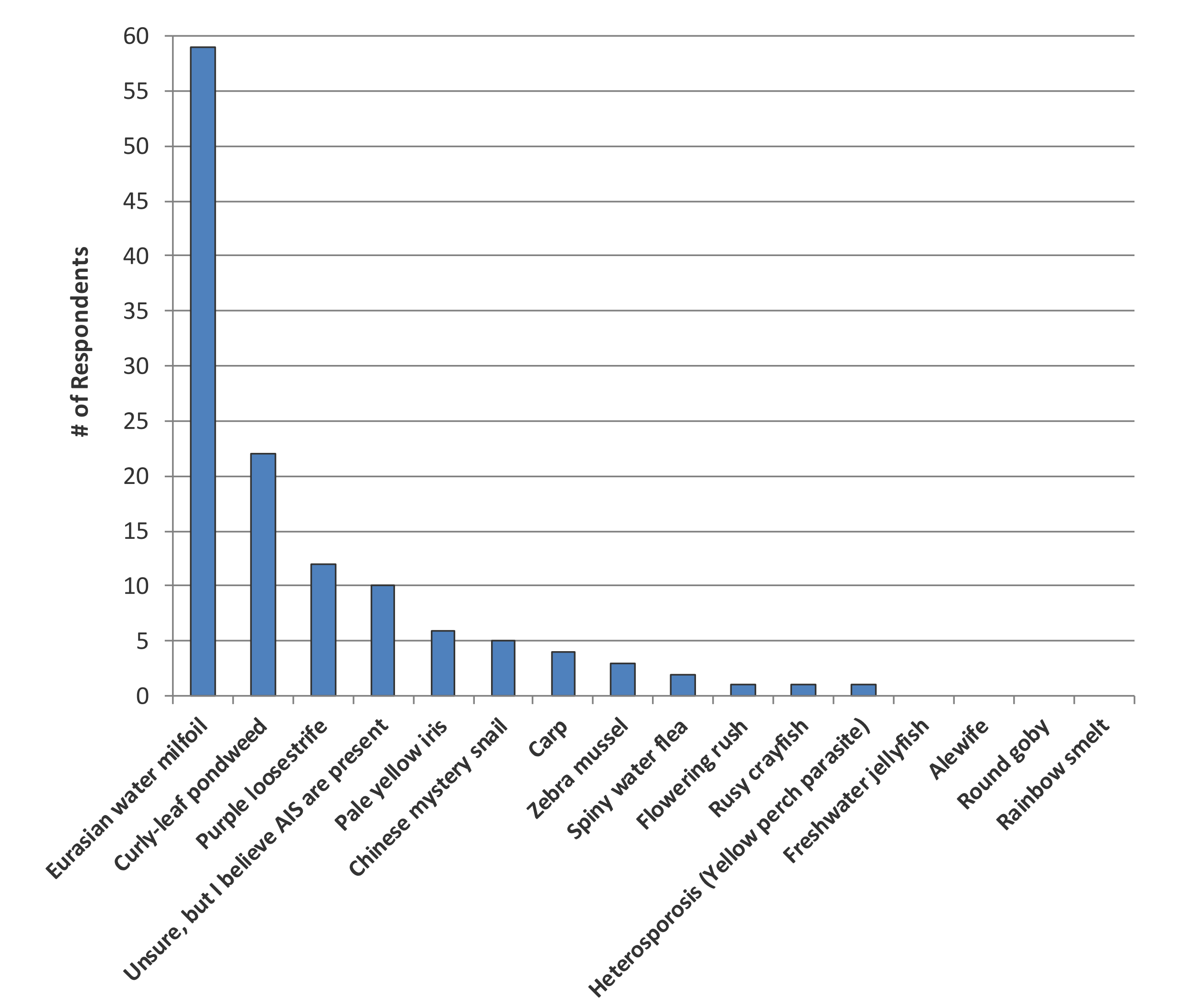


Figure 3.5-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in Loon Lake?

3.6 Fisheries Data Integration

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

Loon Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Loon 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.

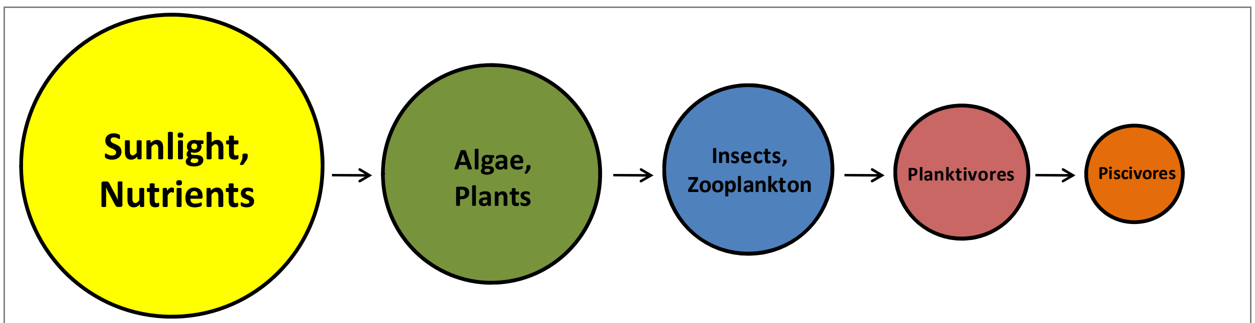


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Loon Lake is a mesotrophic system, meaning it has moderate nutrient content and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Loon Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system. Additional fish species found in past surveys of Loon Lake include white sucker (*Catostomus commersonii*) and the lake chubsucker (*Erimyzon sucetta*). The lake chubsucker is listed as a *special concern species* in the Natural Heritage Inventory for the state of Wisconsin due its relatively rare status in the state.

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

Common Name (*Scientific name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Bullhead (*Ameiurus nebulosus*)	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Green Sunfish (*Lepomis cyanellus*)	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, 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
Orangespotted Sunfish (*Lepomis humilis*)	4	Late May - August	Shallow water with sand or gravel bottom	Crustaceans, copepods, mites and aquatic insects
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
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
White Crappie (*Pomoxis annularis*)	13	May - June	Within 10 m from shore, over hard clay, gravel, or roots	Crustaceans, insects, small fish
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 common passive trap used is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net and sort the fish that were captured.

A common active 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, *galvanotaxis* (stimulation of the nervous system in response to an electric current) transpires and involuntarily causes the fish to swim toward the electrodes. When the fish are in the vicinity of the electrodes, they undergo *narcosis* (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. Electroshocking was conducted on Loon Lake to provide insight and direction for future fisheries management (Niebur 2015).

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


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

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult
fish in a waterbody that were raised in nearby 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. Table 3.6-2 displays 1974-2016 stocking efforts of largemouth bass and walleye in Loon Lake.

Photograph 3.6-2. Fingerling Muskellunge.

Table 3.6-2. Stocking data available for Loon Lake (1974-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in
1974	Walleye	Unspecified	Fingerling	30,000	3.00
1975	Walleye	Unspecified	Fingerling	15,000	5.00
1998	Largemouth Bass	Unspecified	Large Fingerling	900	5.00
2014	Walleye	Lake Michigan	Large Fingerling	2,342	7.30
2016	Walleye	Upper Mississippi River	Large Fingerling	3,293	7.50

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. One method used in calculating the numbers captured is catch per unit effort (CPUE). This number provides a standardized way to compare fish abundances between years when the amount of fishing effort (number of nights' fyke nets are set) differs. When comparing within the same year, CPUE indexes are compared to statewide data by percentiles (Neibur 2015). For example, if a CPUE is in the 90th percentile, it is higher than 90% of the other CPUEs in the state (Neibur 2015). Table 3.6-3 provides total and calculated fishery data for fish captured during the electroshocking survey on Loon Lake in 2015. Ultimately this data shows a healthy population of fish from moderate to high abundances. The lowest percentile rank of species captured was yellow perch (41st) and the highest being largemouth bass (81st). This is one example of how data is analyzed by fisheries biologists to better understand the fishery and how it should be managed.

Table 3.6-3. Data from 2015 WDNR electroshocking survey (Niebur 2015).

Species	Total	Avg length (inches)	Length Range (inches)	CPUE Total (no per mile)	Percentile Rank	Overall Abundance Rating
Bluegill	154	5.0	2.1 - 8.1	96.3	47th	Moderate
Black Crappie	56	6.5	2.9 - 9.9	18.8	75th	High
Largemouth Bass	49	12.7	6.1 - 20	31.9	81st	High
Pumpkinseed	51	5.4	2.8 - 6.9	14.4	58th	Moderate
Yellow Perch	23	5.0	4.1 - 6.1	14.4	41st	Moderate

Gamefish

Brief summaries of popular gamefish present in Loon Lake are provided below based off of the report submitted by WDNR fisheries biologist Al Niebur following the survey completed in 2015.

Largemouth bass was the dominant gamefish in Loon Lake with growth metrics indicating fast growth for quality size bass. Size structure and abundance metrics for largemouth bass were found at moderate levels. The electroshocking survey showed largemouth bass as the dominant gamefish in the lake.

Walleye were not captured in high abundance (five). Walleye that were captured were likely from the 2014 large fingerling stocking event.

Northern Pike and **Muskellunge** were sampled at very low abundances. Spring fyke netting would be a more appropriate method to sample and assess these gamefish species.

Panfish

The panfish population consisted of mainly bluegill, black crappie and yellow perch, and size structure overall was found at suboptimal levels. The WDNR recommends predator management to decrease the density of panfish and improve on growth rates (Neibur 2015).

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), Loon Lake stakeholders enjoy catching bluegill/sunfish the most (Figure 3.6-2). Approximately 80% of the respondents that fish Loon Lake believe the current quality of fishing is fair or good (Figure 3.6-3). Approximately 85% of these same respondents believed that the quality of fishing on the lake either remained the same or had gotten worse since they first began fishing on the lake (Figure 3.6-4).

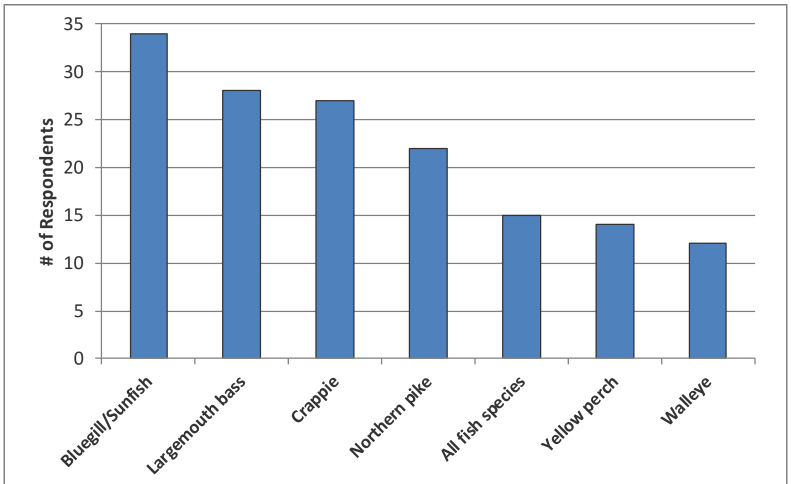


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Loon Lake?

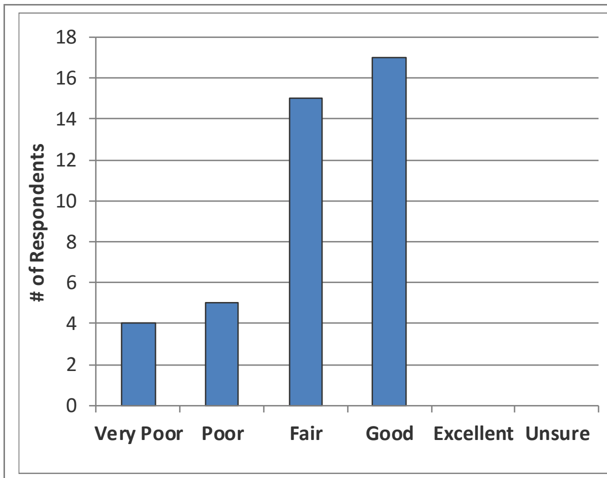


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Loon Lake?

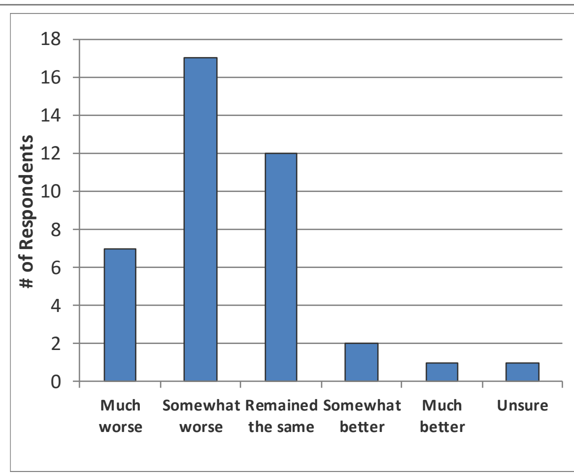


Figure 3.6-4. Stake holder survey response Question #11. How has the quality of fishing changed on Loon Lake since you started fishing the lake?

Loon 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, and contain few aquatic plant species or coarse woody habitat.

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

According to the point-intercept survey conducted by Onterra in 2016, 70% of the substrate sampled in the littoral zone of Loon Lake was soft sediments and 30% was sand substrate.

Coarse Woody Habitat and Fish Sticks Program

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

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

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 (WDNR 2014). Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photo 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. During Onterra's 2016 coarse woody habitat survey, Loon Lake had six coarse woody pieces per mile of shoreline. Loon Lake is an excellent candidate to install coarse woody habitat.

Regulations and Management

Loon Lake has a boating regulation of no wake before 9:00AM and after 5:00PM. The LLWMD encourages personal watercraft to stay out 300ft from shore and for land owners to only use phosphorus-free fertilizer on lawns. Table 3.6-4 displays the 2017-2018 fishing regulations for Loon Lake gamefish species. For specific fishing regulations, 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 3.6-4. WDNR fishing regulations for Loon Lake (2017-2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	May 6, 2017 to March 4, 2018
Muskellunge and hybrids	1	40"	May 27, 2017 to November 30, 2017
Northern pike	5	None	May 6, 2017 to March 4, 2018
Walleye, sauger, and hybrids	3	Only 1 fish over 14"	May 6, 2017 to March 4, 2018

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 3.6-5. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

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

Figure 3.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Conclusions and Management

The WDNR's recommendations for Loon Lake are to continue monitoring fish populations. Loon Lake is currently on an 8-year sampling rotation with the WDNR with the next survey scheduled for 2023 (Neibur 2015). However, the WDNR recommends moving this sampling date earlier to 2019 or 2020 and to include a spring fyke netting survey to conduct a walleye, northern pike and muskellunge population assessment (Neibur 2015). The management objective for panfish is to reduce the abundance and improve the growth rate (Neibur 2015). This can be done by increasing stocking of large fingerling walleye or northern pike to increase predator density (Neibur 2015).

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 Loon Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil.
3) Collect sociological information from Loon 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 needs to be completed to protect and enhance them.

Overall, the studies that were completed on lake indicate that it is healthy in terms of its watershed and water quality. With the exception of two exotic species found in the lake, the aquatic plant community is also believed to be healthy.

5.0 IMPLEMENTATION PLAN

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

The LLWMD will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Loon Lake

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at public access location
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors or possible coordinator
Description:	Loon 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 Loon Lake. The goal is to cover the landing 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. The LLWMD had observed volunteer fatigue in regards to watercraft inspections, achieving approximately 50 hours of annual inspections in recent years. If the LLWMD find it difficult to find sufficient volunteerism to conduct boat landing inspections, they may consider the stream-lined WDNR Clean Boats Clean Waters Grant Program that provide cost coverage for paid watercraft inspections. Volunteer efforts may be sufficient to use as the local match to fund the program.
Action Steps:	
	See description above.

Management Action:	Coordinate volunteer monitoring of CLP
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	LLWMD members have received past training on AIS identification from WDNR and Shawano County staff. Volunteers would conduct informal surveys of the lake, with particular attention being paid to CLP populations. If volunteers find CLP populations increasing or expanding, this would trigger the district to consider hiring a professional firm to conduct a lake-wide mapping survey of this species during its peak growth stage (mid- to late-June).
Action Steps:	
1.	Volunteers from LLWMD update their skills by attending a training session conducted by WDNR/UW-Extension (Paul Skawinski – 715.346.4853).
2.	Trained volunteers recruit and train additional district members.
3.	Complete lake surveys following protocols.
4.	Report results to consultant and LLWMD, entering hours spent into SWIMS.

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

Management Action:	Conduct EWM/HWM Population Control Using Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors or possible coordinator
Description:	The EWM population of Loon Lake is currently at relatively low levels following large-scale herbicide management. At these low levels, the EWM population is not likely causing measurable negative ecological impacts to the system. Along with being a source population for future expansion, the EWM populations may be diminishing the navigability, recreation, aesthetics in localized areas. The LLWMD would implement spot-herbicide treatments to preserve the gains from the large-scale effort. Conducting AIS management at a small scale can be difficult to reach control goals and is relatively expensive. Overall, the LLWMD will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. When a Late Season AIS Survey documents colonized EWM populations that are *dominant* or greater in density, herbicide spot treatment would be considered by the LLWMD. Areas containing high use or riparian frontage would be prioritized for treatment. The LLWMD would devise a strategy where a sufficiently large treatment area can be constructed to hold concentration and exposure times, with attention to ensuring additive spot-treatments do not have additive lake-wide impacts. It is likely that these areas would need to be targeted with herbicides that require short exposure times, such as diquat or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). If populations exceed spot-treatment thresholds, large-scale herbicide strategies may be given consideration. In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied to the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 65°F and active growth tissue is confirmed on the target plants. A pretreatment survey, a week or so prior to treatment would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing. When spot-treatments are being conducted, the LLWMD would like to put a condition on the application that it cannot occur when winds exceed 7-8 mph, and would prefer the application occur when winds are 0-5 mph.
Action Steps:	
	See description above

Management Action:	Conduct EWM Population Control Using Large-Scale Herbicide Treatments
Timeframe:	As Applicable
Facilitator:	Board of Directors or possible coordinator
Description:	Due to the large and broad shape of Loon Lake, past attempts at conducting spatially targeted "spot" treatments have been only marginally effective at achieving more than one year of control (often referred to as *seasonal control*). Once EWM populations within the lake exceed levels that can be managed by herbicide spot treatments, this would trigger that LLWMD to initiate the planning and pretreatment steps necessary to conduct a large-scale treatment on the lake, including a lake-wide point-intercept survey. Once the trigger has been met and the pretreatment data is collected, the LLWMD will review the information, and formally make a decision to move forward with the control program based upon a vote by the Board of Directors. At that time, the LLWMD would also solicit input from the WDNR to understand their position on the strategy and how that impacts permits and funding sources (i.e. AIS-Established Population Control Grants). The decisions to implement a large-scale treatment strategy would have flexibility, particularly if large acreages of high-density EWM colonies (*dominant*, *highly dominant*, or *surface matted*) are confirmed on the lake. Herbicide use patterns may require rotation to avoid population-level herbicide tolerance evolution from occurring. <u>Active Management Monitoring Strategy</u>: A cyclic series of steps will be used to plan and implement the control efforts. The series includes conducting the following surveys during the *year prior to the treatment*, *year of the treatment*, and *year following the treatment:* • A lake-wide mapping assessment of EWM completed while the plant is at peak growth stage (peak biomass). • A detailed assessment of bathymetric data from the lake, potentially augmenting with an acoustic survey of the lake. • Quantitative assessments of the native and non-native aquatic plant community of the lake utilizing point-intercept survey methodology. During previous large-scale management, rebounding EWM/HWM populations were noted late in the year so point-intercept surveys should likely occur in mid- to late-August. During the *year of the treatment*, the project would include verification and refinement of the treatment plan immediately before control strategies are implemented. This potentially would include refinements of herbicide application areas, assessments of growth stage of aquatic plants, and documentation of thermal stratification parameters that influence the final dosing strategy.

	Volunteer-based monitoring of temperature profiles would also be coordinated surrounding the large-scale treatment, as well as collection of post treatment herbicide concentration samples at multiple locations and sampling intervals. The success criteria of a large-scale treatment would be a 70% reduction in EWM littoral frequency of occurrence (LFOO) comparing point-intercept surveys from the *year prior to the treatment* to the *year after the treatment* Native plant impacts are anticipated from any large-scale management action, but evaluation of the long-term success will also take into account the native plant impacts and population rebound. Regardless of treatment efficacy, a whole-lake treatment would not be conducted during the *year following the treatment*.
Action Steps:	
1.	Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2.	Apply for a WDNR Aquatic Invasive Species Grant based on developed project design.
3.	Initiate control and monitoring plan.

<u>Management Action:</u>	Coordinate Periodic Quantitative Vegetation Monitoring
Timeframe:	Point-Intercept Survey every 3-5 years, Community Mapping every 7-8 years
Facilitator:	Board of Directors, Planning Committee, or possible coordinator
Description:	Unless the LLWMD is going to be conducting management actions at a lake-wide scale (e.g. large-scale herbicide treatments), conducting vegetation monitoring through a point-intercept survey would be conducted at a minimum once every 5 years, with the potential of once every 3 years. This will allow an understanding of the submergent aquatic plant community dynamics within Loon Lake. Building this dataset over time will assist in understanding natural and unnatural population dynamics. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in Loon Lake, a community mapping survey would be conducted every 7-8 years. The community mapping survey was conducted on Loon Lake in 2016 serves as a comparative for future replicated surveys. This effort is typically conducted as part of each future lake management planning project update.
Action Steps:	
	See description above

Management Goal 2: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort.
Facilitator:	Board of Directors or possible coordinator
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 is currently being completed annually by Loon 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. This includes collecting Secchi disk transparency and dissolved oxygen readings, as well as sending in water chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected three times during the summer and once during the spring. It is important to note that as a part of this program, the data analyzed are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS). During each sampling interval, the LLWMD's volunteer also collects a temperature and dissolved oxygen profile. The LLWMD volunteer is responsible for entering these data into SWIMS. It will be the Board of Directors responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples within each basin during each year.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data and report results to WDNR and to district members during annual meeting.
2.	CLMN volunteer and/or LLWMD Board of Directors would facilitate new volunteer(s) as needed
3.	Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer (s)

Management Goal 3: Increase LLWMD'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:	Board of Directors or possible coordinator
Description:	Education represents an effective tool to address many lake issues. The LLWMD would like to send out a regularly distributes newsletters (at least once per year) and possibly maintain a public Facebook page. These mediums allow for exceptional communication with district members. This level of communication is important within a management group because it facilitates the spread of important district news, educational topics, and even social happenings. The LLWMD 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. The LLWMD will work with UW-Extension Lakes staff (Pat Goggin: Patrick.Goggin@wisconsin.gov) to use stock articles as appropriate to lessen the workload and ensure the messaging is accurate. *www.uwsp.edu/cnr-ap/UWEXLakes* *Example Educational Topics* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology. • Promote *Lake Courtesy Code* and *User Reminders* • Boating safety (promote existing guidelines and ordinances) • Shoreline habitat restoration and protection • Course woody habitat • Fireworks use and impacts to the lake • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Recreational use of the lakes
Action Steps:	
	See description above as this is an established program.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Every 5-6 years
Facilitator:	Board of Directors or possible coordinator
Description:	Approximately once every 5-6 years, an updated stakeholder survey would be distributed to the Loon 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 Action:	Continue LLWMD's involvement with other entities that have responsibilities in managing (management units) Loon Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The Loon Lake/Wescott Management District (LLWMD) was formed in 1990 to preserve and protect Loon Lake for today and future generations. 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 LLWMD actively engage with all management entities to enhance the district'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
Camp Tekakwitha	Camp Director (Rebecca Sievers - rsievers@gbdioc.org)	Camp falls on shores of Loon Lake,	Check website (www. camptekakwitha.org) for updates.	Make aware of summer camp schedule and periodically as WWLMD would like to use the camp's meeting room facilities
Town of Wescott	Town Clerk (Angela Vreeke wescott.clerk@frontier.com)	Loon Lake falls within this township.	Check website (www.townofwescott.com) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events
Waterways Association of Menominee and Shawano Counties	President (Shanda Hubertus – WAMSCO@gmail.com s)	Facilitated education, research, cooperative sharing of resources and best practices between organizations.	Twice a year or as needed. May check website (https://wamsco.org) for updates	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to local waterways.
Shawano County Land Conservation Department	County Conservationist (Scott Frank – 715.526.6273)	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 (Jason Breeggemann – Jason.Breeggemann@wisconsin.gov)	Manages the fishery of Loon Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery and fish structure
	Lakes Coordinator (Brenda Nordin – 920.360.3167)	Oversees management plans, grants, all lake activities.	Once a year, or more as issues arise	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues including AIS management.
	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.	Early spring: 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.	LLWMD members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Goal 4: Maintain and Improve Lake Resource of Loon Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Ongoing effort
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. In 2016, the shoreland assessment survey indicated that about a half mile, or approximately 13% of the Loon Lake's 3.4-mile shoreline, consists of *urbanized* or *developed-unnatural* areas. 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 Shawano 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

Management Action:	Protect natural shoreland zones around Loon Lake
Timeframe:	Ongoing effort
Facilitator:	Board of Directors or possible coordinator
Description:	Approximately 2.1 miles (60%) of the Loon Lake shoreline was found to be in either a *natural* or *developed-natural* state, much of the land being a part of the district-owned conservation lands (Map 1). The LLWMD is considering the purchase of additional conservation lands on Loon Lake's northwestern shore if the opportunity presents. Private shorelands that are in either a *natural* or *developed-natural state* should be prioritized for education initiatives and physical preservation. A Planning Committee appointed person will work with appropriate entities to research grant programs and other pertinent information that will aid the LLWMD in preserving the Loon Lake shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Shawano County Land Conservation Department. Several websites of interest include: • Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands) • Conservation easements or land trusts: (http://www.northwoodslandtrusts.org/) • UW-Extension Shoreland Restoration: (www.uwex.edu/ces/shoreland/Why1/whyres.htm) • WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)
Action Steps:	
1.	Recruit facilitator (potentially same facilitator as previous management action).
2.	Facilitator gathers appropriate information from sources described above.

Management Action:	Revive the Loon Watch program
Timeframe:	Summer 2018
Facilitator:	Board of Directors
Description:	The LLWMD's Loon Watch program is currently vacant. The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. The LLWMD will attempt to recruit a volunteer for this program, providing information and education to its membership at the association's annual meetings.
Action Steps:	
	See description above

Management Action:	Control and discourage local Canada goose residents
Timeframe:	Ongoing effort
Facilitator:	Board of Directors
Description:	Vegetated and wooded natural shorelines are the best way to discourage geese from inhabiting riparian properties. But green space exists around the lake as it allows riparians to use the nearshore areas for recreation. High populations of geese can leave aesthetically unpleasing waste behind as well as damage valuable native plants and landscaping. In the spring, LLWMD volunteers identify nest sites for control through addling. Addling is the process of applying an oil to the egg to terminate embryo development but leave the egg intact so the goose does not lay additional eggs. The LLWMD hires a professional to conduct this work and secure the appropriate permits.
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 Loon Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by LLWMD members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

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

	Spring		June	July		August	Fall		Winter	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**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	■									

● indicates samples collected by volunteers under proposed project.
■ indicates samples collected by consultant under proposed project.

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Loon Lake during a June 13, 2016 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Loon Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on August 1-2, 2016. A point spacing of 60 meters was used resulting in approximately 365 points.

Community Mapping

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

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

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