Forest Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

January 2020

Sponsored by:

Forest Lake Improvement Association

WDNR Surface Water Grant Program

AEPP-503-17

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Onterra, LLC
Lake Management Planning

Forest Lake

Fond du Lac County, Wisconsin

Comprehensive Management Plan

January 2020

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1.0 INTRODUCTION

According to the 1965 recording sonar WDNR Lake Survey Map, Forest Lake is 50.5 acres. The WDNR website lists the lake as 51 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2015. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 53.6 acres. Forest Lake, Fond du Lac County, is a seepage lake with a maximum depth of 32 feet and a mean depth of 11 feet. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Forest Lake contains 19 native plant species, of which slender naiad is the most common plant. Two exotic plant species are known to exist in Forest Lake.

Field Survey Notes

Water levels have increased since we started working on the system. The property we originally accessed the lake from is now too wet/soft to accommodate a truck and boat trailer. The "island" between the two basins was once shallow enough to be concerned that our props would scrape the lake bottom in this area.

Photograph 1.0-1 Forest Lake, Fond du Lac C

Lake at a Glance - Forest Lake

Morphology	
Acreage	53.6
Maximum Depth (ft)	32
Mean Depth (ft)	11
Shoreline Complexity	1.8
Vegetation	
Number of Native Species	19
Exotic Plant Species	*Hybrid watermilfoil, Purple loosestrife*
Simpson's Diversity	0.85
Average Conservatism	6.0
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	8.7
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	2:1

Forest Lake, Fond du Lac County, contains a single carry-in access location which has been determined by the WDNR as being “sufficient to meet existing demand for access as specified in Wisconsin Administrative Code NR 1.91(4)(b).” The access location, a significant portion (>50%) of the Forest Lake shoreline, and most of Forest Lake’s watershed is within the Kettle Moraine State Forest, an area heavily visited by tourists. The Ice Age Trail runs along the southern end of the lake and the Mauthe Lake Campground abuts the lake, both inviting visitors to the lake (Figure 1.0-1).

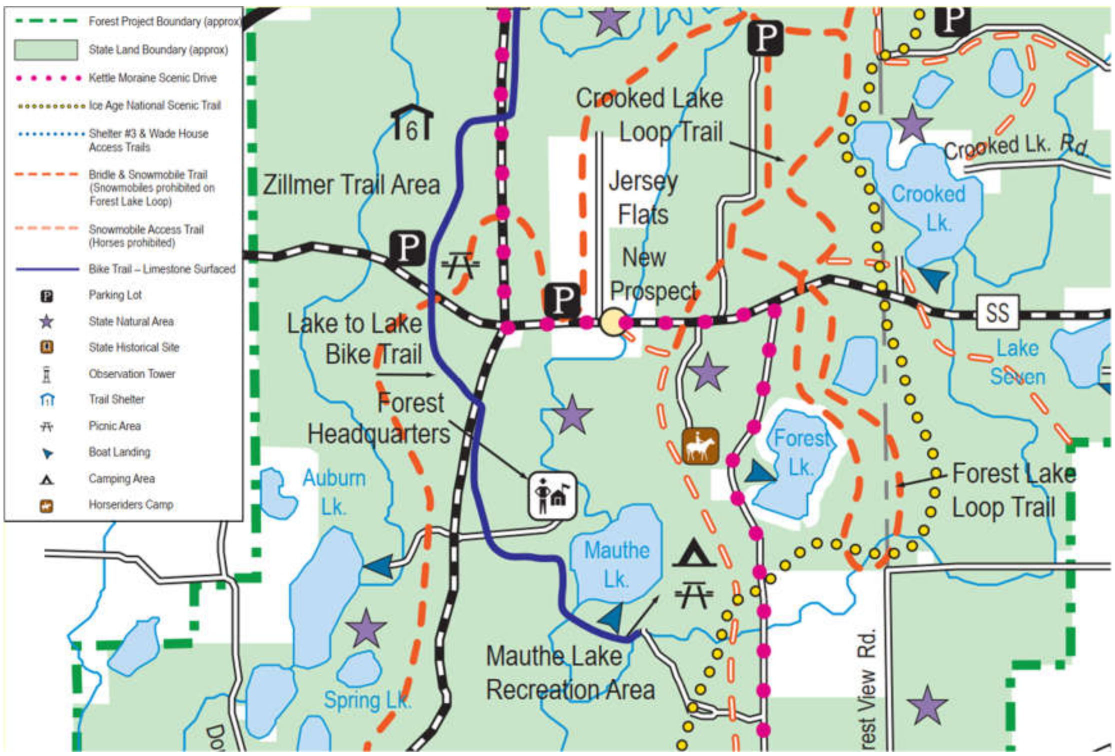


Figure 1.0-1. Kettle Moraine State Forest Northern Unit Trails and Public Use Near Forest Lake. Extracted from https://dnr.wi.gov/topic/parks/name/kmn/PDFs/kmnmap.pdf..

Forest Lake is classified as an Area of Special Natural Resource Interest (ASNRI) by the WDNR. Many Natural Heritage Inventory (NHI) listed species of fish, frogs, salamanders, dragonflies, and plants are known from this area including the state-threatened Blanding’s turtle.

The Forest Lake Improvement Association (FLIA) was established to maintain the lake as a valuable recreational and quality of life resource and to create opportunities to socialize and meet with other property owners to nurture a unified voice on issues that affect the lake.

The FLIA has worked for years to protect and enhance the lake, including management planning efforts in 1993 (LPL-175) and 2004 (LPL-924-04) and the completion of a 3-year study aimed at the understanding the efficacy of whole-lake 2,4-D treatments to control HWM. This project was completed in 2014, funded with an AIS-Early Detection & Response Grant (AIR-097-11). The project results outlined in this report were funded by the first AIS-EPP Grant (AEPP-503-17) for Forest Lake and the FLIA.

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 project updates.

Planning Committee Meeting I

On February 21, 2019, Eddie Heath of Onterra met with eleven members of the Forest Lake Planning Committee for nearly 4 hours. Approximately a week prior to the meeting, attendees were provided an early draft of the study report sections (Section 3.0) 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 aquatic plant inventories, shoreland health, water quality analysis, and watershed modeling were presented and discussed. Many concerns were raised by the committee, but the primary concern was the nuisance conditions caused by the invasive watermilfoil population. Additional discussion regarding past control actions was also a large component of the meeting. The presentation materials from this meeting are included in Appendix A.

Planning Committee Meeting II

On March 21, 2019, Eddie Heath of Onterra met with eleven members of the FLIA Planning Committee for three hours. The meeting opened up with discussion of available fisheries data (mainly stocking data) and then transitioned into discussion of the FLIA's management challenges. The challenges were then discussed within the framework of developing a management goal and associated management actions that can be taken to reach the goal. This meeting included a robust alternatives analysis of invasive watermilfoil management techniques. The presentation materials from this meeting are included in Appendix A.

Planning Committee Consultation Meeting with WDNR

On November 11, 2019, a meeting was held between the FILA (Alan Grzywacz, Rosalind Rouse [phone]), Onterra (Eddie Heath), and WDNR (Mary Gansberg). This meeting focused on the Implementation Plan Section, allowing a multi-directional exchange of information and perspectives.

Management Plan Review and Adoption Process

On May 28, 2019, a draft outline of the Implementation Plan was provided to the Planning Committee for review. Comments were received from the Planning Committee on August 17, 2019 and incorporated into a full-text version of the Implementation Plan Section. This section was provided to the Planning Committee on October 29, 2019 for further discussion. This version of the Implementation Plan Section, along with the Results and Discussion Section (3.0) was provided to the WDNR in advance of the Planning Committee Consultation Meeting with WDNR. Based upon feedback from the Planning Committee and WDNR, the updated Implementation Plan Section (5.0) was married with the report sections and other sections to create the Official First Draft.

On December 17, 2019, an official first draft of the FLIA's Comprehensive Management Plan for Forest Lake was supplied to the WDNR, Fond du Lac County, Town of Auburn, and FLIA's Planning Committee for review. Written review of the draft plan was received on December 27, 2019 from Mary Ganbserg (regional WDNR Lake Biologist). The WDNR comments and how they are addressed in the final plan are contained in Appendix G.

Stakeholder Survey

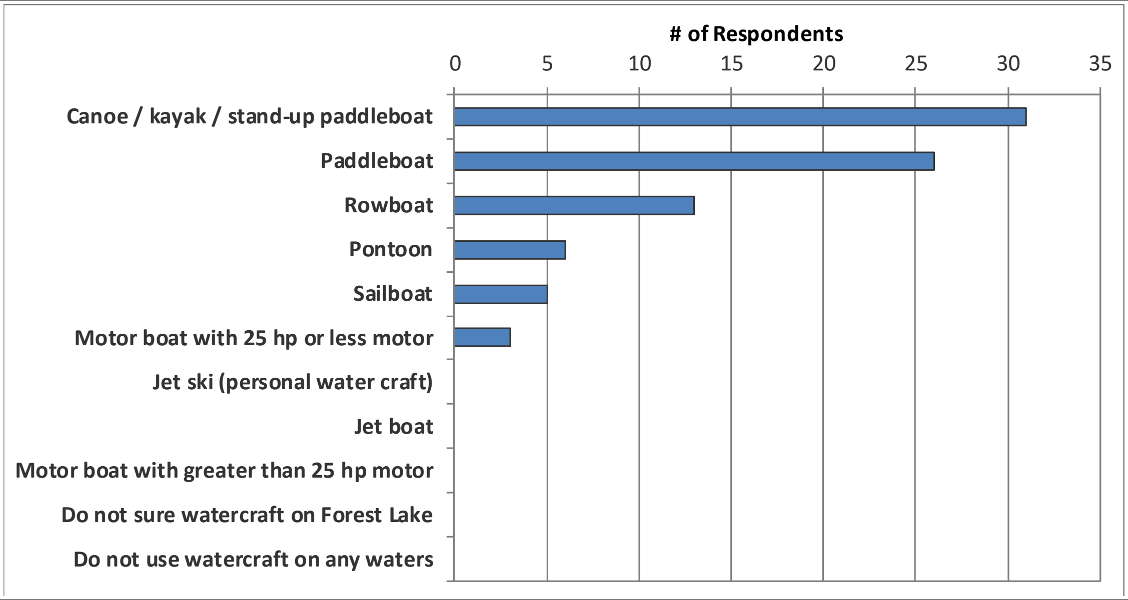
As a part of this project, a stakeholder survey was distributed to riparian property owners and Forest Lake Improvement Association members around Forest Lake. The survey was designed by Onterra staff and the Forest Lake Improvement Association (FLIA) planning committee and reviewed by a WDNR social scientist. During September 2018, the 10-page, 42-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a FLIA volunteer for analysis. Fifty-seven 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 Forest Lake. The majority of stakeholders (40%) live on the lake year-round, while 34% use their property as a seasonal vacation home, 20% are seasonal residents, and 6% use their property only in summer. 69% of stakeholders have owned their property for 15 years or less, and 31% 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 indicated that they use either a canoe or kayak, paddleboat, or a combination of these vessels on Forest Lake (Question 12). Forest Lake has a no gas motor ordinance.

A concern of stakeholders noted throughout the stakeholder survey (see Questions 27-28 and survey comments – Appendix B) was the abundance of aquatic plants, as well as the invasive Eurasian watermilfoil. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

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



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

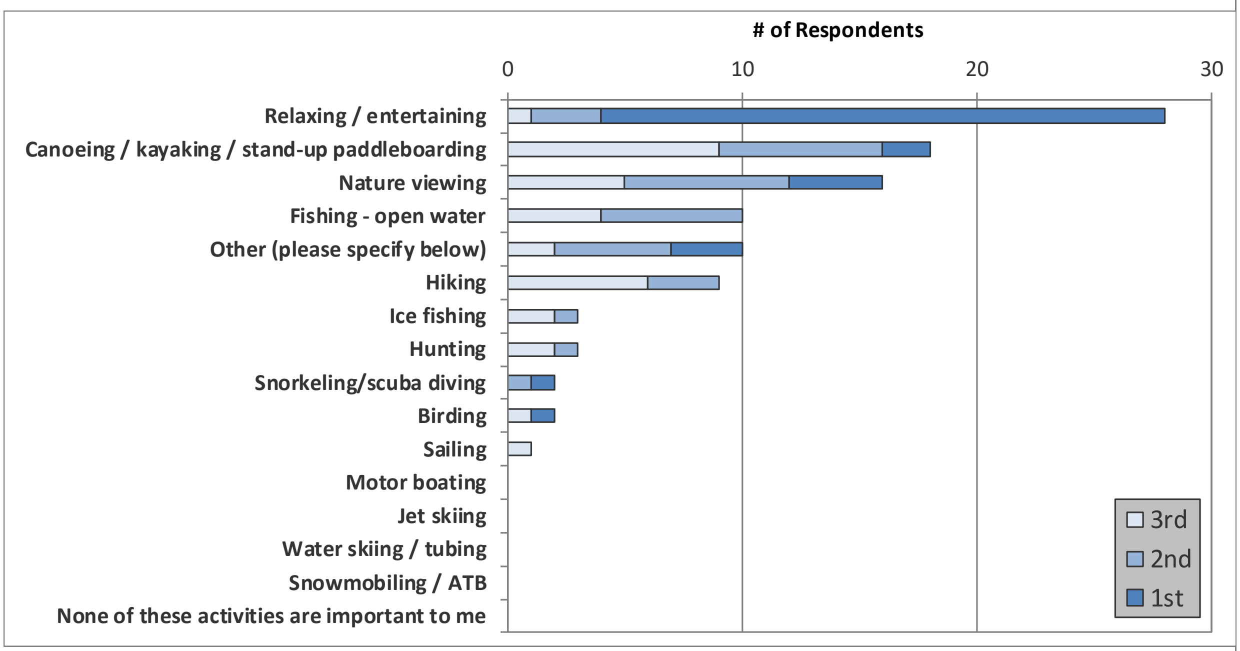
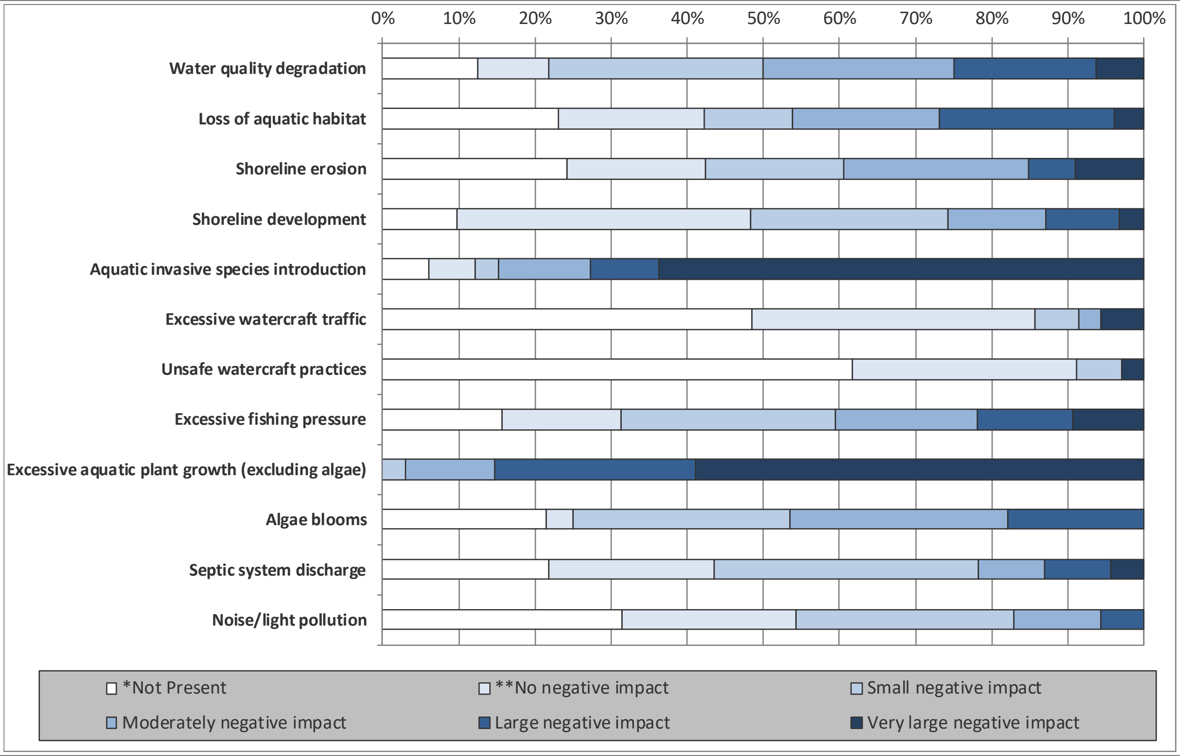


Figure 2.0-1. Select survey responses from the Forest Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 27: To what level do you believe these factors may be negatively impacting Forest Lake?



Question 28: Please rank your top three concerns regarding Forest Lake.

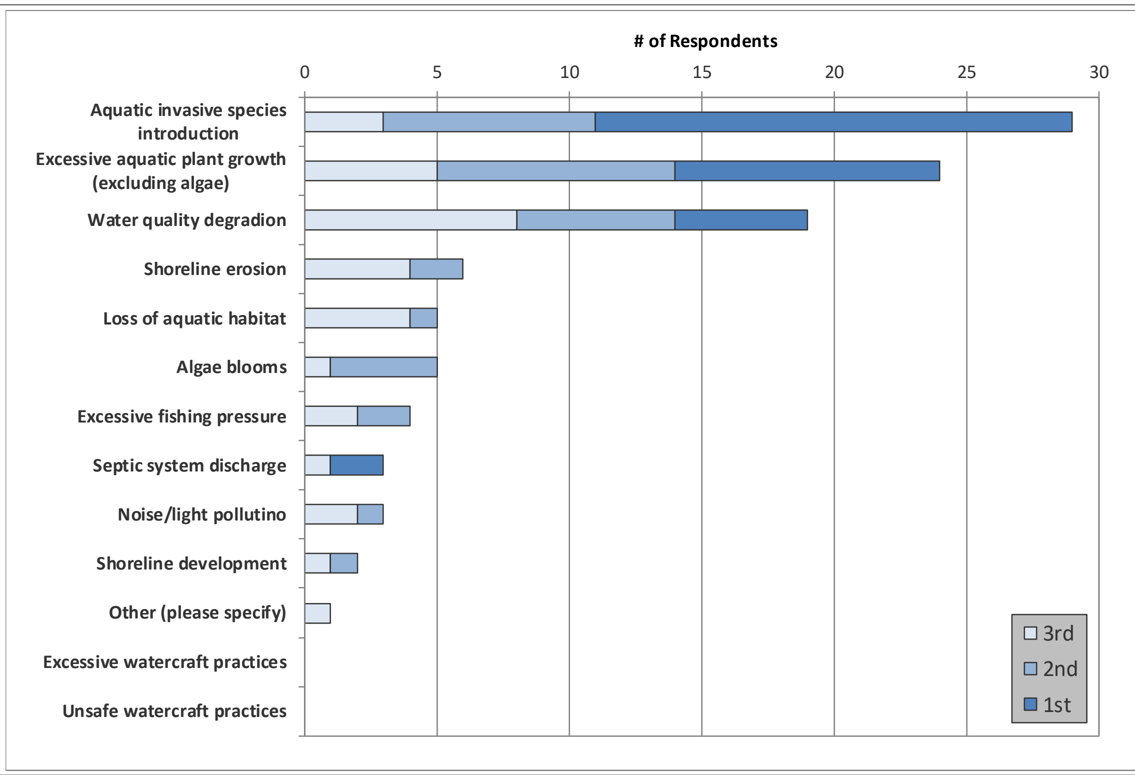


Figure 2.0-2. Select survey responses from the Forest Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

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

Many types of analyses are available for assessing the condition of a particular lake's water quality. In this document, the water quality analysis focuses upon attributes that are directly related to the productivity of the lake. In other words, the water quality that impacts and controls the fishery, plant production, and even the aesthetics of the lake are related here. Specific forms of water quality 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 Forest 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 Forest Lake's water quality analysis:

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

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

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

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fish kills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Forest 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 and hydrology, Forest Lake is classified as a deep seepage lake (category 7 on Figure 3.1-1).

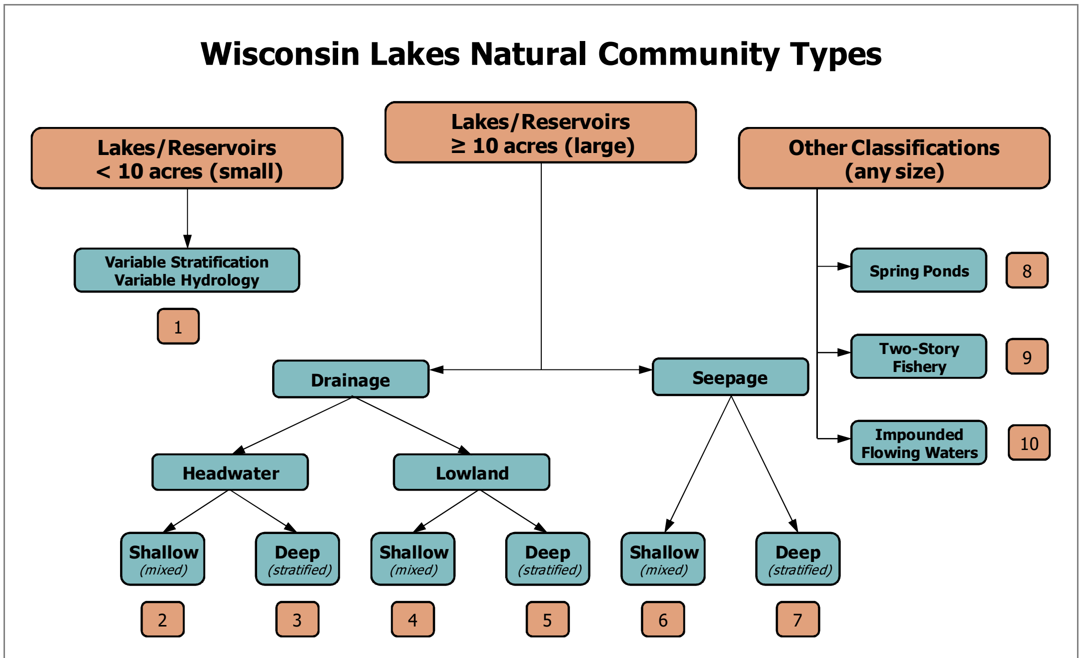


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Forest Lake is within the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

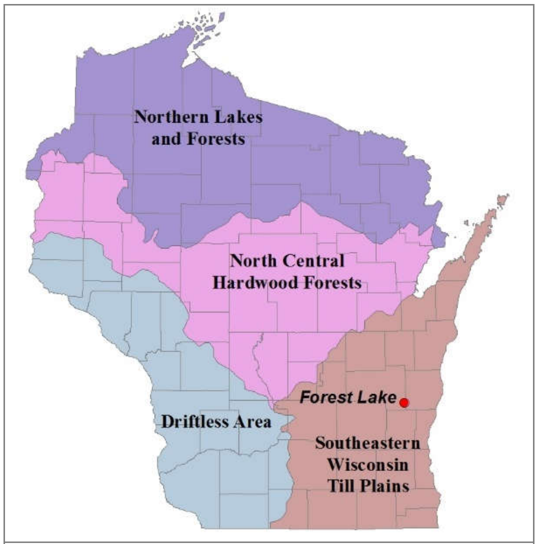


Figure 3.1-2. Location of Forest Lake within the ecoregions of Wisconsin. After Nichols 1999.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Forest Lake is displayed in Figures 3.1-3 - 3.1-11. 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 long-term 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.

Forest Lake Water Quality Analysis

Forest Lake Long-term Trends

Near surface total phosphorus data from Forest Lake are available from 1994-1996, 2004-2005, and 2017 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 11 µg/L in 1996 to 18 in 2004. The weighted summer average total phosphorus concentration was 15 µg/L but concentrations have increased in the last 14 years. The mean of 15 µg/L places the lake in the *good* category for Wisconsin's deep seepage lakes. Forest Lake's phosphorus concentrations are similar to the majority of other deep seepage lakes in the state and are lower than the majority of all lake types within the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

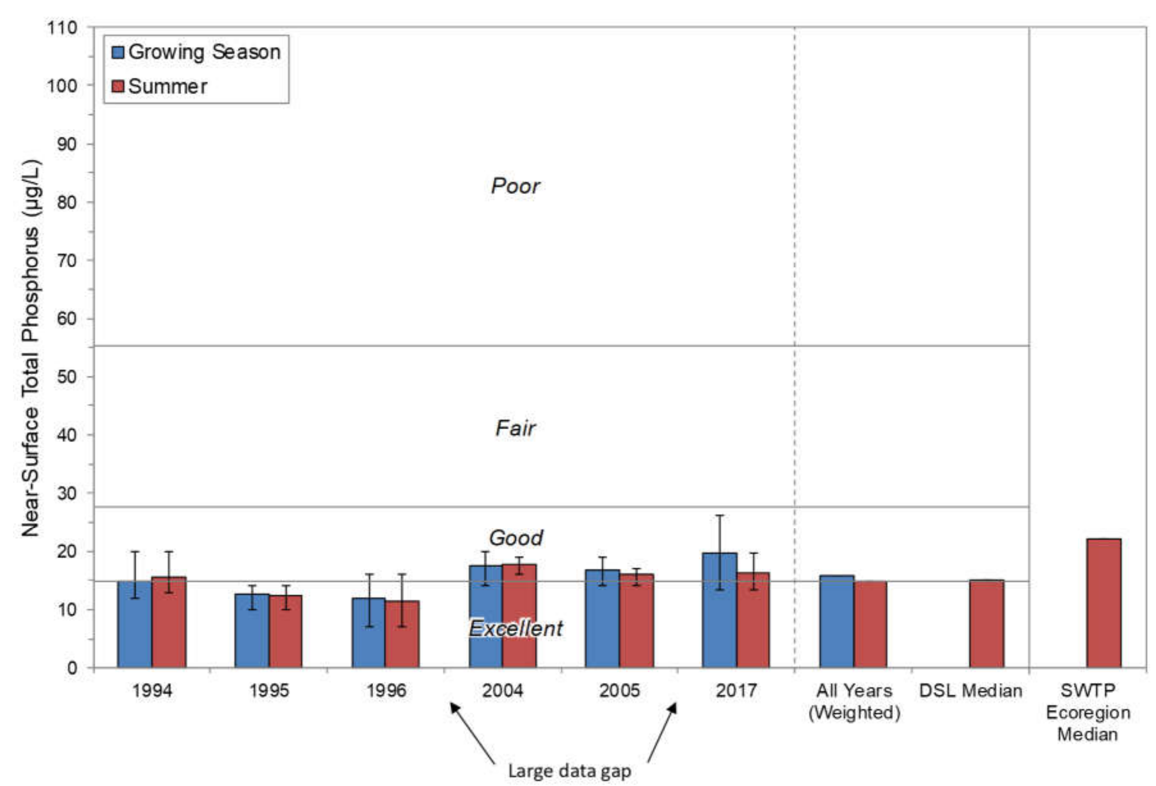


Figure 3.1-3. Forest Lake, state-wide deep seepage lakes, and regional (SWTP) total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-*a* concentration data are also available from Forest Lake from 1994-1996, 2004-2005, and 2017 (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 2 µg/L in 1995 to 4 µg/L in 2004. The weighted summer chlorophyll-*a* concentration was 3.0 µg/L and falls into the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's deep seepage lakes. As with phosphorus, chlorophyll-*a* concentrations have been higher in the last 13 years. Using the mean of these years (3.7 µg/L), places the lake on the border between good and excellent which is where the more recent phosphorus concentrations place the lake. The weighted summer average chlorophyll-*a* concentration falls below the median concentrations for deep seepage lakes in the state and all lake types in the Southeastern Wisconsin Till Plains (SWTP) ecoregion.

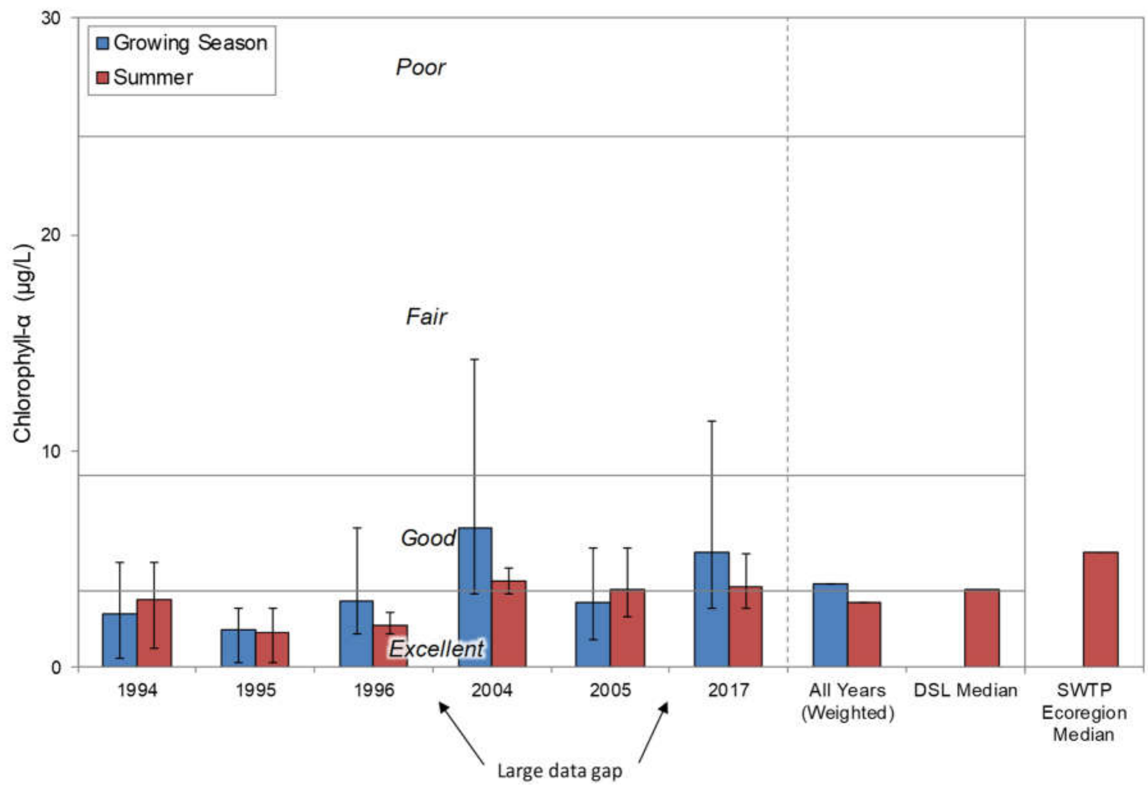


Figure 3.1-4. Forest Lake, state-wide deep seepage lakes, and regional (SWTP) chlorophyll-a concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Annual Secchi disk transparency data are available from Forest Lake from 1986-2003, 2009-2012, and 2017 (Figure 3.1-5). Average summer Secchi disk depths ranged from 9 feet in 2012 to 19 feet in 2000. The weighted summer average Secchi disk depth was 13.9 feet, which falls into the *excellent* category for Secchi disk depth in Wisconsin's deep seepage lakes. The weighted average summer Secchi disk depth exceeded the median values for deep seepage lakes in the state and all lake types within the Southeastern Wisconsin Till Plains (SWTP) ecoregion. Similar to phosphorus and chlorophyll-a concentrations, Secchi depths have declined in recent years compared with most of the years between 1990 and 2010. The Secchi depths in the last few years place the lake in the good category which is slightly worse than other deep seepage lakes but still much better than the median value for all lakes in the SWTP ecoregion.

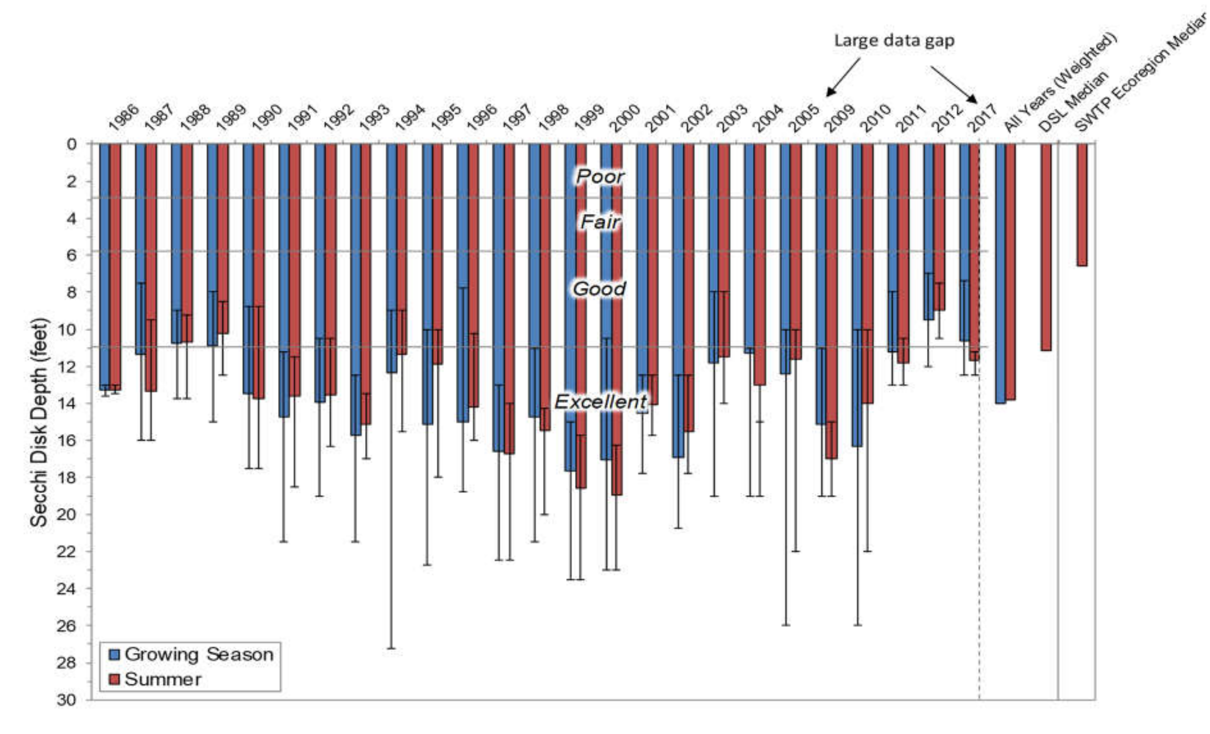


Figure 3.1-5. Forest Lake, state-wide deep seepage lakes, and regional (SWTP) Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed in the primer section, internal nutrient loading is a process by which phosphorus (and other nutrients) are released from sediments when bottom waters become devoid of oxygen (anoxic). Internal nutrient loading is more prevalent in deeper lakes which experience summer stratification or in shallow lakes that are highly productive where high rates of decomposition deplete oxygen near the sediment-water interface. To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake. In lakes which experience high levels of internal nutrient loading, the near bottom phosphorus concentrations are significantly higher than those measured near the surface.

Figure 3.1-6 displays near-surface and near-bottom total phosphorus concentrations collected from Forest Lake in 1994-96, 2004-05, and 2017. As illustrated, in some years the near-bottom total phosphorus concentration is much higher than the values measured near the surface. This indicates that phosphorus is being released from bottom sediments into the hypolimnion. In some years the near bottom concentrations are not significantly higher than surface levels. In those years the amount of internal loading would be much less. It is not clear why some years exhibit much higher bottom concentrations than others.

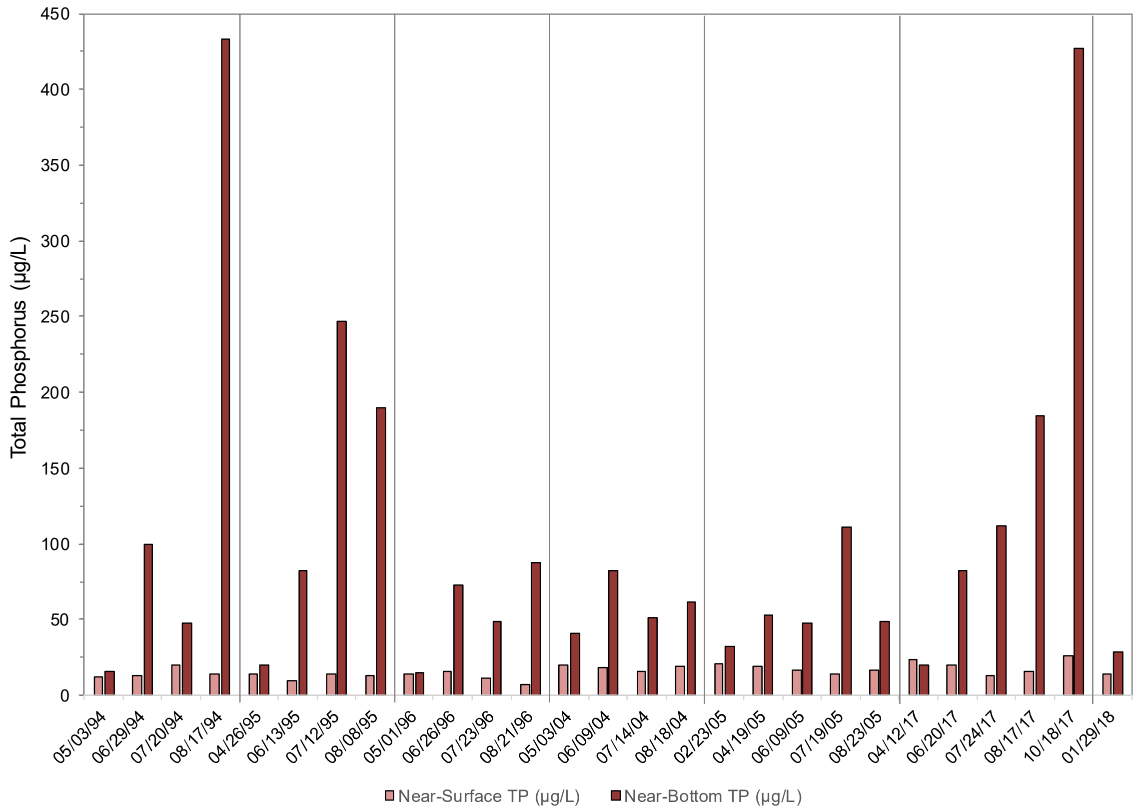


Figure 3.1-6. Forest Lake near-surface and near-bottom total phosphorus concentrations.

Limiting Plant Nutrient of Forest Lake

Using midsummer nitrogen and phosphorus concentrations from Forest Lake, a nitrogen:phosphorus ratio of 51:1 was calculated. This finding indicates that Forest 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.

Forest Lake Trophic State

Figure 3.1-7 contains the weighted average Trophic State Index (TSI) values for Forest 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 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 compounds in the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

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 factors other than phytoplankton. The TSI values for Secchi disk transparency, chlorophyll-*a*, and total phosphorus concentrations range from oligotrophic to mesotrophic; however, TSI values since 2004 have been primarily in the mesotrophic category (Figure 3.1-7). It appears Forest Lake was historically in an oligo-mesotrophic state, based on available historical data, but in more recent years the lake has moved into a mesotrophic state. Forest Lake has similar productivity as other deep seepage lakes in the state and is less productive than the majority of lakes in the Southeastern Wisconsin Till Plains (SWTP).

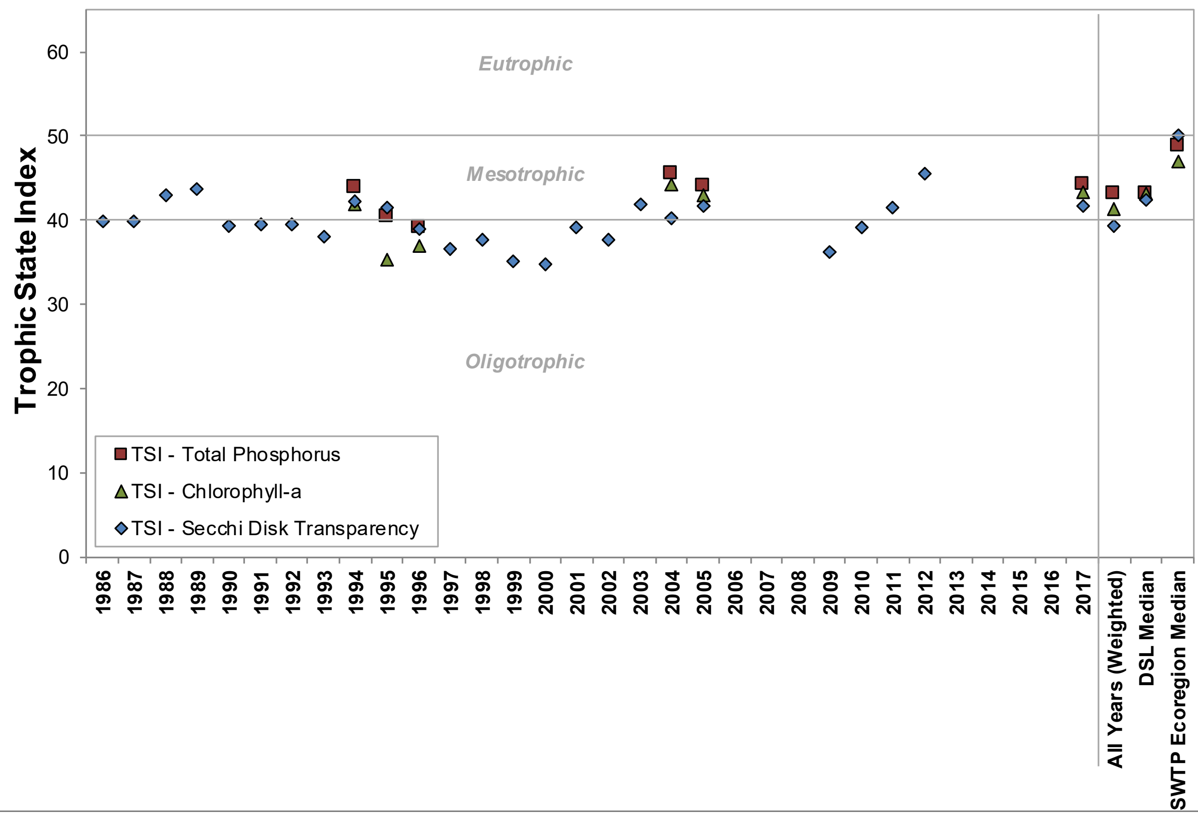


Figure 3.1-7. Forest Lake, state-wide deep seepage lakes, and regional (SWTP) Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Forest Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Forest Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-8. Forest Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, during the spring and fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Forest Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. The data also indicate that there was sufficient oxygen throughout the water column under the ice to support the fishery during late-winter sampling (Figure 3.1-8).

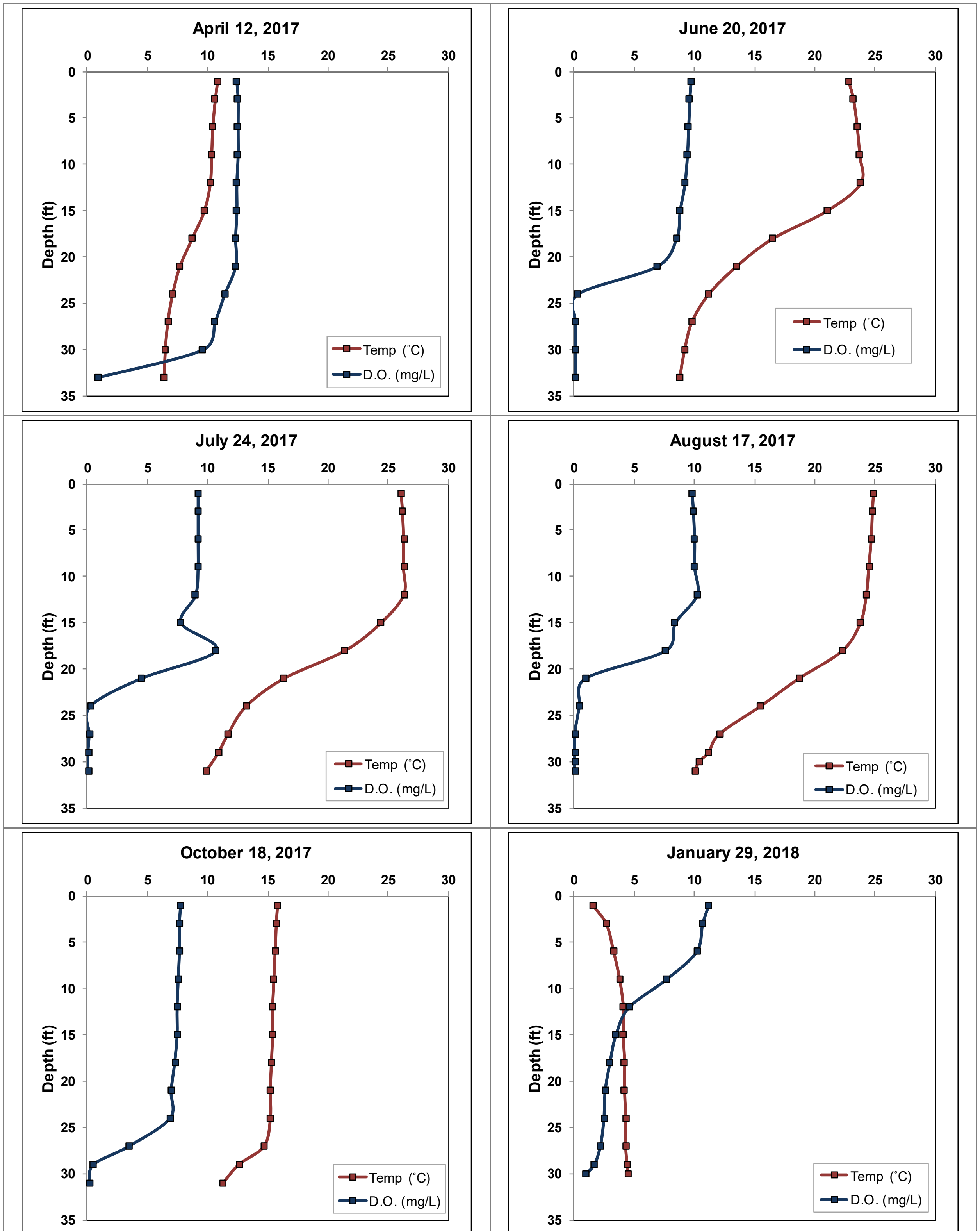


Figure 3.1-8. Forest Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Forest 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 Forest Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The mid-summer pH of the water in Forest Lake was found to be alkaline with a value of 8.7 and falls just outside the normal range for Wisconsin Lakes (Figure 3.1-9). Within the historic records pH values slightly above 9.0 have been recorded from Forest Lake, including during a study investigating the role of pH on milfoil weevil biocontrol survivability.

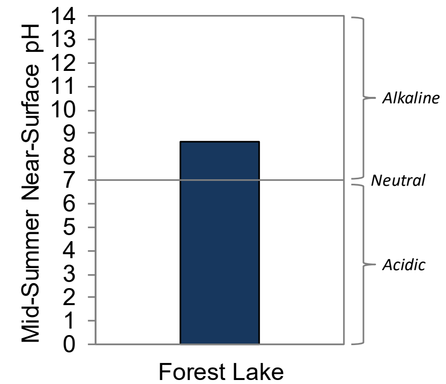


Figure 3.1-9. Forest Lake mid-summer near-surface pH value.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Forest Lake was measured at 110.0 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain (Figure 3.1-10).

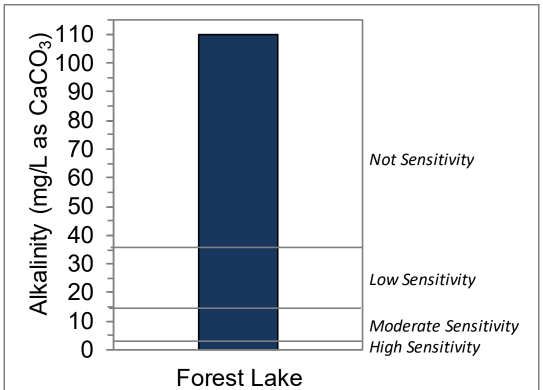


Figure 3.1-10. Forest Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Forest Lake's pH of 8.7 falls just 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 Forest Lake was found to be 23.3 mg/L, falling within the optimal range for zebra mussels (Figure 3.1-11).

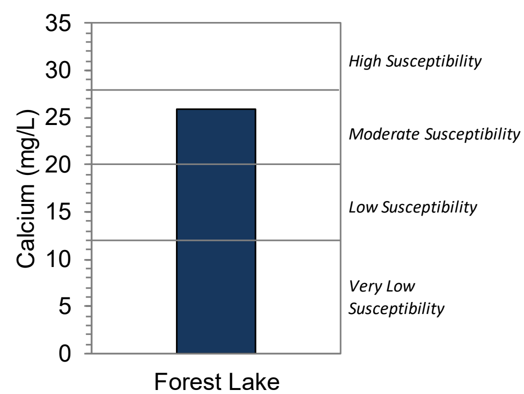


Figure 3.1-11. Forest Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

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

Researchers at the University of Wisconsin - Madison have developed an AIS suitability model called smart prevention (Vander Zanden and Olden 2008). In regards to zebra mussels, this model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu). Based upon this analysis, Forest Lake was considered borderline suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Forest Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys. Zebra mussels are present in nearby Mauthe Lake, Auburn Lake, Kettle Moraine Lake, and Long Lake.

Stakeholder Survey Responses to Forest Lake Water Quality

In 2018, a stakeholder survey was sent to 61 Forest Lake stakeholders. Approximately 57% or 35 surveys were completed. Given the response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative (above 60%) of the population sampled. The results may indicate possible trends and opinions about the stakeholder perceptions of Forest Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about the state of Forest Lake's current water quality, the majority of respondents (76%) described the current water quality as *fair* or *good*, 18% described it as *excellent*, and 6% described it as *poor* (Figure 3.1-12). When asked how water quality has changed in Forest Lake since they first visited the lake, approximately 47% of respondents indicated water quality has *somewhat degraded*, 29% indicated it has *remained the same,* 15% indicated it has *somewhat improved*, 4% indicated it has *greatly improved*, 6% indicated it as *unsure*, and 3% were *severely degraded* (Figure 3.1-12).

As is discussed in the previous sections, total phosphorus, chlorophyll-*a*, and Secchi disk transparency in Forest Lake fall within the *good, excellent and excellent* categories, respectively, for shallow lowland drainage lakes in Wisconsin. While 29% of respondents indicated that the water quality in Forest Lake has not changed since they first visited the lake, approximately 15% indicated water quality has improved while another 50% indicated water quality as degraded. In the previous sections, trends analysis showed that water quality in Forest Lake in terms of water clarity have declined in recent years compared with most of the data between 1990 and 2010.

17. How would you describe the current water quality of Forest Lake?

18. How as the water quality changed in Forest Lake since you first visited the lake?

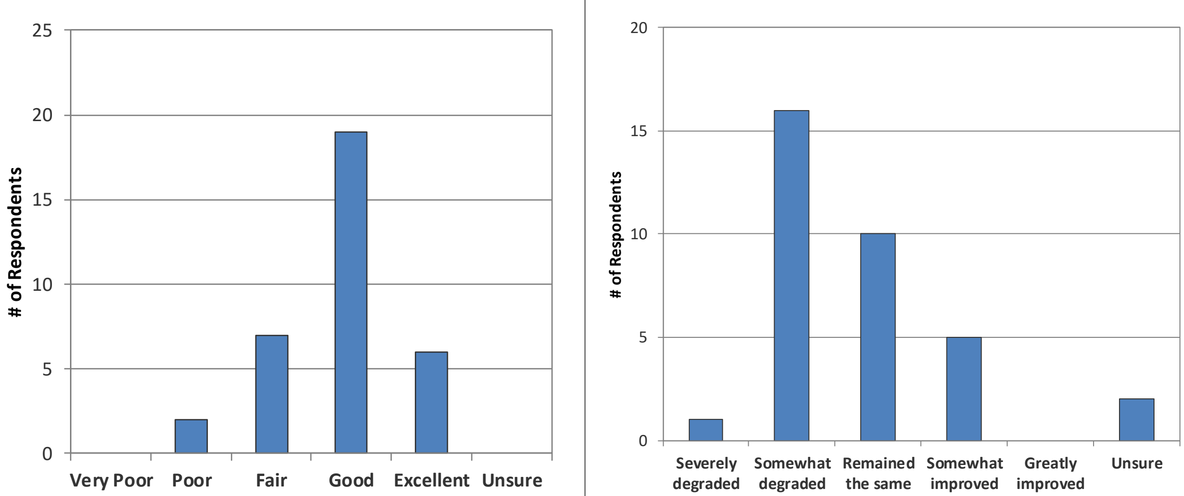


Figure 3.1-12. Forest Lake stakeholder survey responses to questions regarding perceptions of lake water quality.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Forest Lake Watershed Assessment

Forest Lake's watershed encompasses an area of approximately 143 acres, yielding a small watershed to lake area ratio of approximately 2:1 (Map 2). In other words, approximately two acres of land drain to every one acre of Forest Lake. Approximately 40% of Forest Lake's watershed is composed of forest, 38% of the lake's surface, 13% of wetlands, 5% of pasture/grass, and 4% of rural residential areas (Figure 3.2-1, left frame). Forest Lake is estimated to have a water flushing rate of 0.12 times per year which means that water remains in the lake about 8 years before it leaves the lake.

Utilizing the land cover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Forest Lake's watershed. What is listed as rural residential are homes near the shoreline while pasture/grass are other lawns. Studies conducted in Wisconsin have found that phosphorus runoff from these landuses can be higher along lakeshores. This is especially true in Forest Lake as the land around the lake is relatively steep. A runoff coefficient of 0.45 lbs /ac/year was used for shoreland homes and a coefficient of 0.27 lbs/ac/year was used for the remaining lawns.

It was estimated that approximately 37 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.2-1). Phosphorus loading from septic systems was also estimated using data obtained from the 2017 stakeholder survey of riparian property owners. Of the estimated 37 pounds being delivered to Forest Lake, 38% is estimated to originate from direct atmospheric deposition into the lake, 33% from septic systems, 12% from forest, 12% from homes and lawns around the lake and 5% from wetlands.

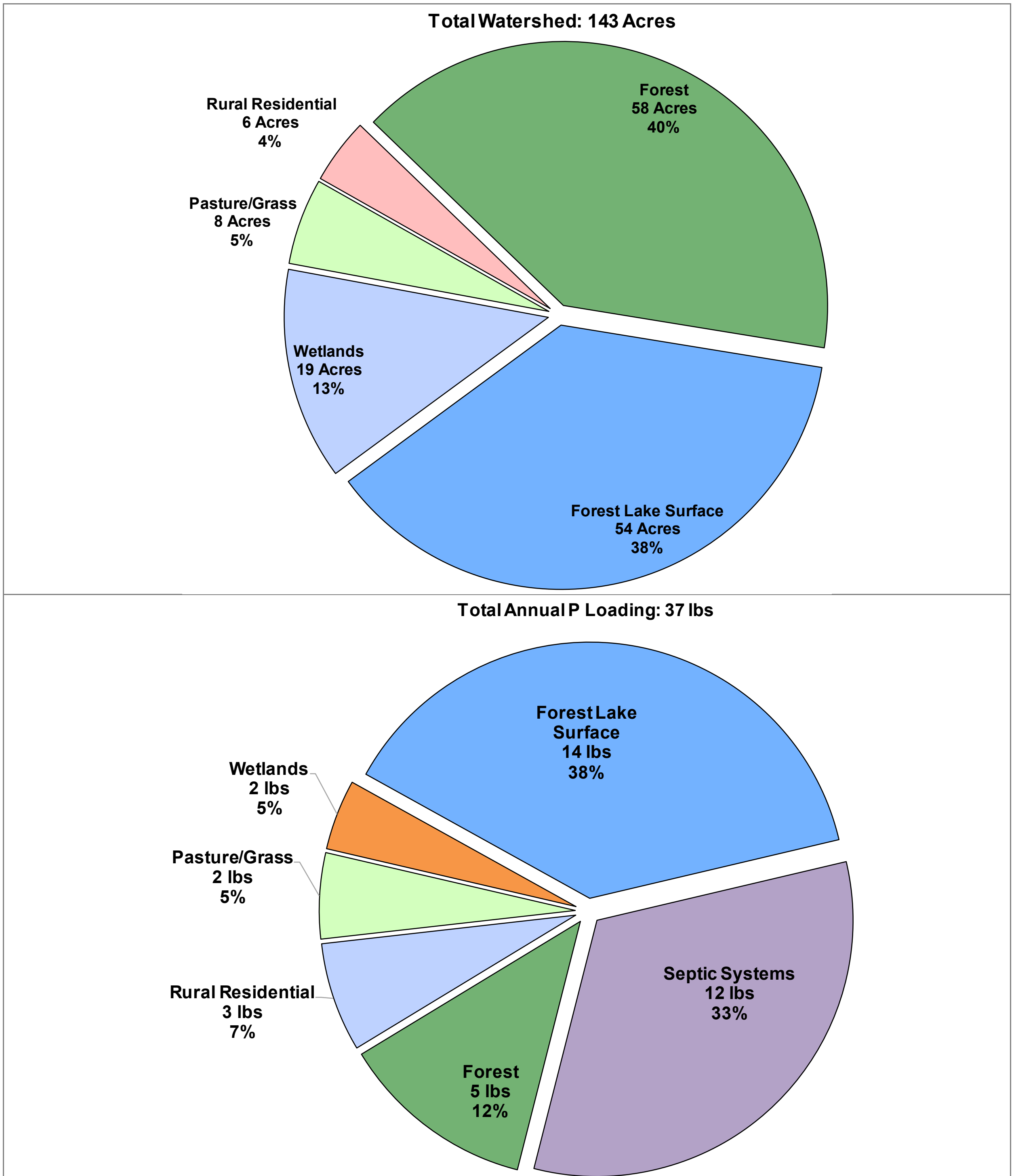


Figure 3.2-1. Forest Lake watershed land cover types in acres (top) and external phosphorus loading in pounds (bottom). Based upon National Land Cover Database (NLCD – Fry et. al 2011) and Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using predictive equations, WiLMS estimates Forest Lake should have a growing season mean total phosphorus concentration of approximately 14 µg/L to 28 µg/L. The lower phosphorus concentration estimate is likely more realistic due to the lake's calcium-rich water, and is much closer to the measured growing season mean total phosphorus concentration in recent years of 18 µg/L. The high amount of calcium in the water combines with phosphorus and coprecipitates to the lake bottom. This mechanism reduces phosphorus levels in the water. Since the predicted phosphorus concentration is similar to the measured value it is likely that there is not significant internal phosphorus loading occurring. Even though phosphorus concentration were elevated in the lake's deepest waters, this represents as small water volume and thus the load is insignificant.

A nutrient budget created for Forest Lake in 2007 used the Source Loading and Management Model (SLAMM). SLAMM predicted an annual phosphorus load of 35.3 lbs per year, with septic systems contributing 11.5 lbs or 32.6% of the total. Both WiLMS and SLAMM predict septic systems contributing approximately one third of the annual phosphorus budget to Forest Lake. It is important to note that 11-12 lbs of phosphorus from septic systems is a low amount. Because the overall annual load to Forest Lake is also very small (35.3-SLAAM, 37 WilMS), the percent input of septic system seems large. For reference, the annual phosphorus load to nearby Kettle Moraine Lake is 111 lbs, and Long Lake's annual load is 4,416 lbs. Septic system modeling can also be problematic, as it assumes that the groundwater flow is always toward the lake. When in fact, some of the septic systems may actually drain away from the lake. A more detailed and thorough study would be needed to fully understand the Forest Lake watershed.

3.3 Shoreland Condition

Lake Shoreland Zone and its Importance

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

- Vegetation Removal: For the first 35 feet of property (shoreland zone), no vegetation removal is permitted except for: sound forestry practices on larger pieces of land, access and viewing corridors (may not exceed 35 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).
- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit.
- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if the same type of structure is being built in the previous location with the same footprint. All construction needs to follow general zoning or floodplain zoning authority
    - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet
- Mitigation requirements: Language in NR-115 specifies mitigation techniques that may be incorporated on a property to offset the impacts of impervious surface, replacement of nonconforming structure, or other development projects. Practices such as buffer restorations along the shoreland zone, rain gardens, removal of fire pits, and beaches all may be acceptable mitigation methods.

Wisconsin Act 31

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

Shoreland Research

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

A separate USGS study was conducted on the Lauderdale Lakes in southern Wisconsin, looking at nutrient runoff from different types of developed shorelands – regular fertilizer application lawns (fertilizer with phosphorus), non-phosphorus fertilizer application sites, and unfertilized sites (Garn 2002). One of the important findings stemming from this study was that the amount of dissolved phosphorus coming off of regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae. Therefore, these studies show us that it is a developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led to the 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. 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.

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

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

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

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

National Lakes Assessment

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

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

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

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

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

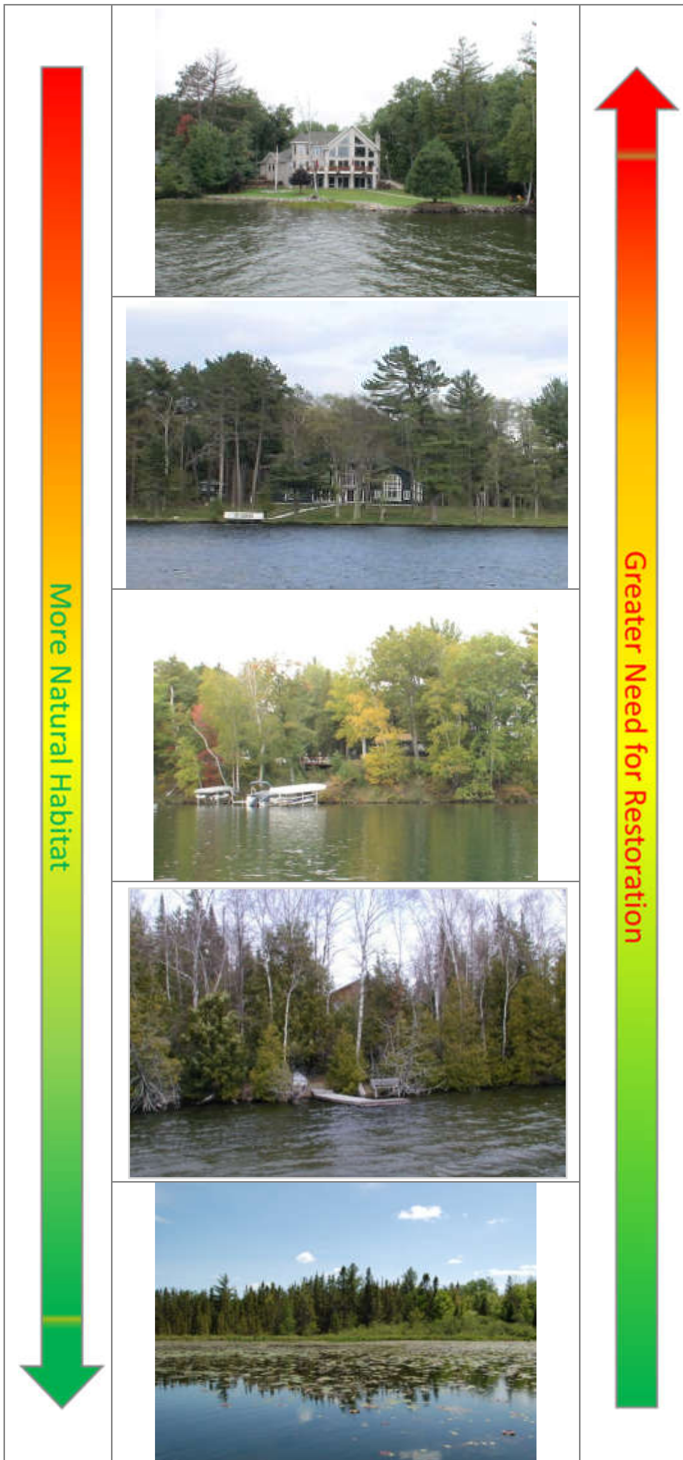
Wisconsin's Healthy Lakes & Rivers Action Plan

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

Forest Lake Shoreland Zone Condition

Shoreland Development

Forest 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 Forest Lake, the development stage of the entire shoreland was surveyed during fall of 2017, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

Forest Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.6 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.2-4). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.4 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Forest 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.

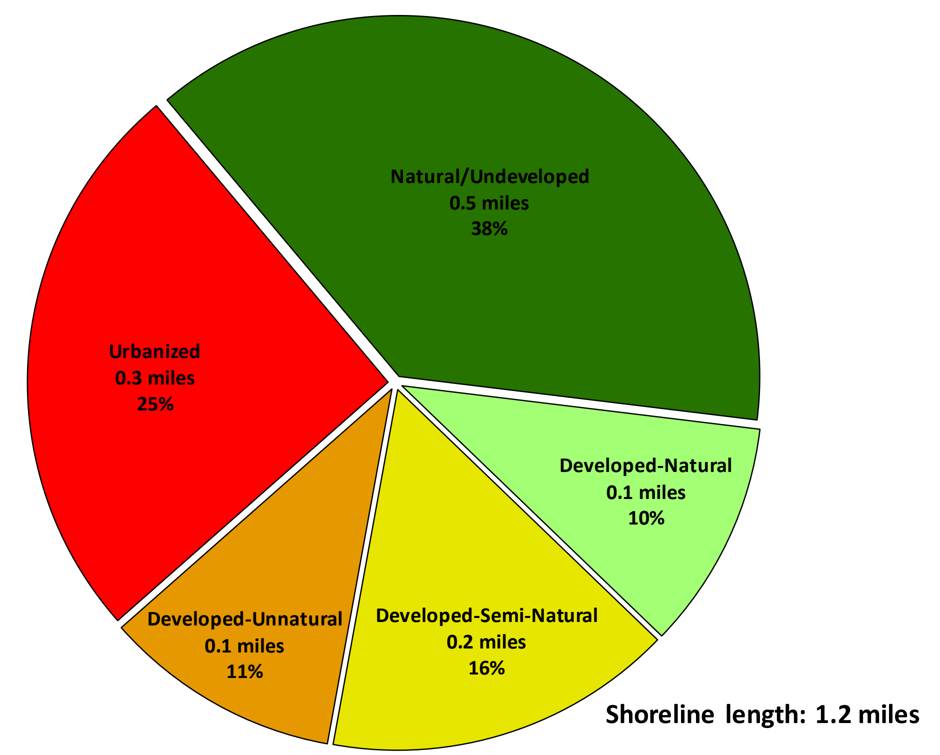


Figure 3.3-2. Forest Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Map 3.

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

The planning committee wanted to understand the stakeholders' reporting of the condition of their property. Figure 3.3-3 shows that over 50% of respondents believe that most or all of their shoreline has a vegetative buffer. When asked if the riparian used salt during the winter on their driveway, 84% indicated no and 17% indicated yes (Appendix B, Question 21). Only one respondent indicated that lawn is treated with fertilizer (Appendix B, Question 23). The FLIA has invested a lot of time discussing the importance of shoreland health and minimizing additional nutrient inputs into Forest Lake.

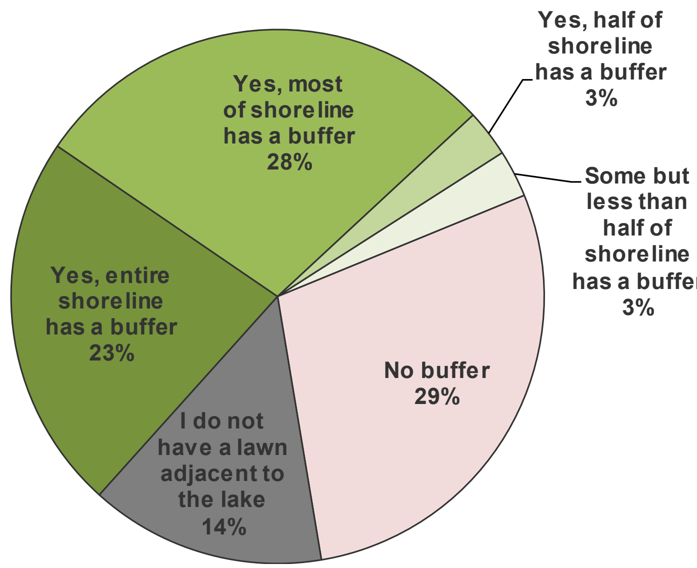


Figure 3.3-3. Stakeholder survey response Question #22. Is there a vegetative buffer (i.e. shrubs, trees, wetland plants, etc.) between your lawn and the lake?

Coarse Woody Habitat

As part of the shoreland condition assessment, Forest 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, or clusters 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, 51 total pieces of coarse woody habitat were observed along 1.4 miles of shoreline (Map 4), which gives Forest Lake a coarse woody habitat to shoreline mile ratio of 37:1 (Figure 3.3-4). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Thirty-seven pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, fourteen pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters 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 Forest 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 as of 2017, with the majority occurring in the Northern Lakes and Forests ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Forest Lake falls at the approximate 73rd percentile of these 98 lakes (Figure 3.3-4).

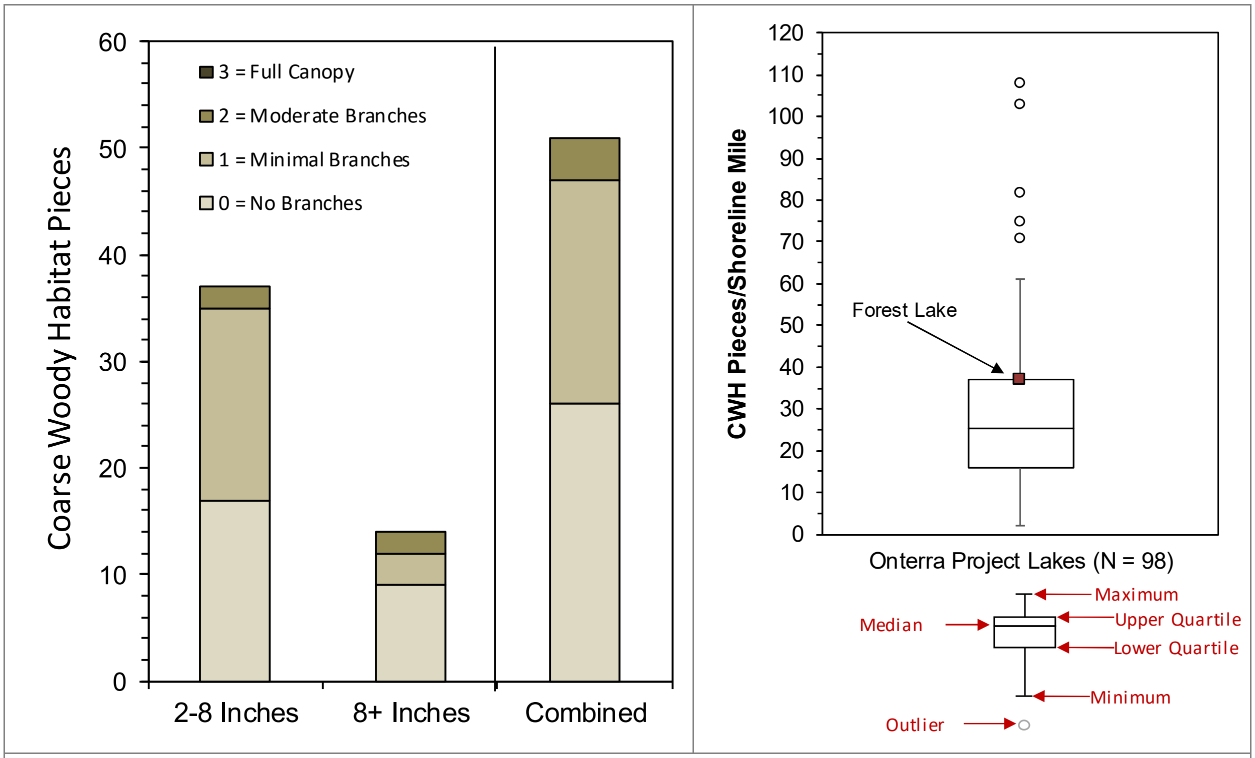


Figure 3.3-4. Forest Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Forest Lake coarse woody habitat can be found on Map 4.

3.0 RESULTS & DISCUSSION

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

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

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

Permits

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

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

Manual Removal (Hand-Harvesting & DASH)

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.

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

Cost
Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

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

Bottom Screens

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

Cost

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

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

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. Table 3.4-1 provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from Netherland (2009).

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

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

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

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

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

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

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

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

Cost

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

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

Biological Controls

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

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

Cost

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

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian 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 emergent or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Forest 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 Forest Lake. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Forest 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 Forest 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. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan et al. 2018). 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 Forest Lake is compared to data collected by Onterra and the WDNR Science Services on 77 lakes withn the Southeast Wisconsin Till Plain 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 Forest Lake were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Exotic Plants

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

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-1). 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. In some situations, Eurasian watermilfoil integrates itself into the native plant community without causing wide-scale ecological impacts nor impacts to human uses of the lake.

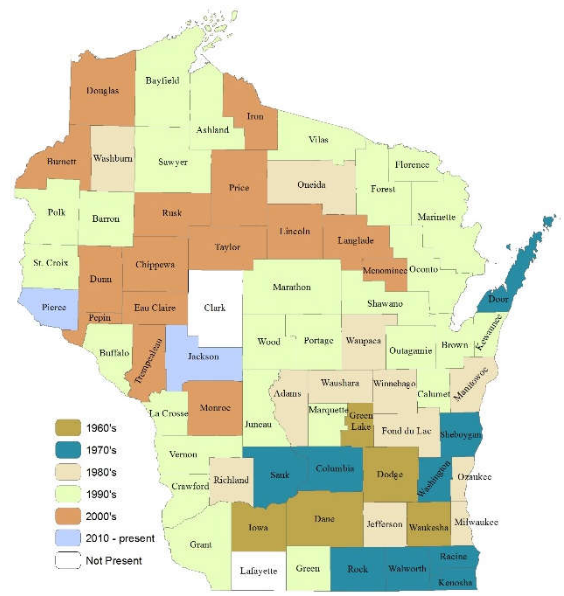


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

During the aquatic plant surveys completed on Forest Lake in 2018, a total of 21 species of plants were located, two of which are considered non-native, invasive species: Eurasian watermilfoil (EWM) and purple loosestrife (Table 3.4-2). The populations of these non-native plants in Forest Lake are discussed in detail in the subsequent Non-Native Aquatic Plants Subsection.

Table 3.4-2. Aquatic plant species located on Forest Lake during 2018 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2018 (Onterra)
Emergent	*Iris versicolor*	Northern blue flag	5	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Schoenoplectus pungens	Three-square rush	5	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Typha spp.	Cattail spp.	1	I
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X
	Najas guadalupensis	Southern naiad	7	X
	Nitella spp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Stuckenia pectinata	Sago pondweed	3	X
	Vallisneria americana	Wild celery	6	X

FL = Floating Leaf
X = Located on rake during point-intercept survey; I = Incidental Species

The sediment within littoral areas of Forest Lake is very conducive for supporting lush aquatic plant growth. Acoustic data collected in August 2018 regarding substrate hardness is displayed on Figure 3.4-2. Substrate hardness is highest within the shallowest areas of Forest Lake whereas the majority of the lake is of softer sediments. 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. Data from the point-intercept survey indicate that approximately 79% of the sampling locations located under approximately 15 feet (the length of the survey rake pole) and within the littoral zone, contained soft sediments (muck), 19% contained sand, and 2% contained rock (Figure 3.4-2).

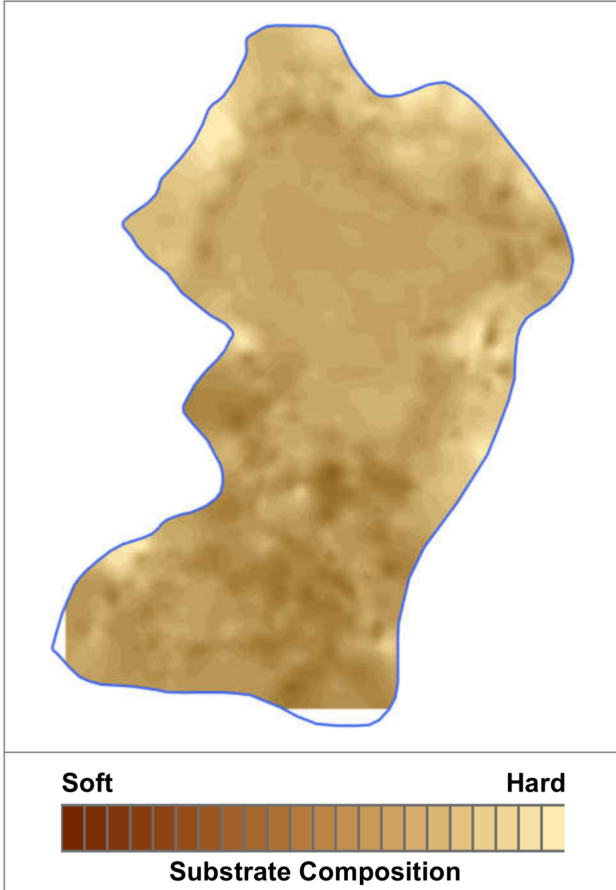


Figure 3.4-2. Forest Lake substrate hardness. Created using data from August 2018 acoustic survey.

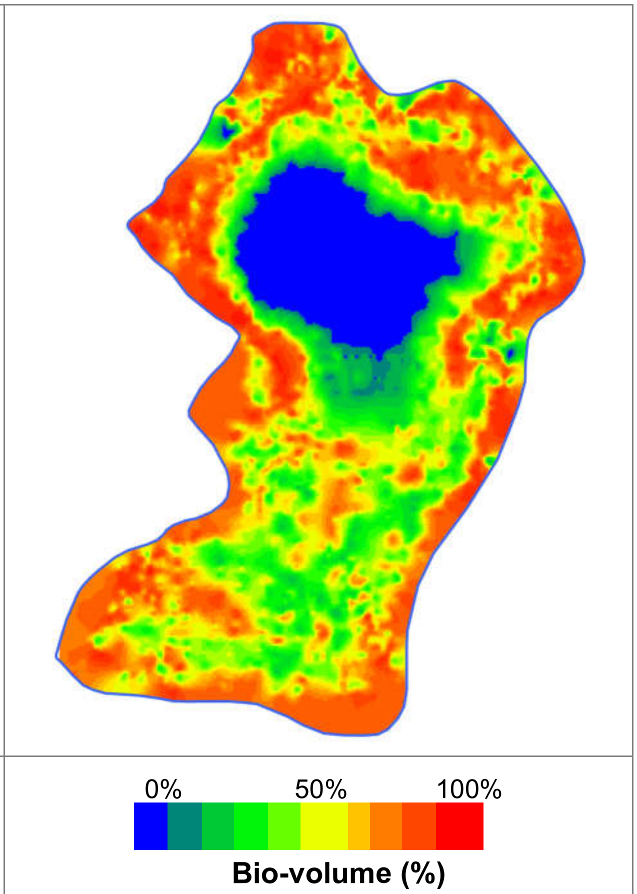


Figure 3.4-3. Forest Lake aquatic plant biovolume. Created using data from August 2018 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. Aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2018 aquatic plant bio-volume data are displayed in Figure 3.4-3. 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 2018 bio-volume data indicate many areas of the lake have a high bio-volume percentage as reflected by the red colors on Figure 3.4-3. Many of the high bio-volume areas on Forest Lake correspond with the HWM population.

The acoustic bio-volume data indicates that the majority of Forest Lake's surface area is littoral with the exception of the deeper waters in the northern end of the lake (Figure 3.4-3). Forest Lake's littoral zone is almost entirely vegetated, with approximately 92% of the point- intercept sampling locations that fell within the maximum depth of aquatic plant growth (25 feet) containing aquatic vegetation. Figure 3.4-4 displays the number of point-intercept sampling points that had either native vegetation, native vegetation and Eurasian watermilfoil, or just Eurasian watermilfoil. With the exception of 2016, the average number of sampling points with native plants has been approximately between 135-160 points. Native plants were sampled on just 80 sampling sites in 2016 following a large-scale herbicide treatment. The number of sampling points with HWM reached a high of 85 in 2015 and was reduced to 29 following treatment. Sampling sites with HWM has increased to 51 in the 2017 survey and 78 in the 2018 survey (Figure 3.4-4).

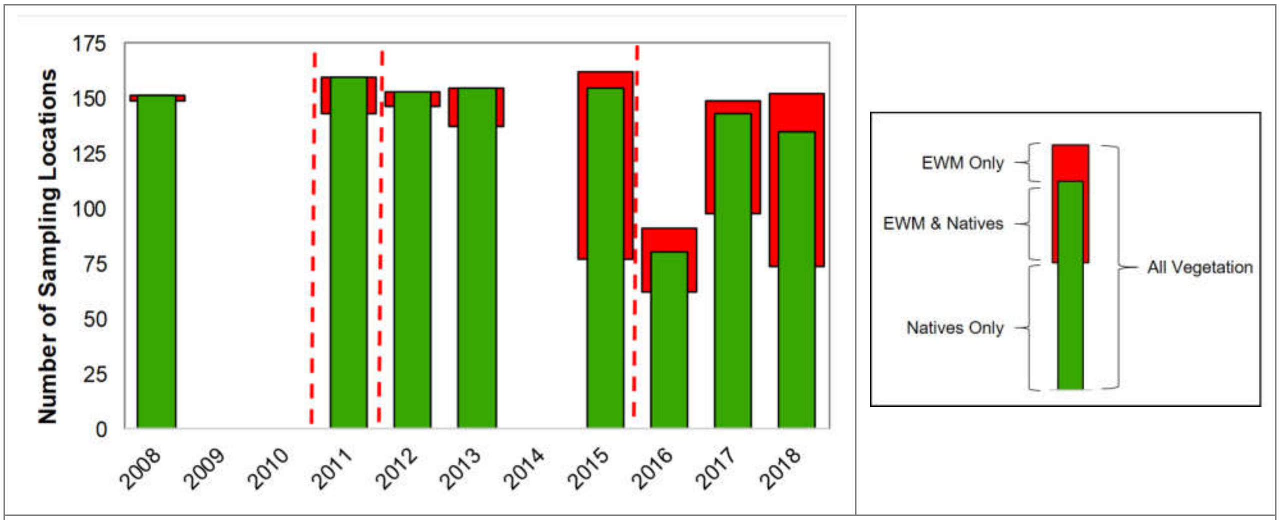


Figure 3.4-4. Number of point-intercept sampling locations that contained native plants, HWM, or native plants and HWM during surveys completed from 2008-2018 in Forest Lake. Created using data from 2008 - 2018 whole-lake point-intercept surveys. Red dashed lines represent whole-lake treatments, grey dashed line represents spot-treatment.

Of the 21 aquatic plant species that were located during aquatic plant surveys in 2018, 16 species were physically encountered on the rake during the point-intercept survey. Additional species that are observed during the survey but are not physically sampled on the survey rake are listed as *incidental* species. An incidentally-located species means the plant was not directly sampled on the rake during the point-intercept survey, but was observed in the lake by Onterra ecologists and was recorded/collected. The majority of incidentally-located plants typically include emergent species growing along the lake's margins and submersed species that are relatively rare within the lake's plant community. Of the 16 species encountered on the rake in 2018, hybrid water-milfoil was the most frequently encountered species. Hybrid watermilfoil was sampled on 78 of the 165 sampling points that were below the maximum depth of plant growth in the 2018 survey, which equates to a littoral frequency of occurrence of 47.3%. Slender naiad (37.6%), muskgrasses (17.6%) and Illinois pondweed (12.1%) were the three most frequently encountered native aquatic plant species (Figure 3.4-5).

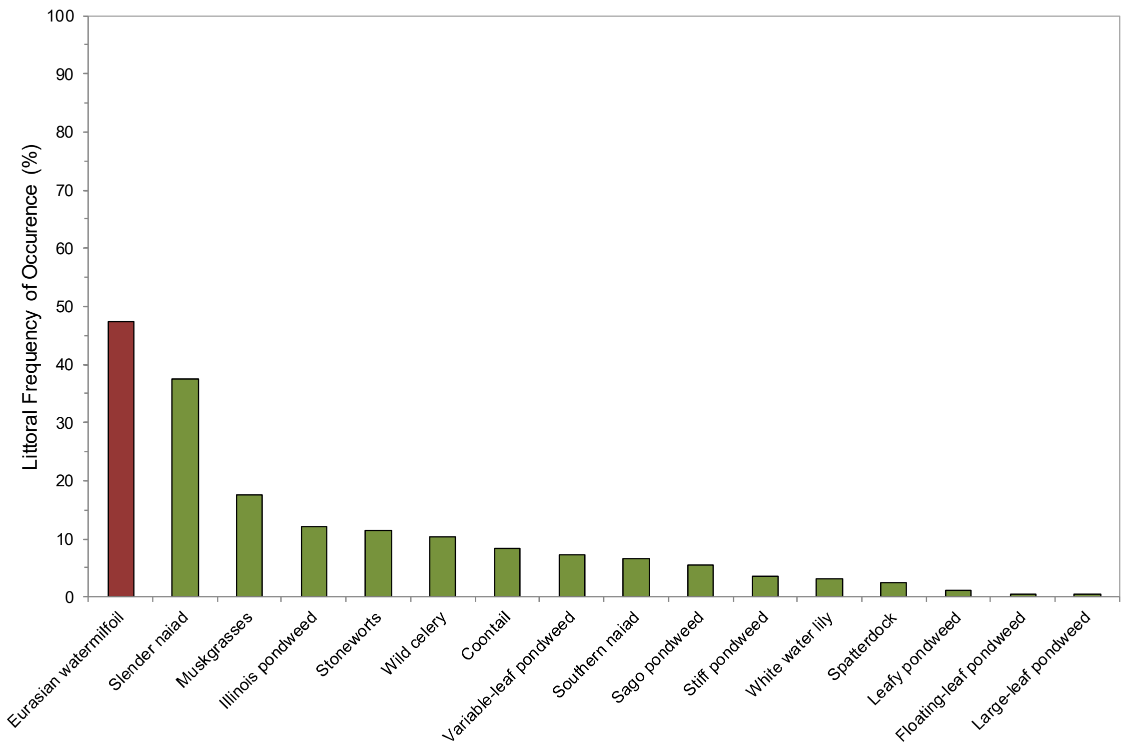


Figure 3.4-5. Forest Lake 2018 aquatic plant littoral frequency of occurrence. Exotic species indicated with red. Created using data from August 2018 whole-lake point-intercept survey.

Slender naiad 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. Southern naiad is similar to slender naiad, and they are often difficult to separate (Photograph 3.4-5). While southern naiad is native to North America, observations have been indicating that populations of this plant have been expanding and behaving invasively, particularly in northern Wisconsin lakes. It is not known if this behavior represents recent introductions of these plants to waterbodies where it was not found naturally, or if certain environmental conditions are favoring the expansion of southern naiad.

Past point-intercept surveys may not have reliably differentiated between the two naiad species, therefore the analysis on Figure 3.4-6 shows the pooled population of these species. A distinctive decline in the pooled naiad populations is evident following the 2016 herbicide treatment, however continued monitoring in 2017-2018 indicate that the population has recovered to a level that is not statistically different to pre-treatment levels (Figure 3.4-6). Slender naiad has been shown to be particularly susceptible to large-scale 2,4-D treatments during the year of treatment (Nault et al. 2018). Onterra's experience is that slender naiad populations often rebound as early as the year after treatment, sometimes exceeding pretreatment levels. Southern naiad is typically more resilient to large-scale 2,4-D treatments.

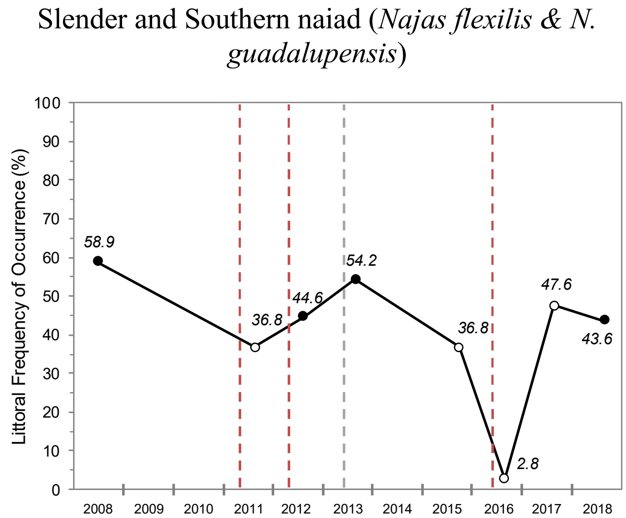


Figure 3.4-6. Littoral occurrence of naiad species in Forest Lake. Open circle indicates that occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red dashed line indicates large-scale treatment, grey dashed line represents spot-treatment.

Photograph 3.4-5. Slender naiad (Najas flexilis; left) and southern naiad (N. guadalupensis; right). Photo credit Onterra.

Photograph 3.4-6. Aquatic macroalgae muskgrasses (*Chara* spp.). Photo credit Onterra.

In 2018, muskgrasses were the second-most encountered native aquatic plant with a littoral frequency of occurrence of 17.6% (Figure 3.4-5). Muskgrasses are a genus of macroalgae represented by seven species in Wisconsin (Photograph 3.4-6). Muskgrasses are typically common in hardwater lakes like Forest Lake. 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).

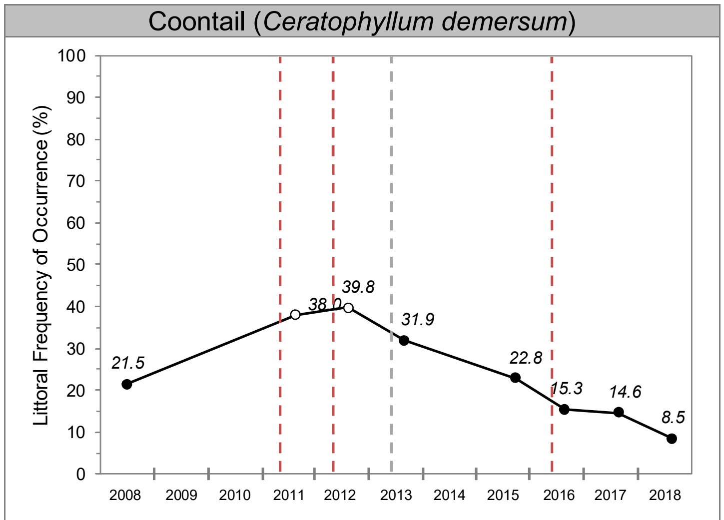


Figure 3.4-7. Littoral frequency of occurrence of coontail in Forest Lake from 2008-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Created using data from 2007-2018 whole-lake point-intercept surveys. Red dashed line represents whole-lake herbicide treatments. Grey dashed line represents spot-treatments.

Coontail, arguably the most common aquatic plant in Wisconsin, has historically been one of the most common species in Forest Lake. The population of coontail in Forest Lake has been trending downward since 2012 when the littoral frequency of occurrence was 39.8%. In 2018, the littoral frequency of occurrence of coontail was 8.5% (Figure 3.4-7). Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross et al. 2013). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with higher nutrients and lower water clarity. Coontail provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and helps maintain Forest Lake's clear-water state.

The quality of Forest Lake's plant community is also demonstrated by the emergent and floating-leaf plant communities that occur around the lake. The 2018 community map indicates that approximately 5.6 acres (10.4%) of the 54 acre-lake contain these types of plant communities (Table 3.4-3 and Map 5). The floating-leaf plant community on the lake is dominated by white water lily and spatterdock (bullhead pond lily). The emergent plant communities in the lake are mostly around the lake's edges and include cattails, northern blue-flag iris, three-square rush, softstem bulrush and purple loosestrife (Map 5). The floating-leaf and emergent species located in Forest Lake provide 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.

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 Forest 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.

Table 3.4-3. Forest Lake acres of plant community types. Created from August 2018 community mapping survey.

Plant Community	Acres
Emergent	0.04
Floating-leaf	5.56
Mixed Emergent & Floating-leaf	0.0
Total	**5.60**

Aquatic plant point-intercept datasets from Forest Lake are available dating back to 2008, and the methodology and sampling locations were the same as the survey completed in 2018. These datasets can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or individual species abundance have occurred over the time period. Aquatic plant surveys that were completed prior to the 2008 survey in Forest Lake used a much different transect-based methodology and are not directly comparable to the point-intercept survey methods that have been since widely adopted for assessing aquatic plants in Wisconsin's lakes.

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. Figure 3.4-8 displays the number of native aquatic plant species that were present at each sampling site from the 2008-2018 point-intercept surveys. These data indicate that from 2008 to 2015 the average number of species per sampling site ranged between 2.22 and 2.89. From 2016-2018, the average number of native species per site has ranged from a low of 0.73 in 2016 to 1.79 in 2017 and 1.28 in 2018.

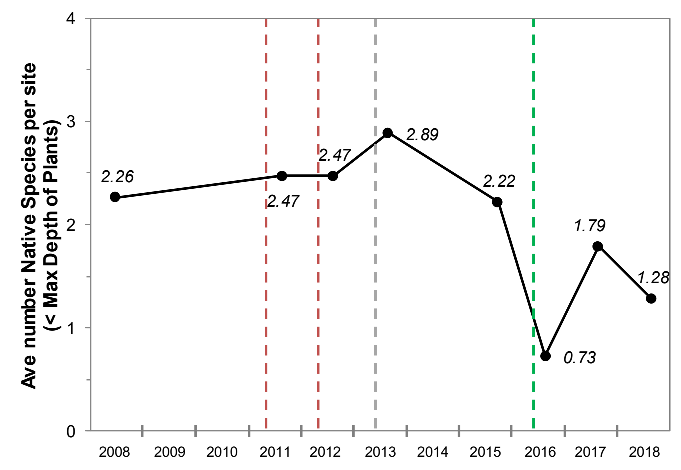


Figure 3.4-8. Average number of native species per sampling site in Forest Lake from 2008-2018. Created using data from 2008-2018 point-intercept surveys. Red dashed line represents whole-lake herbicide treatments. Grey dashed line represents spot-treatments.

In addition to examining changes in the overall occurrence of vegetation in Forest Lake from 2018, changes in the occurrence of individual plant species were also investigated. Some species within Forest Lake have similar morphological characteristics and cannot always be easily be identified in the field and were combined for this analysis. For this analysis, slender/southern naiad refers to the combined occurrences of *Najas flexilis* and *N. guadalupensis*. Similarly, the collective occurrences of Illinois pondweed (*Potamogeton illinoensis*), variable-leaf pondweed (*Potamogeton gramineus*) and a hybrid pondweed (*Potamogeton sp*.) are combined in the analysis. Further, Fries' pondweed and stiff pondweed are combined in the analysis as well as small pondweed and slender pondweed due to difficulty in separating these species during field identifications.

Figure 3.4-9 displays the average littoral frequency (and range) of select aquatic plants within Forest Lake from 2008-2018 compared to the 2018 whole-lake point-intercept survey. The data indicate that in 2018, many native species had a frequency that was below their average for the entire timeframe, while HWM was near the high end of its range of frequencies.

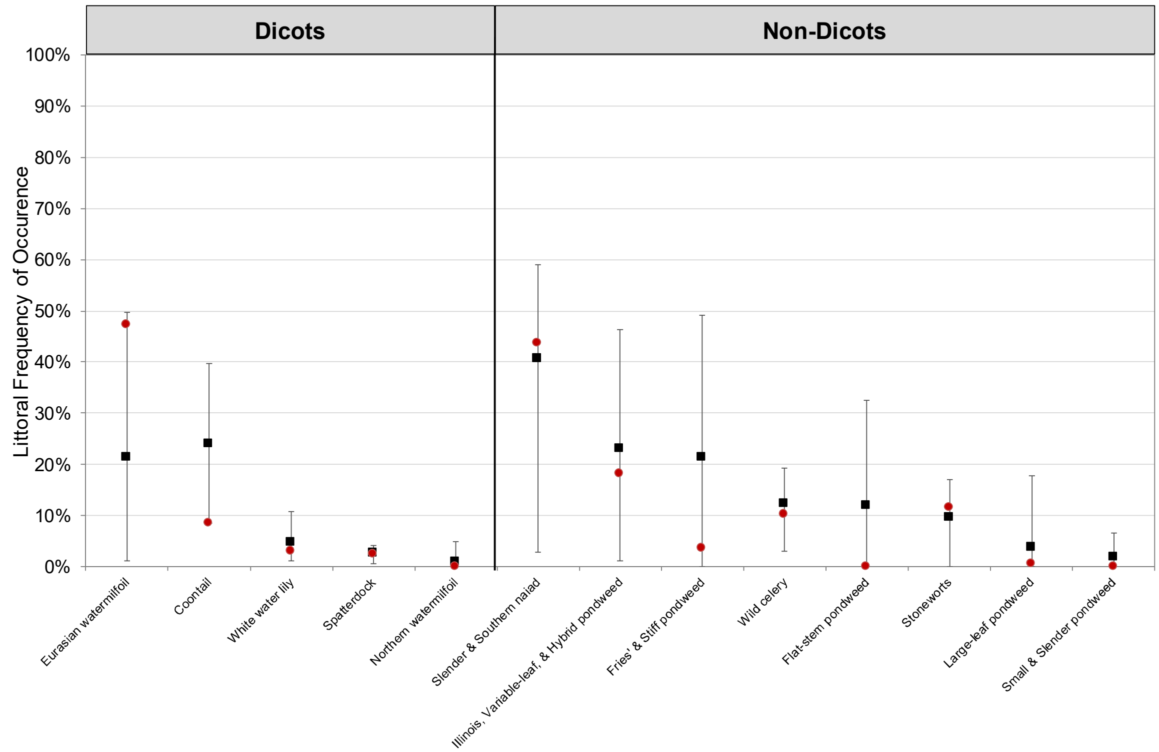


Figure 3.4-9. Forest Lake aquatic plant littoral frequency of occurrence from 2008-2018. Square symbol represents mean frequency of occurrence pooled from all point-intercept surveys, error bars represent range of annual frequencies, red circle represents 2018 occurrence.

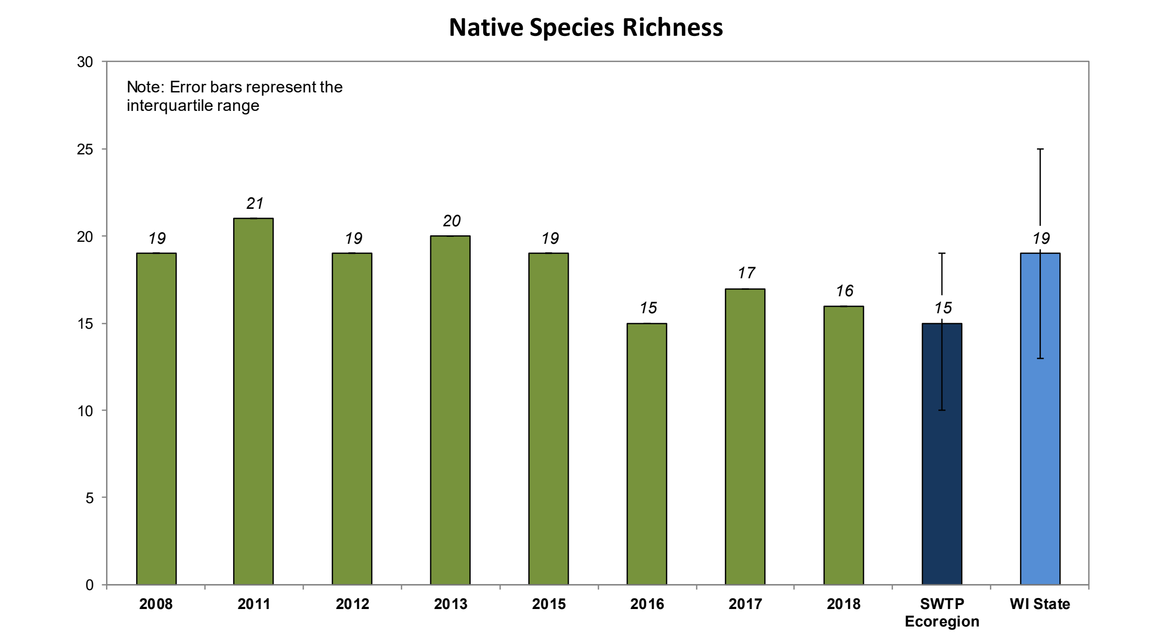


Figure 3.4-10. Forest Lake Native Species Richness. Created using data from 2008-2018 whole-lake point-intercept surveys. Regional and state medians calculated with Onterra and WDNR data.

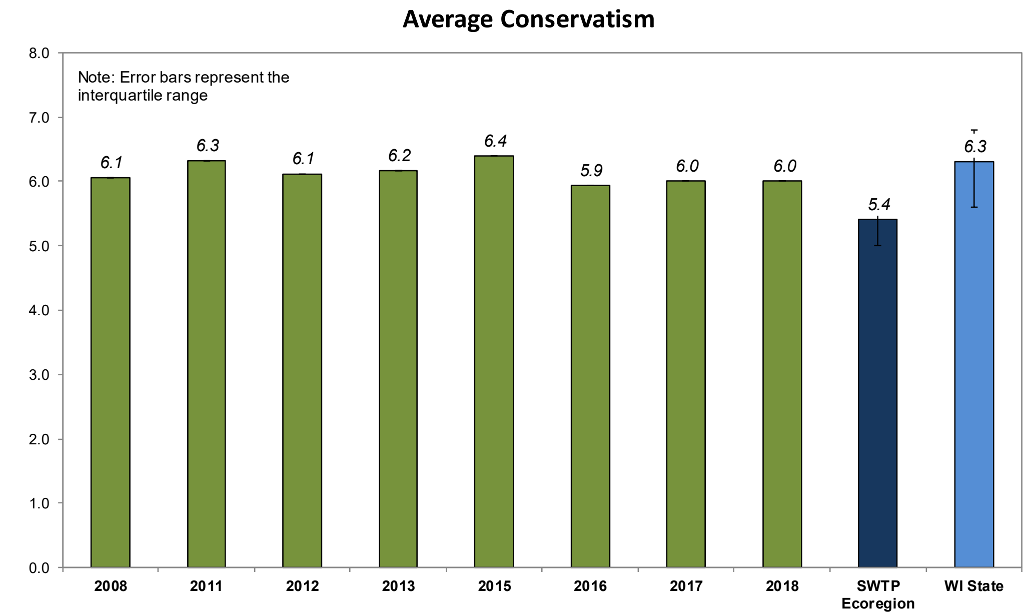


Figure 3.4-11. Forest Lake Average Conservatism. Created using data from WDNR and Onterra 2008-2018 surveys.

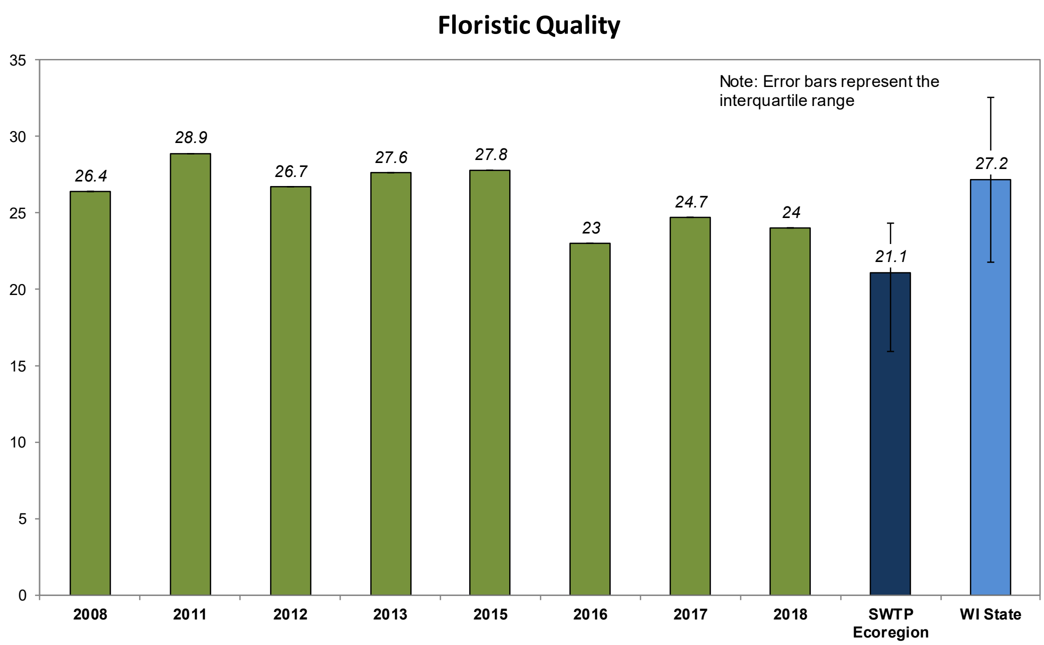


Figure 3.4-12. Forest Lake Floristic Quality Index. Created using data from WDNR and Onterra 2008-2018 surveys.

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 19 native aquatic plant species were located in Forest Lake during the 2018 surveys, 15 were encountered on the rake during the point-intercept survey. The native aquatic plant species located on the rake during the point-intercept surveys from 2008 to 2018 and their conservatism values were used to calculate the FQI for each year. Native plant species richness has ranged between 13 and 29 with an average of 18 species (Figure 3.4-10). The average native plant species richness falls above the median values for other lakes within the SWTP ecoregion and below the median value for lakes throughout Wisconsin.

Average species conservatism ranged between 5.9 to 6.4 between the 2008-2018 surveys with an average of 6.1, falling above the median value for lakes in the SWTP region (5.4) but below the median for lakes within the state (6.3) (Figure 3.4-11). Using Forest Lake's annual species richness and average conservatism to calculate the annual FQI yielded values ranging between 23 and 28.9 with an average of 26.1 (Figure 3.4-12). The average FQI value for Forest Lake's aquatic plant community falls above the median for lakes within the SWTP ecoregion (21.1) but below the median for lakes throughout Wisconsin (27.2).

Overall, the FQI analysis indicates that the native plant community of Forest Lake is of higher quality when compared to regional lakes but lower quality when compared to lakes throughout the state.

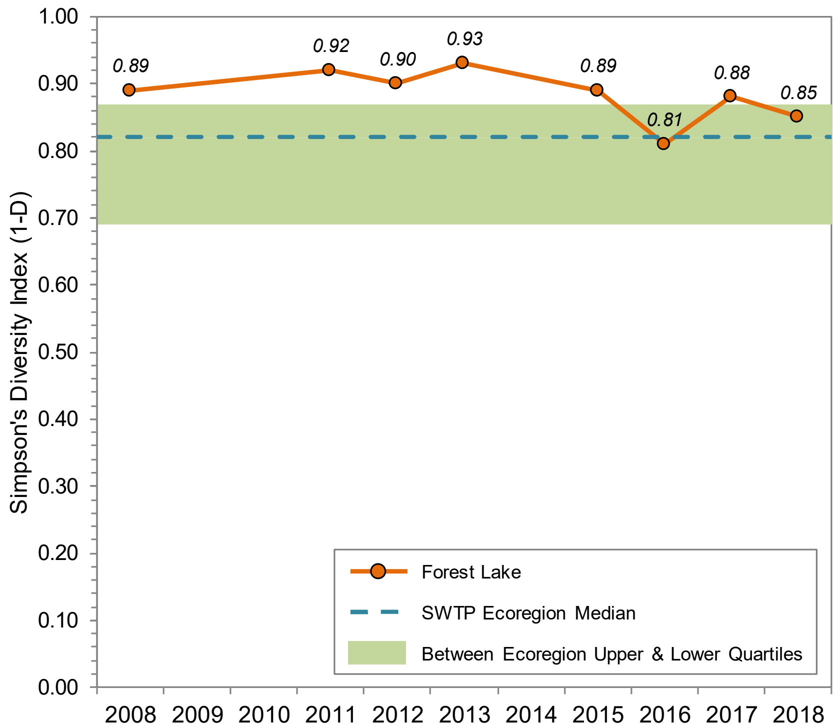


Figure 3.4-13. Forest Lake 2008-2018 Simpson's Diversity Index. Created using data from 2008-2018 whole lake-lake point intercept surveys.

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 Forest Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 77 lakes within the SWTP Ecoregion (Figure 3.4-13). Using the data collected from the 2008-2018 whole-lake point-intercept surveys, Forest Lake's aquatic plant species diversity ranged between 0.81 and 0.93 with an average of 0.88. Aquatic plant species diversity was 0.85 in 2018.

The average species diversity value of 0.88 falls above the median value for lakes within the SWTP ecoregion, indicating high species diversity for this region.

Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while HWM was found at 47% of the sampling locations in Forest Lake in 2018, its relative frequency of occurrence was approximately 27%. Explained another way, if 100 plants were randomly sampled from Forest Lake, 27 of them would be HWM. Looking at relative frequency of occurrence (Figure 3.4-14), Forest Lake's aquatic plant community is dominated by Eurasian watermilfoil with slender naiad being the most dominant native species with a relative frequency of 21%

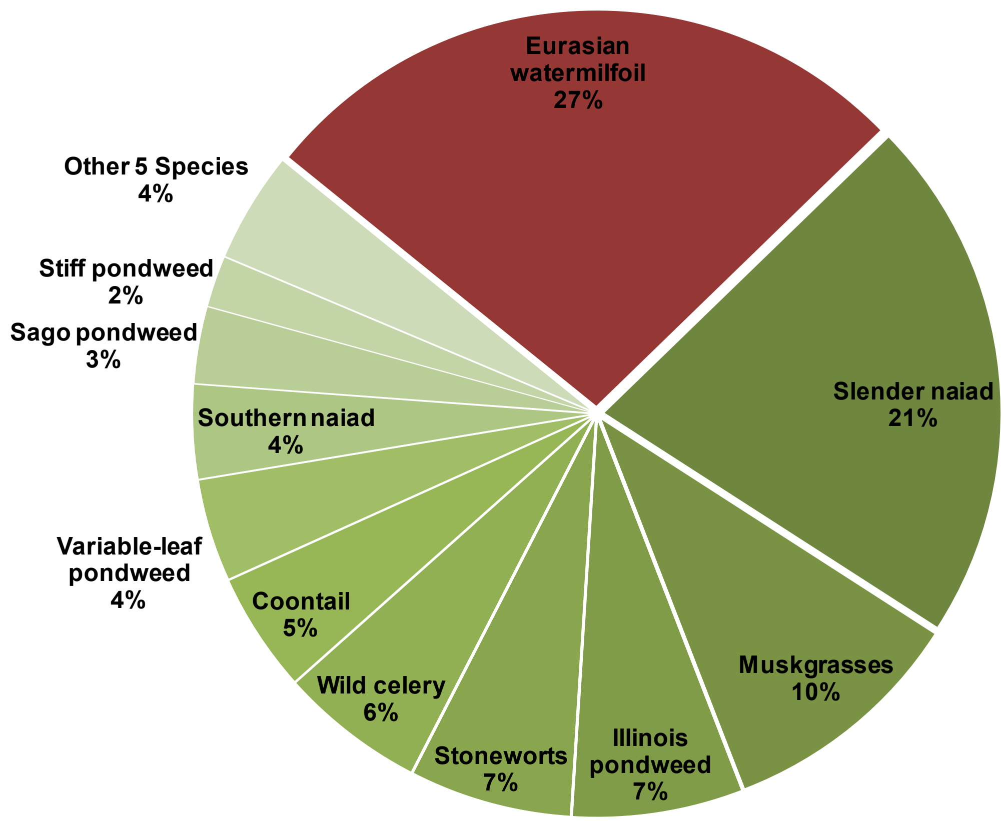


Figure 3.4-14. Relative frequency of occurrence of aquatic plants in Forest Lake. Created using data from 2018 point-intercept survey.

Non-native Plants in Forest Lake

Eurasian watermilfoil

Eurasian watermilfoil (EWM, *Myriophyllum spicatum*) was first documented in Forest Lake in 1992 but may have been present as early as the 1980s. For over 30 years, the Forest Lake Improvement Association (FLIA) has worked with the WDNR to battle EWM including the use of benthic barriers, weevil introduction (and monitoring), numerous spatially targeted herbicide spot treatments, and large-scale 2,4-D treatments in 2011 and 2012. In 2010, the FLIA contracted with Onterra to initiate a three-year AIS control and monitoring project with a goal to reduce the

HWM population within Forest Lake to more manageable levels while at the same time minimizing impacts to valuable native aquatic plant species. Map 6 displays the late-summer HWM mapping results during this timeframe which and shows the HWM population dynamics during this period of active management. Most recently a large-scale 2,4-D/endothall treatment occurred in 2016 (Table 3.4-4). Exhibiting some morphological characteristics of the native northern watermilfoil, EWM samples from Forest Lake were collected and sent by Onterra to the Annis Water Resources Institute at Grand Valley State University in Michigan for DNA analysis in 2010. Their results confirmed that the milfoil samples tested are hybrid watermilfoil (HWM), a cross between EWM and the native northern watermilfoil (*M. sibiricum*).

Table 3.4-4. HWM Management and Study History for Forest Lake.

- 1993 – small (< 0.01 acre) treatment with granular 2,4-D (ester)
- 1995 - Feasibility study using benthic screens
- 1996 – Feasibility study using benthic screens and benthic barriers – Controlled the growth of plants, but once removed EWM rapidly spread in 1997-1998, "far exceeding any progress that was made with the barriers"
- 1999-2000 – 28,000 milfoil weevils introduced. Follow-up surveys produced no evidence of weevils or any damage to EWM.
- 2001 – Study to check weevil survival/reproduction – company indicated that weevil larvae are unable to survive long enough to reach pupae/adult life form (Forest Lake's pH was 59x more alkaline than the medium the weevils were cultured in)
- 2003 – 12 acres treated with granular 2,4-D (ester)
  Unintentional whole-lake treatment
- 2004 – 5 acres treated with granular 2,4-D (ester)
- 2006 – 2 acres treated with granular 2,4-D (ester)
- 2008 – 1.9 acres treated with granular 2,4-D (ester)
- 2011 – 19.3 acres treated with liquid 2,4-D (amine)
  Intentional whole-lake treatment
- 2012 – 21.6 acres treated with liquid 2,4-D (amine)
  Intentional whole-lake treatment
- 2013 – 3.4 acres treated with granular 2,4-D (amine)
  Whole-lake impacts to sensitive native plants likely, but not to HWM population
- 2015 – Research Project with Lonza: *Comparison of Select Herbicides, Algaecides, and Adjuvants for Control of Hybrid Watermilfoil from Forest Lake, WI: Mesocosm Evaluation*
- 2016 – 19.2 acres treated with 2,4-D (amine) and Endothall (dipotassium salt)
  Intentional whole-lake treatment

A subsequent research project lead by Colorado State University (Scott Nissen) had Onterra systematically collect invasive milfoil samples from Forest Lake during the spring of 2016 (pretreatment) to determine the relative composition EWM and HWM within the lake. The preliminary results indicate that Forest Lake supports only a population of HWM and that no pure-strain EWM was present within the lake. However, this screening does not indicate if the hybrid individuals are different strains or not. There can be much genetic variability within hybrid milfoils because a different amount of each parents' genetic material is contributed to the offspring. Ongoing research is attempting to quantify the amount of genetic variation of hybrid milfoils within a particular lake. Some strains of hybrid watermilfoil have been shown to be less susceptible to certain herbicide control strategies.

The concept of heterosis, or hybrid vigor, is important in regards to hybrid water milfoil management in Forest Lake. The root of this concept is that hybrid individuals typically have improved function compared to their pure-strain parents. Hybrid water-milfoil 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). 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.

Eurasian watermilfoil is more sensitive to 2,4-D than most strains of HWM. The 2,4-D use history of Forest Lake may have resulted in sensitive strains being removed from the population resulting in a population of 2,4-D tolerant invasive milfoil within Forest Lake. Therefore, based on the results of the past large-scale 2,4-D treatments on Forest Lake as well as emerging data from other HWM control projects, a large-scale 2,4-D treatment was not considered for Forest Lake in 2016.

Laboratory studies termed "challenge testing" can be conducted to determine if milfoil samples from a particular lake are less-responsive to particular herbicide use patterns. In 2015, the WDNR partnered with Lonza to conduct outdoor mesocosm challenge tests of HWM from a number of lakes, including from Forest Lake (Wersal, and Khanzada 2015). During these test, HWM plants from Forest Lake collected in 2015 were grown in outdoor containers and subjected to various herbicides use patterns (herbicide type, concentration, exposure time, and additives) to see how they would respond. The combination of 2,4-D (0.3 ppm ae) and endothall (0.75 ppm ai) was exposed to HWM plants from Forest Lake for 7 days to mimic a large-scale herbicide treatment. The plants were then grown in absence of herbicide for 5 weeks before biomass measurements were taken. The plants within this mesocosm study were completely controlled and had no biomass remaining at the end of 5 weeks post treatment. Ultimately, this herbicide use pattern was adopted for the 2016 treatment on Forest Lake.

During February 2016, an AIS-EPC Grant was applied for to fund the large-scale combination treatment and monitoring using the strategy developed through this process. However, the WDNR grant ranking committee felt that the existing management plan was not current enough and therefore was deemed ineligible for the grant. Following the unsuccessful attempt to receive WDNR funds, the FLIA partnered with United Phosphorus, Inc. (UPI), whom donated the endothall component of the 2016 treatment (>$20K) for the purposes of furthering the scientific exploration. The remaining treatment, monitoring, and reporting costs from 2016 were paid directly by the FLIA without state funds. With Onterra's assistance, the FLIA was later awarded a WDNR AIS-Education, Prevention, and Planning Grant to commence a Comprehensive Lake Management Planning Project in 2017. This grant also contained cost coverage to monitor the results of the 2016 treatment during the *year of treatment* (2017) and *year after treatment* (2018).

The 2016 combination 2,4-D/endothall treatment did not meet lake manger's expectations for control. Especially considering the higher-than-target herbicide concentrations achieved, a higher level of HWM control and longer lasting control was anticipated. Hybrid watermilfoil rooted in waters deeper than the herbicide mixing zone contain biomass that extends into the herbicide mixing zone. The biomass that was within the herbicide mixing zone is theorized to uptake the herbicide and systematically move the herbicide throughout the plant tissue. The information collected during this project suggest that the HWM plants rooted below the herbicide mixing zone may have received a diluted herbicide dose and the HWM plants were able to survive.

Impacts to the native plant community were observed following the 2016 herbicide treatment. Continued monitoring of native species in 2017-2018 allows for an understanding of the longer-term impacts to individual native species. It appears clear that HWM control was initially higher in shallower waters, those depths that were within the herbicide mixing zone.

No herbicide control methods were recommended in 2018 as the FLIA were in the process of completing a comprehensive lake management plan. While alternative herbicide options were being considered (e.g. fluridone), it is not clear whether the role of stratification or pH are barriers to the effectiveness of all herbicide options.

Forest Lake has a high pH (mid-summer average 8.7) and high alkalinity (110 mg/L as $CaCo_3$), further intriguing lake managers about expectations from herbicide treatments under these conditions. It is unclear if pH can impact HWM control directly or indirectly by limiting herbicide uptake into the plant.

The latest point-intercept survey of Forest Lake was from 2018. At 47.3%, the occurrence of HWM in 2018 was approximately at the level that was documented in 2015 prior to the last large-scale control effort (Figure 3.4-15). While a point-intercept survey was not conducted in 2018, the qualitative mapping data confirm a trend of increasing density (Map 7, Figure 3.4-17). In 2019, the entire littoral zone of Forest Lake contained colonized HWM, with almost 20 acres being comprised of *highly dominant* or *surface matting*. These relatively dense colonies of HWM are highly visible to lake users and cause reductions in user services that the lake provides such as boating and swimming, particularly as a no gas motor lake.

Nault et al. 2016 investigated point-intercept data from almost 400 Wisconsin Lakes that had EWM populations. Within this dataset, 94.7% of lakes contained EWM populations less than 50%. This indicates that Forest Lake's current invasive watermilfoil population is roughly within the top 5% of Wisconsin lakes that have EWM populations (Figure 3.4-16).

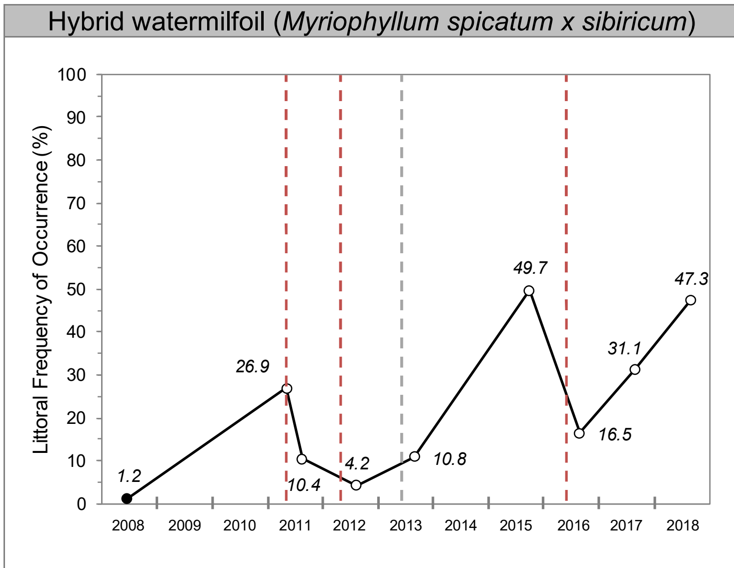


Figure 3.4-15. Littoral frequency of occurrence of Eurasian watermilfoil in Forest Lake from 2008-2018. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Created using data from 2007-2018 whole-lake point-intercept surveys. Red dashed line represents whole-lake herbicide treatments. Grey dashed line represents spot-treatments.

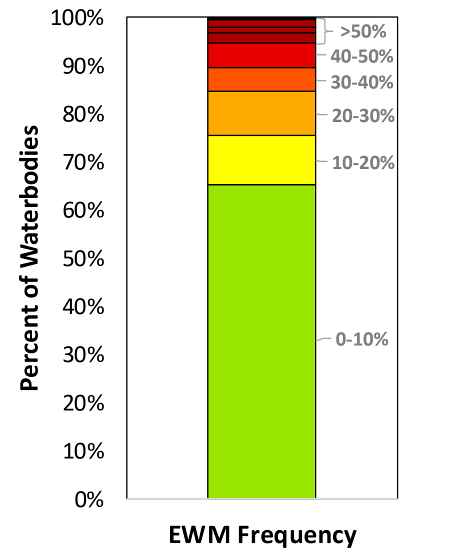


Figure 3.4-16. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

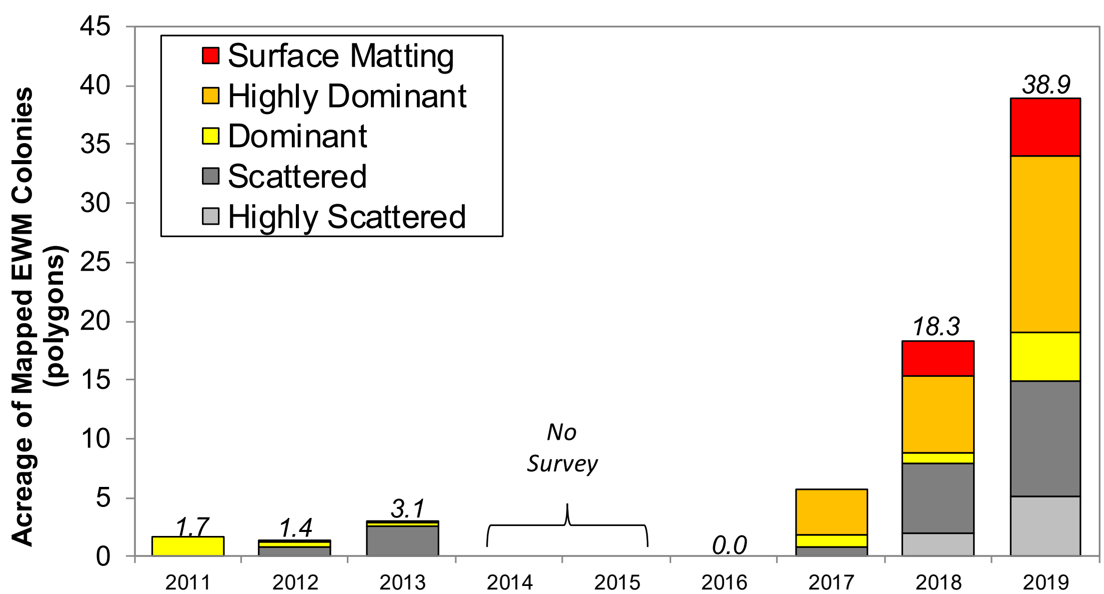


Figure 3.4-17. Acreage of mapped HWM colonies on Forest Lake.

Stakeholder Survey Responses to Aquatic Vegetation in Forest Lake

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the survey was 57%. In instances where stakeholder survey response rates are 60% or above, the results can be interpreted as being a statistical representation of the population. While the survey response rate of 57% may not be sufficient to be a statistical representation of the population, the FLIA believe the sentiments of the stakeholder respondents is sufficient to provide a generalized indication of riparian preferences and concerns. Said another way, these are the best quantitative data the FLIA has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

Figures 3.4-18 and 3.4-19 display the responses of members of Forest Lake stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts the enjoyment of Forest Lake, no respondents indicated *never* and 3% indicated *rarely*. The remainder of stakeholder survey respondents indicated aquatic plant growth *sometimes* (23%), *often* (49%), or *always* (26%) negatively impact their enjoyment of Forest Lake (Figure 3.4-18). When asked if they believe aquatic plant control is needed on Forest Lake (Figure 3.4-19), one respondent indicated *probably no*, while the remainder indicated *probably yes* (17%) or *definitely yes* (80%).

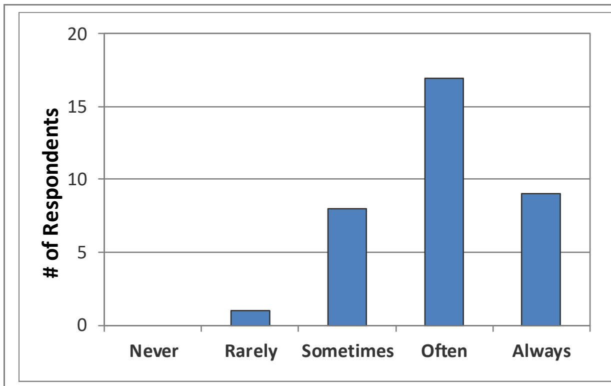


Figure 3.4-18. Stakeholder survey response Question #30. Do you believe aquatic plant control is needed on Forest Lake?

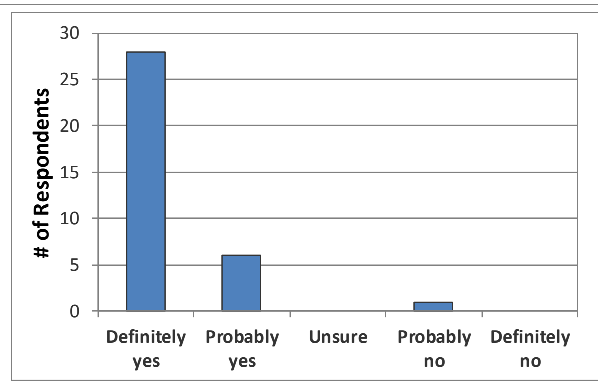


Figure 3.4-19. Stakeholder survey response Question #29. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Forest Lake?

The planning committee wanted to understand the stakeholders' perceptions on the use of various active management techniques (Figure 3.4-20). 83% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of using herbicides on Forest Lake, whereas 9% were unsupportive (pooled *not supportive* and *moderately un-supportive* responses). 9% of respondents were *neutral* or *unsure: need more information.* 40% of stakeholder respondents indicated they were supportive (pooled *highly supportive* and *moderately supportive* responses) of mechanical harvesting, with 26% being *neutral* or *unsure: need more information.*

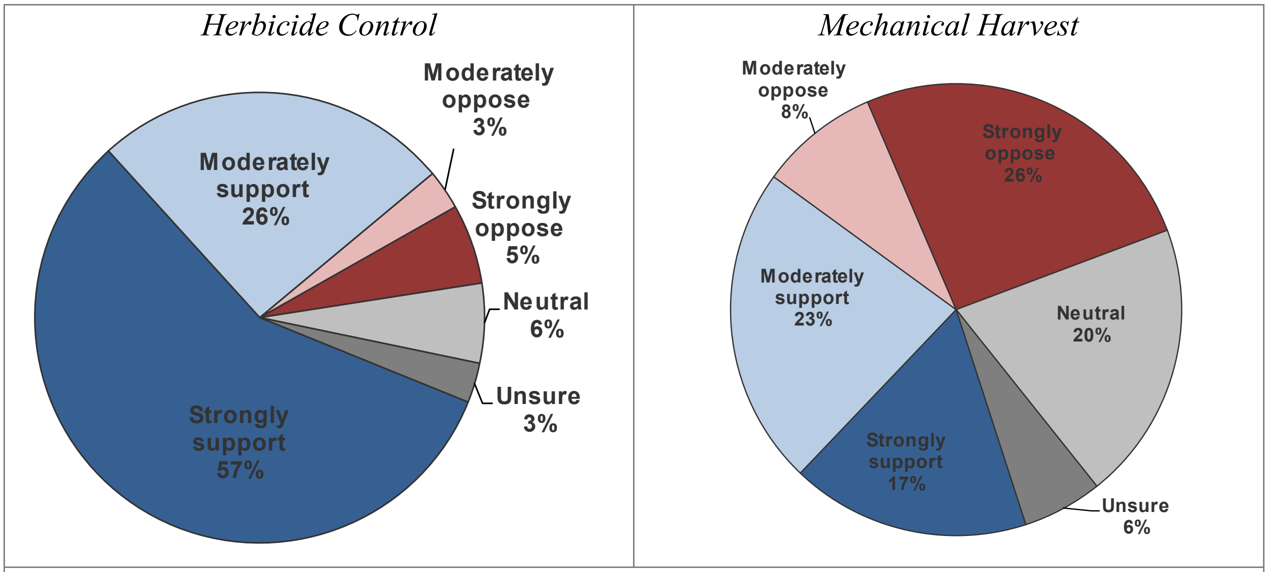


Figure 3.4-20. Stakeholder survey response Question #31. What is your level of support for the responsible use of the following techniques?

All of respondents (100%) were aware that aquatic herbicides had been applied to Forest Lake to manage EWM (Appendix B, question #32). Approximately 91% of respondents indicated that they *completely supportive* or *moderately supportive* of the past use of herbicides to treat AIS in previous years. One respondents indicated they were *unsure/neutral* and 2 respondents indicated they *moderately opposed* or *completely opposed* to past use of herbicides for AIS management (Figure 3.4-21).

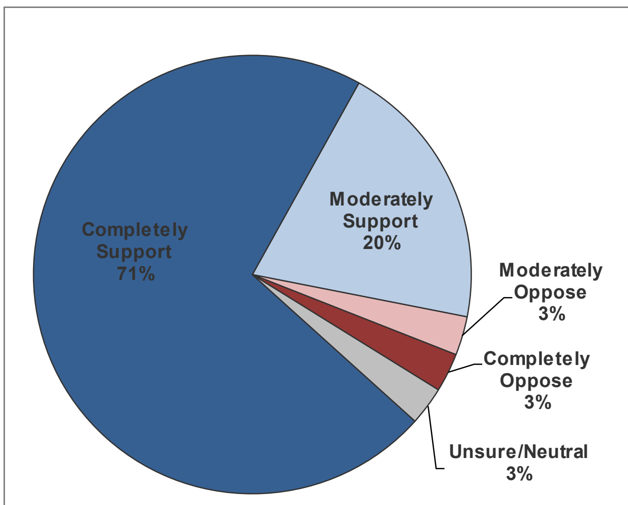


Figure 3.4-21. Stakeholder survey response Question #33. How do you feel about the past use of herbicides to treat AIS in previous years?

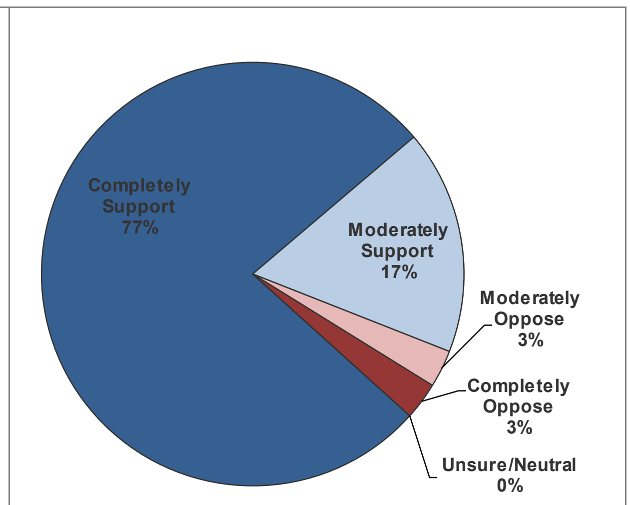


Figure 3.4-22. Stakeholder survey response Question #30. What is your level of support or opposition for future aquatic herbicide use to target AIS in Forest Lake?

When asked what their level of support or opposition for future aquatic herbicide use to manage AIS in Forest Lake, the majority of respondents, 94%, indicated they *completely support* or *moderately support* future use, none of the respondents indicated they were *unsure/neutral*, and 2 respondents (6%) indicated they *moderately oppose* or *completely oppose* the future use of aquatic herbicides (Figure 3.4-18). Both respondents that indicated they either *moderately oppose* or *completely oppose* the future use of aquatic herbicides indicated their opposition is due to the potential impacts to human health and that the future impacts are unknown (Question 31, Appendix B). One of the respondents indicated that they were not in favor of future herbicide treatment because they believe it will "select for resistant species."

Future AIS Management

During the strategic Planning Committee meetings, Onterra outlined three broad potential EWM population goals for consideration including a recommended action plan to help reach each of the goals (Figure 3.4-19). Each management goal was discussed and considered for applicability. The following paragraphs provide brief overview of these extensive conversations.

During the management planning process, Onterra outlined three potential HWM population management perspectives for consideration. The FLIA reviewed these potential HWM management goals, including the associated potential action plans for applicability on Forest Lake. The following paragraphs provide brief overview of these extensive conversations. During these discussions, conversation regarding risk assessment of the various management actions were prominent. Onterra provided extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for the FLIA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Forest Lake Ecosystem. These chapters are included as Appendix E.

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

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

Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may be to manage the EWM population at a reduced level with the perceived goal to allow the lake to function as it had prior to EWM establishment. Due to the inevitable collateral impacts from most forms of EWM management, lake managers and natural resource regulators question whether that is an achievable goal. The WDNR maintains a cost-share grant funding program for projects that aim to reduced established aquatic invasive species populations.

In early EWM populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. Large-scale management can reduce EWM populations for several years, but will not eradicate it from the lake. Subsequent smaller scale management (e.g. hand-harvesting or spot treatments) is typically employed to slow the rebound of the population until another large-scale effort may be considered again. Large-scale control efforts, especially using herbicide treatments, can be impactful of some native plant species as well as carry a risk of environmental toxicity. Some argue that the impacts of the control actions may have greater negative impacts to the ecology of the system than if the EWM population was not managed.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*), like yellow garden loosestrife, is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed in a number of locations around Forest Lake (Map 5).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option.

Photograph 3.4-7. Purple loosestrife in shoreland area. Photo credit Onterra.

3.5 Aquatic Invasive Species in Forest Lake

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

Table 3.5-1. AIS present within Forest Lake

Type	Common name	Scientific name	Location within the report
Plants	Hybrid watermilfoil	*Myriophyllum sibiricum x M. spicatum*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
Fish	Common carp	*Cyprinus carpio*	Section 3.5 - Aquatic Invasive Species

Figure 3.5-1 displays the 6 aquatic invasive species that Forest Lake stakeholders believe are in Forest Lake. Only the species present in Forest Lake are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

Aquatic Animals

Common Carp

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

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

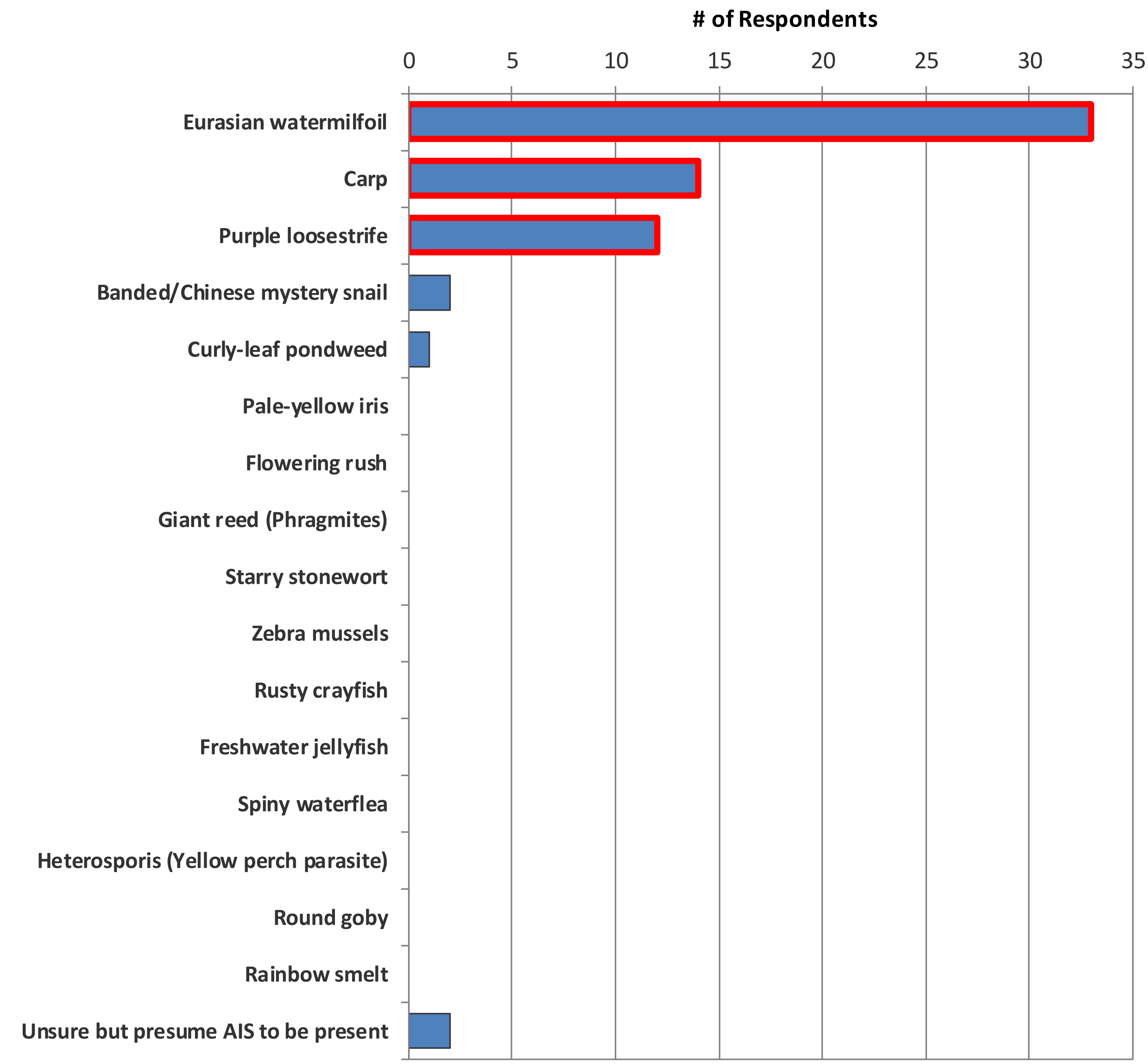


Figure 3.5-1. Stakeholder survey response Question #26. Which aquatic invasive species do you believe are in Forest Lake? Species with red border are confirmed from Forest Lake.

3.6 Fisheries Data Integration

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

Forest 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 Forest 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.

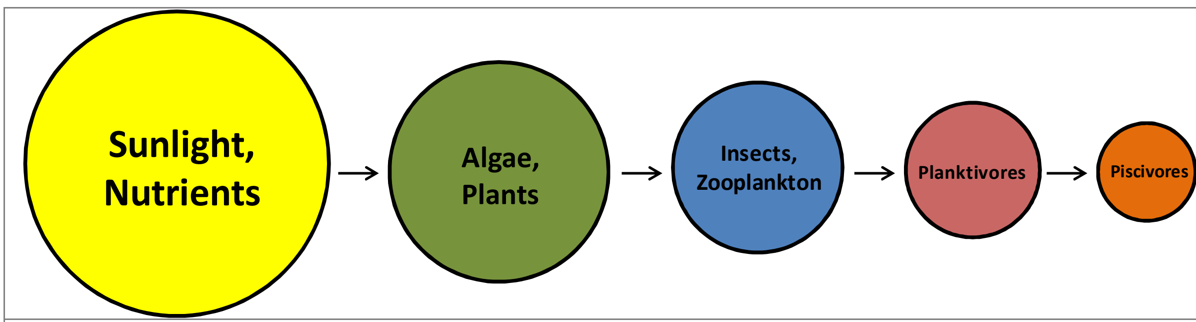


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Forest Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Forest Lake should be able to support an appropriately sized population of predatory fish (piscovores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system.

Additional species documented in Forest Lake include common carp (*Cyprinus carpio*) which is discussed within the Aquatic Invasive Species Section (3.5).

Table 3.6-1. Gamefish present in Forest 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
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
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Warmouth (*Lepomis gulosus*)	13	Mid May - Early July	Shallow water 0.6 - 0.8 m, with rubble slightly covered with silt	Crayfish, small fish, odonata, and other invertebrates
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. Due to the access on Forest Lake only electroshocking was done during the 2004 WDNR fisheries survey.

Electrofishing (Photograph 3.6-1) is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes. Biological characteristics are recorded and documented before the fish is released.

Photograph 3.6-1. Electroshocking boat.

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Forest Lake was stocked from 1973 to 2018 with several species (Table 3.6-2).

Photograph 3.6-2. Fingerling Largemouth Bass.

Table 3.6-2. Stocking data available for Forest Lake (1973-2018).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Largemouth Bass	Fingerling	2,500	3
1978	Largemouth Bass	Fingerling	5,000	-
1980	Largemouth Bass	Fingerling	10,000	2
1984	Largemouth Bass	Fingerling	7,000	3
1985	Largemouth Bass	Fingerling	5,100	2
2018	Largemouth Bass	Large Fingerling	100	6.5
1984	Walleye	Fingerling	3,000	1
1987	Walleye	Fingerling	7,500	2
1973	Northern Pike	Yearling	130	-
1974	Northern Pike	Yearling	150	-
1975	Northern Pike	Yearling	150	-
1976	Northern Pike	Yearling	150	-
1978	Northern Pike	Fry	137,000	-
1978	Northern Pike	Yearling	150	-
1984	Northern Pike	Fingerling	300	8
1995	Northern Pike	Fingerling	102	10.5
2014	Northern Pike	Large Fingerling	59	10
2018	Northern Pike	Large Fingerling	56	11
2018	Black Crappie	Large Fingerling	307	4
2018	Yellow perch	Yearling	300	6

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open water and ice) were two of the least important reasons for owning property on or near Forest Lake (Question #15). Relaxing/entertaining, nature viewing, and swimming were all more important reasons than fishing. Figure 3.6-2 displays the fish that Forest Lake stakeholders enjoy catching the most, with all fish species being the most popular option selected. Approximately 83% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3).

Approximately 74% of respondents who fish Forest Lake believe the quality of fishing has remained the same or is somewhat worse since they started fishing the lake (Figure 3.6-4).

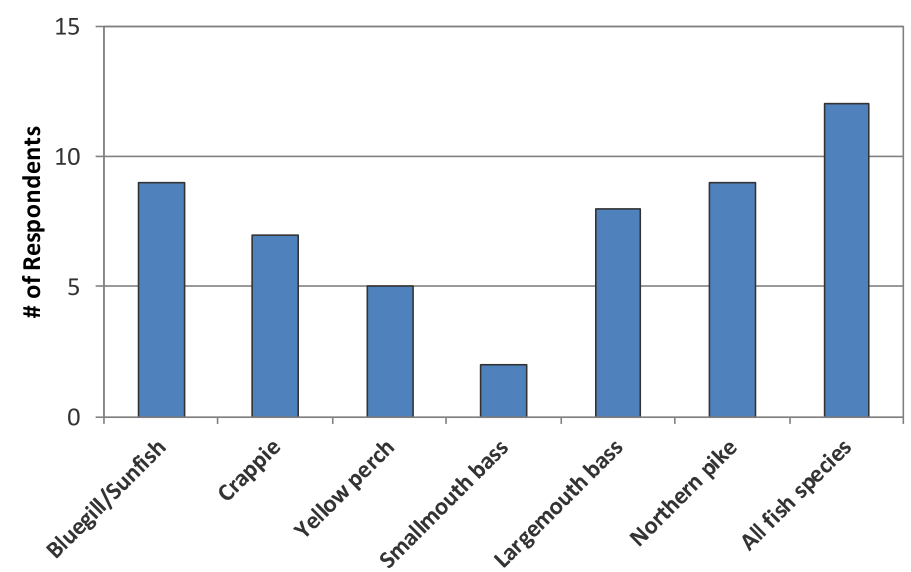


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on Forest Lake?

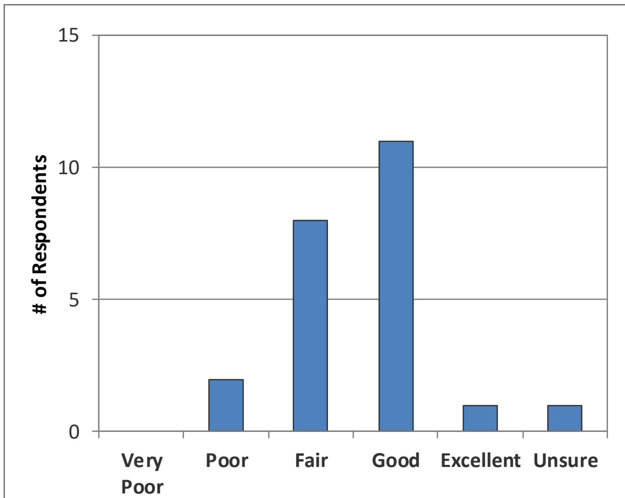


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on Forest Lake?

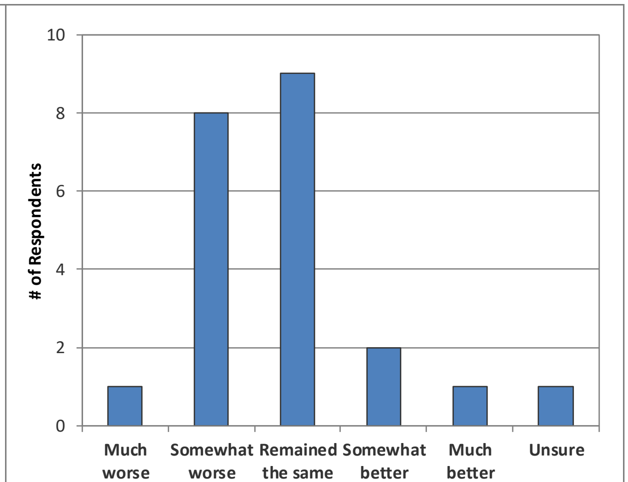


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed on Forest Lake since you started fishing the lake?

Fish Populations and Trends

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

Gamefish

The purpose of the 2004 WDNR fisheries survey was to collect baseline data and compare Forest Lake to similar surveys being conducted statewide (Appendix F). The results for the stakeholder survey show landowners prefer to catch all fish species on Forest Lake (Figure 3.6-2). Historically Forest Lake has seen an overabundance of bluegill which was found again in the 2004 survey. Additionally, size structure of the bluegill was very poor with majority of the population being in the 3.5 - 4.0 inch size group. Largemouth bass were found to be the dominant predator and the catch rate was below other lakes Forest Lake was compared to.

Fish Kill

Onterra staff observed a fish kill on Forest Lake in August of 2018 while conducting routine aquatic plant surveys. About 25-50 largemouth bass from 15 to 20 inches in length were found throughout the lake. WDNR was notified of the fish kill occurrence, however, because the fish had been dead for several days further testing for collumnaris or VHS could not be conducted. Columnaris is a common bacterial disease of fish which is one possible cause of the fish kill. The bacteria thrive in 65 to 70°F water temperatures and after rain events which bring organic material into the water body (WDNR 2019). Forest Lake does not have any historical fish kill investigations by the WDNR (Fisheries Biologist Addie Dutton, 2019).

Forest Lake Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2017, 94% of the substrate sampled in the littoral zone of Forest Lake were soft sediments, 2% was composed of rock and 4% were composed of sand sediments.

Woody Habitat

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

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006). A fall 2017 survey documented 51 pieces of coarse woody along the shores of Forest Lake, resulting in a ratio of approximately 37 pieces per mile of shoreline.

Fish Habitat Structures

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

Fish cribs are a fish habitat structure that is placed on the lakebed. Placement of fish cribs in a lake does not require a permit if the project meets certain conditions outlined by the WDNR's checklist available online:

(*http://dnr.wi.gov/topic/waterways/documents/permitExemptionChecklists/02A-fishCrib.pdf*).

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption may be requested. Installing fish cribs may be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure.

Regulations and Management

Regulations for Forest Lake gamefish species as of October 2019 are displayed in Table 3.6-3. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-3. WDNR fishing regulations for Forest Lake (As of October 2019).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass and Largemouth Bass	Catch and release only	None	-
Northern pike	Catch and release only	None	-
Walleye, sauger, and hybrids	Catch and release only	None	-

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

Photograph 3.6-4. Catch and release fishing notice posted at the Forest Lake carry-in access.

The WDNR has not completed any recent stocking or fishery surveys due to an inadequate access point to launch their equipment and boats. However, the WDNR is still involved with management of regulations and investigation of severe fish kills. Forest Lake implements catch and release regulations for gamefish species but does offer a panfish fishing season open year-round with a daily bag limit of 25 fish (Table 3.6-3). Additionally, these regulations are highlighted at the carry-in access for fishermen to observe before launching and fishing on the lake.

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/)

Forest Lake Management

According to fisheries biologist Travis Motl, Forest Lake does not provide an adequate boat access for the WDNR to be involved in fisheries management. Consequently, the WDNR does not plan to update to the 2004 fishery summary in the near future.

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 Forest 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 Forest 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 Forest Lake ecosystem, the folks that care about the lakes, and what steps can be taken by the FLIA to protect and enhance the system.

Forest Lake contains *Good* to *Excellent* water quality compared to other deep seepage lakes. Water clarity, total phosphorus, and chlorophyll-a parameters are all similar to mean values of other deep seepage lakes and slightly better than the mean values of lakes in the Southeastern WI Till Plains ecoregion. There is some evidence that productivity within the lake has increased since 2004, but it is unclear if it is a cyclical trend, perhaps tied to water levels, or is something that FLIA should be concerned about. Continued water quality monitoring is import for Forest Lake.

Forest Lake contains a small watershed compared to the size of the lake, with most of the land within the watershed consisting of those types that deliver the least amount of phosphorus to the lake. Having a small watershed, the land use around the immediate shoreline areas are going to have a large influence over the lake's water quality. Approximately 36% of Forest Lake's shoreline consisted of the two most impactful categories (*urbanize*d and *developed–unnatural* shoreland, whereas 48% consisted of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*). It is fundamental to the health of Forest Lake to preserve natural shorelands and take steps towards shifting the proportion of developed shorelines into less impactful categories.

Forest Lake anglers primarily target panfish and bass. With limited access to the lake, the WDNR does not typically assess the fisheries condition of Forest Lake. In recent years, the FLIA has been actively engaged with fisheries related issues, such as conducting supplemental stocking efforts and working to change panfish regulations.

Exotic species, particularly HWM has been a focus of management for the FLIA. This species has the capacity to do extremely well in Forest Lake, causing recreation and navigation impediments to almost all riparians. As a no gas motor lake, the impacts of surface matted HWM on paddlers or electric motors can be debilitating. The FLIA has active in their attempt to suppress the HWM population within Forest Lake. Unfortunately, these attempts have only resulted in relatively short term HWM population reductions and relatively impactful collateral impacts to the native plant community. The native plant populations are rebounding, but at a slower rate than the HWM population. Some question if it is realistic to expect the native plant populations to ever completely rebound now with such a large HWM population in place.

The FLIA will continue to investigate HWM management techniques. In the short term, nuisance control efforts through coordinate hand-harvesting campaigns are being attempted. Considering the scale of the HWM population within Forest Lake, these strategies can only provide so much relief. The FLIA will continue to investigate future herbicide management options, which were heavily discussed within this management planning process. At the time of this writing, a low concentration (1.75-3 ppb) and long (over a year) exposure fluridone treatment appears to have the best likelihood of longer term HWM population reduction. However, this use pattern is relatively new and only limited field trials exist. Higher concentration (6 ppb or greater) and slightly shorter (6-9 month) exposures to fluridone have yielded high collateral impacts to many of the species that exist in Forest Lake. If additional field trials indicate that some of the species in Forest Lake may be more resilient to the low and long fluridone use pattern, perhaps this strategy can be discussed again between the FLIA and WDNR.

Through the process of this lake management planning effort, the FLIA has learned much about their system, both in terms of its positive and negative attributes. The FLIA continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Forest Lake ecosystem

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the FLIA Planning Committee and ecologist/planners from Onterra. It represents the path the FLIA will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Forest Lake stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

While the FLIA Board of Directors is listed as the facilitator of the majority of management actions listed below, along with the name of a current director. The FLIA will be responsible for ensuring that a director is in place to achieve the various management goals.

Management Goal 1: Prevent Further Aquatic Invasive Species Infestations within Forest Lake

Management Action:	Monitor Forest Lake entry points for aquatic invasive species
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors – John Bardenwerper
Description:	This action would not only work to prevent additional invasive species from entering the lake, but also to prevent the infestation of other waterways with invasive species that originated in Forest Lake. Forest Lake's single carry-in access location does not receive the traffic to warrant watercraft inspectors following traditional CBCW protocols. Further, all watercraft entering Forest Lake from this access location need to be carried down a steep hill along an unimproved trail. This largely limits the type of watercraft being brought through this point of entry to kayaks, canoes, and small jon boats. When folks are observed attempting to bring watercraft into the lake, trained FLIA volunteer(s) would make contact and discuss CBCW messages. Mauthe Lake and Long Lake (thru its organization) represents a good opportunity for the FLIA CBCW volunteers to engage fisherman and boaters on behalf of this statewide program. The FLIA would ensure that the carry-in access location contains the proper signage with updated AIS messages. The FLIA intends to provide pressure to the WDNR to better maintain this location. With cooperation from the WDNR, the FLIA would be willing to consider assisting with construction of advance signage including an educational kiosk and watercraft cleaning equipment.

	Forest Lake is potentially most vulnerable to additional non-native species introduction through private access points that are located around the lake and utilized by lake residents and their guests. This potentially makes the lake more vulnerable to exotic introduction than a lake with a single, public access that could be more easily monitored. Education represents a good tool to address these issues. The FLIA would share distributable CBCW messaging materials to select property owners that have suitable watercraft access opportunities. Forest Lake guests are able to rent non-motorized watercraft (i.e. kayak and row boat) which are placed by the Parkview General Store (permission and coordination from Kettle Moraine State Forest – Northern Unit) at the public access location. The FLIA would discuss proper decontamination procedures with this entity, including providing information on the WDNR's manual code on *Boat, Gear, and Equipment Decontamination and Disinfection Manual Code* (9183.1).
Action Steps:	
	See description above as this is an established program.

<u>Management Action:</u>	Provide riparians and stakeholders with AIS materials
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	The previous management action targets the distribution of AIS educational material to access sites to Forest Lake. The FLIA would extend additional AIS education and CBCW messaging materials to more passive access sites around the lake – through lake residence. This would include educating all riparians that likely use their properties to bring portable watercraft in and out of Forest Lake. As appropriate, the FLIA would extend education and AIS outreach through local fishing clubs, at local bait shops, at tourist events (i.e. Dundee Days), and at the area campgrounds. Cooperation with the lake groups at Mauthe Lake and Long Lake presents a good opportunity for the FLIA CBCW volunteers to engage fisherman and boaters on behalf of this statewide program.
Action Steps:	
	See description above

Management Goal 2: Manage Invasive Watermilfoil within Forest Lake

Management Action:	Develop whole-lake HWM management strategy for Forest Lake
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	Due to Forest Lake's relatively small water volume, almost any spot-treatment with a weak-acid herbicide would dilute to levels that could impact the entire lake. Purposeful whole-lake herbicide treatments were conducted on Forest Lake in 2011, 2012, and 2016. Past spot herbicide treatments, including one conducted in 2013, likely resulted in lake-wide concentrations vulnerable to sensitive aquatic plants although were at concentrations too low to impact durable species like HWM. As discussed within the Non-Native Plants subsection of the Aquatic Plant Section (3.4), the past treatments had an impact on species frequency and plant diversity. That being said, approximately 94% of Forest Lake riparian stakeholder survey respondents indicated support (pooled *completely support* and *moderately support*) for future herbicide use on Forest Lake. When the littoral frequency of HWM, according to the point-intercept survey, exceeds 30% (trigger), the FLIA would give consideration to investigating the applicability of a whole-lake management strategy. At the time of this writing, it is unclear if any whole-lake herbicide management strategies will produce multi-year HWM control with "acceptable" collateral native plant impacts. The following five whole-lake herbicide treatment strategies were discussed during the planning project are included here for reference. The FLIA will continue to investigate the applicability of these strategies, modified use-patterns of these herbicides, and new herbicides as it relates to future whole-lake HWM management of Forest Lake. Also discussed here is the applicability of biologic control methods for HWM management in Forest Lake. 1. Whole-lake 2,4-D amine treatments resulted in short-term HWM suppression (1-2 summers), even at elevated rates to account for known tolerance of hybrid watermilfoil. Native plant impacts from these treatments were considered within the acceptable range to the FLIA and some lake managers. 2. Triclopyr has a similar mode of action to 2,4-D (auxin hormone mimic), but due to higher cost of implementation, is typically reserved for instances where past 2,4-D treatments have had rapid degradation due to high biological activity. Triclopyr is anticipated to have a longer exposure time as it degrades photolytically rather than microbially. Past whole-lake 2,4-D amine treatments on Forest Lake have had adequate

	concentration and exposure times, therefor exchanging one auxin-mimic with another is not likely to produce different results. 3. Coupling 2,4-D amine (auxin) with endothall is used to target HWM populations that have not responded to auxin herbicides alone. This strategy was implemented on Forest Lake in 2016, providing a single season of HWM population suppression with high native plant impacts. Based upon these results, this strategy is not being considered for Forest Lake. 4. Fluridone is often used when targeting difficult invasive milfoil populations, particularly HWM populations that have not been effectively controlled by prior applications of auxins or auxin/endothall combinations. Fluridone has a checkered history in Wisconsin as prior treatments have been particularly impactful to native plant communities. A relatively new fluridone use-pattern consisting of a lower target concentration but the need for sustaining that concentration throughout an entire growing season, appears to produce increased selectivity while retaining a high level of HWM control. However, only a limited number of lakes have employed this strategy in Wisconsin to date. For Forest Lake, a number of the most frequent vascular plants in the system may be vulnerable to this fluridone use pattern. Considering that Forest Lake continues to rebound from the 2016 whole-lake herbicide management strategy, and the unknown level of magnitude of native plant impact from a potential low-and-long fluridone strategy (i.e. pelletized fluridone), this strategy is not advised for current implementation. Continued monitoring of the trial treatments being conducted in the state may shed light on the future applicability of this strategy for Forest Lake. 5. Florpyrauxifen-benzyl (ProcellaCOR™) is a new chemistry specifically designed to control invasive watermilfoil in short exposure time scenarios. The product has a high affinity for binding to organic materials (i.e. high KOC), which many believe limits dissipation away from the targeted application site. It is unclear if this herbicide will be applicable at the whole-lake scale, or just for spot treatments. The FLIA will follow the emerging case studies of this product to determine potential applicability for whole-lake or spot treatment use on Forest Lake. 6. In 1999 and 2000, a total of 28,000 milfoil weevils were stocked into Forest Lake, with follow-up studies being unable to document life cycle continuation or damage to HWM. Early discussion and research focused on the high pH of Forest Lake, which may be inhibiting reproduction fitness. More recent research on weevil has indicated that background populations of these native weevils in most lakes is quite high, with

	stocking efforts having an insignificant impact on fostering a population sufficient to impact EWM/HWM (Knight and Havel 2013). The current consensus for a weevil density threshold that would result in watermilfoil control is 0.25 weevils per stem (Paul Skawinski pers. comm.). If the FLIA would like to investigate biological control in the future, it is first recommended to gain an understanding of the current weevil densities within Forest Lake. And while the purchase of weevils is not an eligible WDNR grant expense, recent advancements in weevil rearing by lake groups may be a viable option for the FLIA. If a whole-lake management strategy emerges in the future, specific details of the control and monitoring strategy will be included within a stand-along report, being provided to the WDNR with sufficient time to review if a WDNR AIS-EPC Grant is being pursued (i.e. 60 days). The whole-lake treatment would include herbicide concentration monitoring to understand the concentrations and exposure times achieved. An aquatic plant monitoring strategy would include point-intercept surveys the year prior to the treatment, year of the treatment, and year after the treatment. Depending on the herbicide use-pattern employed, point-intercept monitoring the year of the treatment may not be applicable (e.g. during active fluridone treatments). Consideration to HWM mapping surveys during this same timeframe would be made to help drive subsequent Integrated Pest Management (IPM) for the rebounding HWM population. The IPM plan would be initiated to preserve the magnitude and the length of the gains received from the whole-lake treatment strategy. The IPM plan would be reactive to the scale of the HWM population rebound and would preferably consist of hand-harvesting methods.
Action Steps:	
	See description above

Management Action:	Conduct nuisance management actions towards HWM
Timeframe:	2020 and beyond
Facilitator:	Board of Directors - Deborah Kossup and Phil Tripoli
Description:	To reduce the lake-wide HWM population in Forest Lake, the only current option that is scale appropriate is through a whole-lake treatment as discussed in the previous management action. Particularly on lakes like Forest Lake that have large HWM populations, it may be impractical, unpopular, or too ecologically damaging to target with a whole-lake herbicide treatment. In these cases, the lake group can coordinate a strategy to improve the navigability and recreational use

	within the lake. With watercraft on Forest Lake being restricted to non-motor or non-gas motor, dense aquatic vegetation close to the surface can pose large navigation and recreational impediments. **<u>Mechanical Harvesting</u>** The FLIA conducted a feasibility study for contracting a firm to cut areas or lanes within the dense HWM with a mechanical harvester. The main obstacle using mechanical harvesting on Forest Lake is the access, both in terms of getting the machinery into the lake and for offloading harvested plant material. The carry-in access point is not compatible for launching or offloading. The smallest mechanical harvester the FLIA was able to identify was the Silver Mist Eco Harvester. Of the known private access locations, none would currently be able to accommodate the weight of the machinery (approximately 5,000 lbs with trailer) or the size (8.5 feet wide by 19 feet long) without modifications. Because mechanized equipment is used in the process, the WDNR requires a permit for mechanical harvesting activities, along with a precise plan for implementation. If a suitable access location is identified/created at a later date, the FLIA may consider mechanical harvesting as a way to address the nuisance conditions caused by HWM. But at this point, mechanical harvesting is not applicable to Forest Lake. Further, budget realities for FLIA are prohibitive for any ongoing harvesting contract. **<u>Manual Removal</u>** As discussed in the Aquatic Plants Section (3.4), manual removal of invasive aquatic plants does not require a permit from the WDNR when performed in a manner that does not excessively harm the native aquatic plant community. During these activities, all plant material needs to be completely removed from the lake. The FLIA will promote individual riparians to remove HWM within their recreational corridor to restore their ability to use this area of the lake. In select parts of the lake, coordinated manual removal will occur to create navigation lanes through dense areas. On a trial basis, volunteer members will organize work force teams to remove HWM with non-mechanized means to investigate the effectiveness and efficiency (i.e. cost and time) of the process. The FLIA will stress limiting impacts to valuable native plant communities during this process.
Action Steps:	

	See description above

Management Goal 2: Monitor Aquatic Vegetation on Forest Lake

Management Action:	Coordinate Periodic Point-Intercept Surveys
Timeframe:	Every 3-5 years depending on management strategies being employed
Facilitator:	Board of Directors
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) have been conducted on Forest Lake in 2008, 2011-2013, and 2015-2018. At each point-intercept location within the *littoral zone,* information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally recommends that a whole-lake point-intercept survey be conducted once every 5 years if a lake group wants to understand the aquatic plant community dynamics of a lake. This will also allow an understanding of changes in the EWM population for determination if active management should be considered, particularly if EWM populations continues to exceed 30% of the littoral zone as measured by the point-intercept survey. The FLIA will plan to complete a point-intercept survey on Forest Lake at approximately 5-year intervals. As outlined in the whole-lake herbicide treatment management action, point-intercept monitoring of a whole-lake treatment would occur the *year prior to the treatment*, *year of the treatment*, and *year after the treatment*.
Action Steps:	
	See description above

Management Action:	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Every 10 years unless prompted
Facilitator:	Board of Directors
Description:	In 2018, a floating-leaf and emergent community mapping survey was conducted on Forest Lake, creating a snap shot of the locations and extents of these communities in the lake. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities of Forest Lake, a community mapping survey would be conducted approximately every 10 years unless a specific rationale prompts a

	shorter interval. This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system.
Action Steps:	
	See description above

Management Action:	Coordinate professional monitoring of HWM
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	As the name implies, the Late-Season EWM Mapping Survey is completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For Forest Lake, this survey would likely take place in mid-August to late-September. This survey would include a complete meander survey of the lake's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). This survey would serve three main roles: 1) document the EWM population at the peak of its growth stage in a given year, 2) assess the management efforts that took place over the growing season, and 3) be used to formulate a management strategy. This survey was conducted on Forest Lake in 2011-2013, 2017-2019. If the FLIA is conducting or considering active HWM management, this survey would occur during the *year prior to management* and the *year of management*. The FLIA may also consider periodically conducting the Late-Season HWM Mapping Survey to track the HWM population dynamics in the lake.
Action Steps:	
	See description above as this is an established program.

Management Goal 3: 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 – Deborah Kossup, Rosalind Rouse
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring should be completed annually by Forest 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. Volunteers have historically collected Secchi disk transparency on Forest Lake as a part of the CLMN program. While some data was collected in recent years, the data has not been entered into Surface Water Integrated Monitoring System (SWIMS), the WDNR's online database. The FLIA would like to refresh this program, including working to enter past information into the database. The FLIA will also entertain the possibility of enter into the advanced CLMN program after a few years of demonstrating commitment collecting Secchi disk data. The advanced CLMN program includes the collection of water chemistry samples (chlorophyll-*a*, and total phosphorus) to be analyzed by the Wisconsin State Laboratory of Hygiene. Within this program, samples are collected three times during the summer and once during the spring. Mary Gansberg (920.662.5489) or the appropriate WDNR/UW Extension staff should be contacted to enroll in this program, ensure the proper training occurs, and the necessary sampling materials are received. It also must be noted that the CLMN program may be changing in the near future, as enrollment in the program is currently capped. If there is not an ability for the FLIA to participate in the advanced CLMN program, they are open to considering self-funding the analysis of these samples on an annual or semi-annual basis.
Action Steps:	
1.	Contact Mary Gansberg (920.662.5489) to enroll in the CLMN program.
2.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to district members during annual meeting.
3.	CLMN volunteer and/or FLIA would facilitate new volunteer(s) as needed

Management Goal 4: Increase FLIA'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
Description:	Education represents an effective tool to address many lake issues. The FLIA is comprised of a small and close group of riparian. Information is primarily spread by word of mouth, but directed outreach occurs with special mailings and at the semi-annual meetings. The FLIA has implemented a Nextdoor Page to encourage community engagement. The FLIA will continue to make the education of lake-related issues a priority, particularly at FLIA meetings. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • Specific topics brought forth in other management actions • Basic lake ecology • Boating safety & ordinances • Noise, air, and light pollution • Shoreline habitat restoration and protection • Septic Maintenance • No lawn fertilizer pledge • Water levels • Fishing regulations and overfishing • Minimizing disturbance to spawning fish
Action Steps:	
	See description above as this is an established program.

Management Action:	Continue FLIA's involvement with other entities that have responsibilities in managing (management units) Forest Lake
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The FLIA is dedicated to enhancing, preserving and protecting the quality of Forest Lake for future generations through effective environmental and education policies. The FLIA promotes policies and practices that protect the interests of Forest Lake stakeholders and enhance their ability to maximize enjoyment of their shared resource.

	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 FLIA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next pages:
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Auburn	Bonnie Berg, Clerk (auburn@kmoraine.com)	Forest Lake falls within the Town of Auburn	Once a year, or more as needed.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
FDL County Land & Water Cons. Dept.	Paul Tollard, County Conservationist (paul.tollard@wi.nacdnet.net)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements.
Wisconsin Department of Natural Resources	Addie Dutton, Fisheries Biologist (adeline.dutton@wisconsin.gov)	Manages the fishery of Forest Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Mary Gansberg– (mary.gansberg@wisconsin.gov)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Nick Miofsky, Conservation Warden (920.579.2751)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367)	Contact regarding suspected violations pertaining to recreational activity on Forest Lake, include fishing, boating safety, ordinance violations, etc.
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.	FLIA should send rep. to 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.
KM State Forest – Northern Unit	Headquarters (262-626-2116)	Forest Lake is within the state forest.	As needed.	Coordinates Parkview General Store boat rental, which are available on Forest Lake.
Friends of Kettle Moraine - Northern Unit	Jackie Schargenberg, Naturalist, (Jackie.scharfenberg@wisconsin.gov)	Nonprofit group to educate on area glacial history	As needed	Along with organizing educational outreach, also donates money raised locally.
SE Wisconsin Invasive Species Consortium	https://sewisc.org/	Promotes management of invasive species	As needed	Organizes local invasive species management, as well as provides education
Boy Scouts of America (Potawatomi Area Council)	Camp Long Lake: 920.533.8258	Camp Long Lake is located on nearby Long Lake that makes periodic trips to Forest Lake	As needed	Contact to solicit possible assistance in conducting lake stewardship activities as part of the camp experience

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 Forest 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 2017, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

Management Goal 5: Maintain and Improve Lake Resource of Forest Lake

Management Action:	Educate Stakeholders on the Importance of Shoreland Condition and Shoreland Restoration
Timeframe:	Ongoing effort
Facilitator:	Board of Directors – Rob Boehm, Jim Radtke, Diane Ostrowski
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. This is particularly important for lakes with small watersheds like Forest 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 2017, the shoreland assessment survey indicated that about a half mile, or approximately 36% of the Forest Lake's 1.2-mile shoreline, consists of *urbanized* or *developed-unnatural* areas. The FLIA would focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative.

	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 Fond du Lac 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 continue maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice)
Action Steps:	
	See description above

<u>Management Action:</u>	Determine feasibility of coarse woody habitat additions (i.e. fish sticks projects) on Forest Lake
Timeframe:	Initiate 2020
Facilitator:	Board of Directors – Gary Emmer, Al Grzywacz
Description:	Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail. The FLIA would like to focus on educating riparians about the importance of coarse woody habitat enhancement in order to help the ecosystem reach its maximum fishery potential. Further, the FLIA is considering a fish sticks demonstration project on the state-owned lands. This may provide an example for riparians with larger lot sizes to consider adding woody habit. The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (fish sticks). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced

	engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
	  o The landowner would need to commit to leaving the area un-mowed
	  o The landowner would need to implement a native planting (also cost share thought this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
1.	Recruit facilitator from Planning Committee (potentially same facilitator as previous management actions).
2.	Facilitator contacts WDNR Fisheries Biologist to gather information on initiating and conducting coarse woody habitat projects.

Management Action:	Conduct supplemental fish stocking
Timeframe:	Ongoing effort
Facilitator:	Board of Directors – John Bardenwerper
Description:	Because of Forest Lake's limited public access, the WDNR plays a limited role in actively managing or monitoring the fisheries of Forest Lake. The FLIA will continue to conduct private fish stocking, specifically largemouth bass, black crappie, northern pike, and yellow perch as fundraising allows and approval from WDNR is received.
Action Steps:	
	See description above as this is an ongoing effort

Management Action:	Work with WDNR to increase the population and size structure of panfish in Forest Lake
Timeframe:	Initiate 2020
Facilitator:	Board of Directors – John Bardenwerper
Description:	Forest Lake is currently a catch-and-release lake for gamefish and a harvestable lake for panfish. The current regulation allows 25 panfish to be harvested from Forest Lake. The FLIA would like to lobby the WDNR to consider a revised set of regulations for panfish in attempt to increase the population and size structure. These concepts are supported in the WDNR's Panfish Plan (click here) and trial panfish regulations (click here).
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 Forest Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Forest 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)

Early Season AIS Survey

Early Season AIS Surveys were completed annually on Forest Lake in 2017 in order to correspond with the anticipated peak growth of curly-leaf pondweed and pale yellow iris.. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Forest 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. A point spacing of 33 meters was used resulting in approximately 184 points.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Forest 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.

AIS Monitoring Surveys

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

Acoustic Modeling Survey

During the mid- to late-summer 2018, Onterra systematically collected continuous, advanced sonar data across Forest Lake. The resulting data was electronically sent to a Minnesota-based firm (Navico) for initial processing. The acoustic data collected during the lake management planning project was analyzed for bathymetry, submersed aquatic vegetation bio-volumes, and substrate analysis models.

7.0 LITERATURE CITED

Asplund, T.R. and C.M. Cook. 1997. Effects of motor boats on submerged aquatic macrophytes. Lake and Reserv. Manage. 13(1): 1 – 12.

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. London, EnFLIAnd.

Boston, H.L. and M.S. Adams. 1987. Productivity, growth, and photosynthesis of two small 'isoetid' plants, *Littorella uniflora*, and *Isoetes macrospora*. J. Ecol. 75: 333 – 350.

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

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

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

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

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

Fischer J.R. and R.M. Krogman. 2013. Influences of native and non-native benthivorous fishes on aquatic ecosystem degradation. Hydrobiologia. Vol. 711. 187–199.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

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

Garrison, P., Jennings, M., Mikulyuk, A., Lyons, J., Rasmussen, P., Hauxwell, J., Wong, D., Brandt, J. and G. Hatzenbeler. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. Pub-SS-1044.

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

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

Great Lakes Indian Fish and Wildlife Service. 2017A. Interactive Mapping Website. Available at http://maps.glifwc.org. Last accessed January 2018.

Great Lakes Indian Fish and Wildlife Service. 2017B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Regulations/WI_Spearing.pdf. Last accessed January 2018.

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

Hinterthuer, A. 2015. Lake Invaders: Raise the Cost of Conservation Efforts. Limnology News. 24. Available at: https://limnology.wisc.edu/annual-limnology-newsletter/lake-invaders-raise-the-cost-of-conservation-efforts/

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

Knight, S. and J. Havel. 2013. A field test on the effectiveness of milfoil weevils for controlling Eurasian water-milfoil in northern lakes. Progess report.

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

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

Lin Y. and C.H. Wu. 2013. Response of bottom sediment stability after carp removal in a small lake. Ann. Limnol. – Int. J. Lim. Vol. 49. 157–168.

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

Lutze, Kay. 2015. 2015 Wisconsin Act 55 and Shoreland Zoning. State of Wisconsin Department of Natural Resources

Murphy, K.J. and J.W. Eaton. 1983. Effects of pleasure-boat traffic on macrophyte growth in canals. Journal of Applied Ecology 20: 713 – 729.

Netherland, M.D. 2009. Chapter 11, "Chemical Control of Aquatic Weeds." Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook,* L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

Neuswanger, D., and M. A. Bozek. 2004. Preliminary Assessment of Effects Of Rock Habitat Projects On Walleye Reproduction In 20 Northern Wisconsin Lakes.

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

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

Panuska, J.C., and J.C. Kreider. 2003. Wisconsin Lake Modeling Suite Program Documentation and User's Manual Version 3.3. WDNR Publication PUBL-WR-363-94.

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

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

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

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

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

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

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

United States Environmental Protection Agency. 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

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

Vermaat, J.E. and R.J. De Bruyne. 1993. Factors limiting the distribution of submersed waterplants in the lowland River Vecht (The Netherlands). Freshwat. Biol. 30: 147 – 157.

Weber, M.J., M.J. Hennen, and M.L. Brown. 2011. Simulated population responses of common carp to commercial exploitation. North American Journal of Fisheries Management. Vol. 31. 269–279.

Wersal, R. and A. Khanzada. 2015. Comparison of Select Herbicides, Algaecides, and Adjuvants for Control of Hybrid Watermilfoil from Forest Lake, WI: Mesocosm Evaluation. Confidential Report by Lonza.

Whittier, T.R., Ringold, P.L., Herlihy, A.T. and S.M Pierson. 2008. A calcium-based invasion risk assessment for zebra and quagga mussels (*Dreissena* spp). Frontiers In Ecology and the Environment. Vol. 6(4): 180-184

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

Wisconsin Department of Natural Resources – Bureau of Science Services. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. PUB-SS-1044.

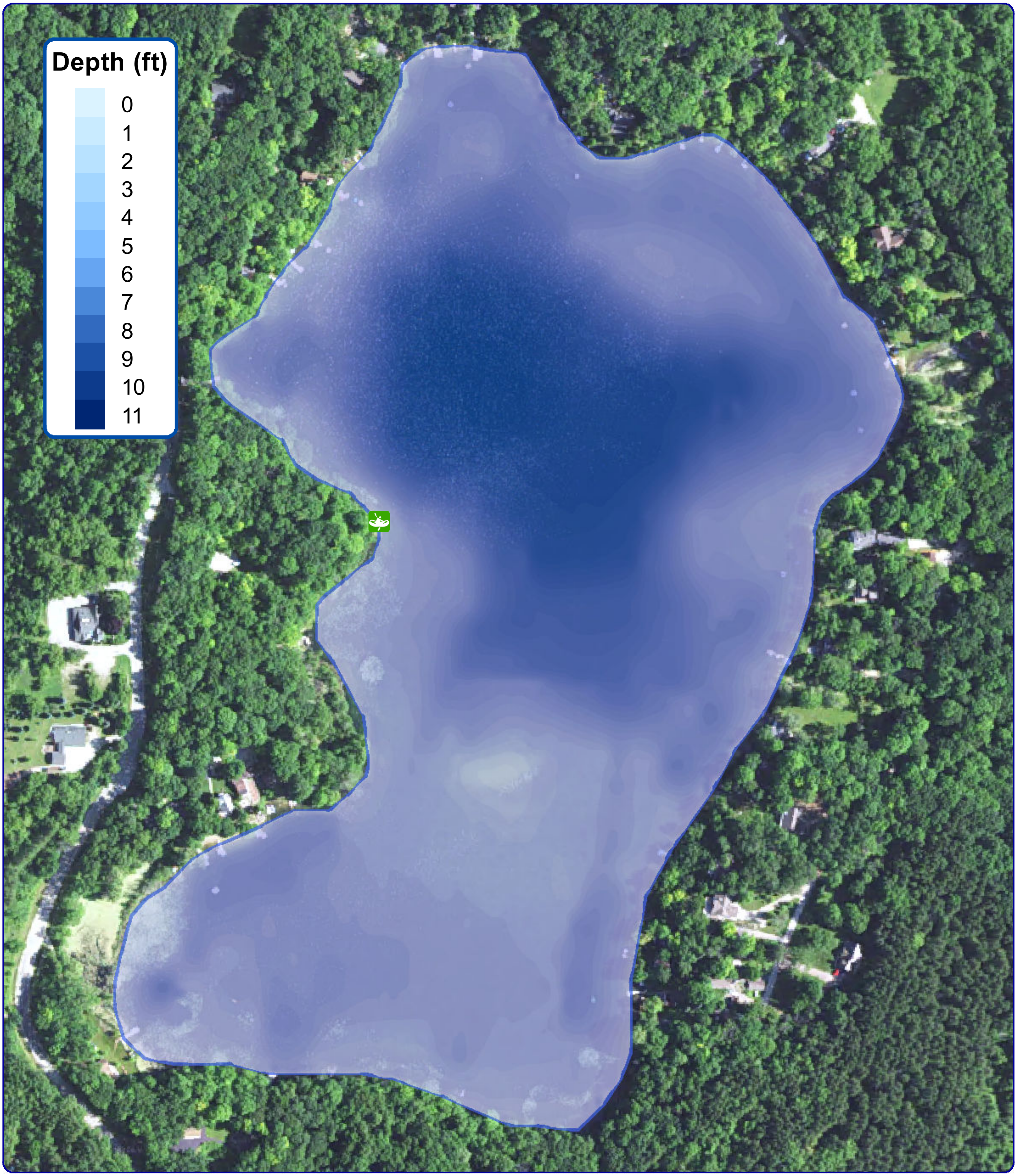
Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2014. Fish sticks: Improving lake habitat with woody structure. Available at: http://dnr.wi.gov/topic/fishing/documents/outreach/FishSticksBestPractices.pdf

Wisconsin Department of Natural Resources – Bureau of Fisheries Management. 2017. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed January 2018.

Wisconsin Department of Natural Resources (WDNR). 2017. Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM). Bureau of Water Quality Program Guidance.

Wisconsin Open Water Spearing Report (Annual). Great Lakes Indian Fish and Wildlife Commission. Administrative Reports. Available at: http://data.glifwc.org/reports/.

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



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Feet

Onterra LLC
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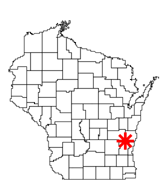
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map Date: February 15, 2019 JMB
Filename: Map1_ForestFDL_Location.mxd


Project Location in Wisconsin

Legend

Forest Lake ~51 acres

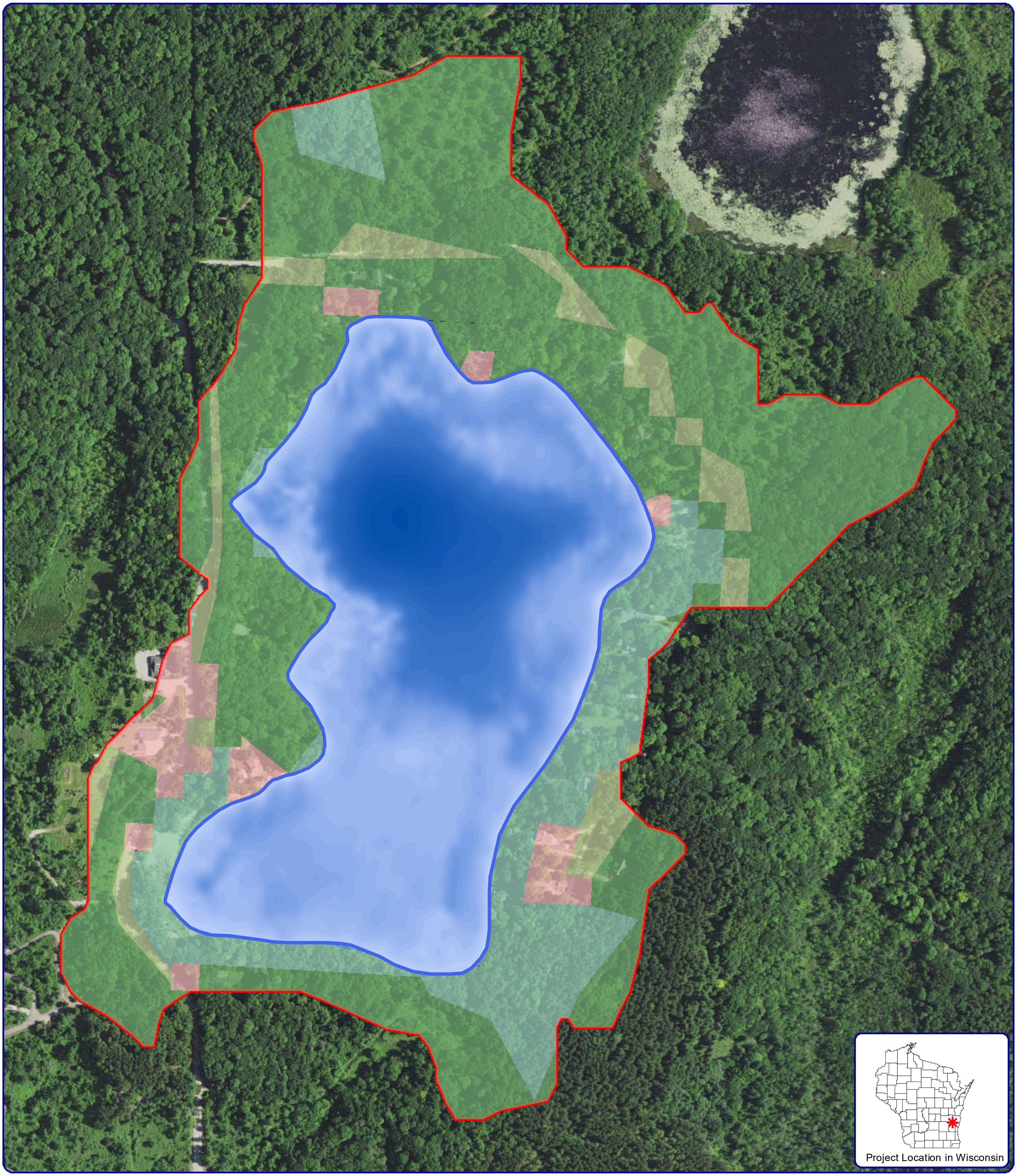
Carry-in Access

Map 1

Forest Lake

Fond du Lac County, Wisconsin

Project Location & Lake Boundaries



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Legend

Land Cover Types

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

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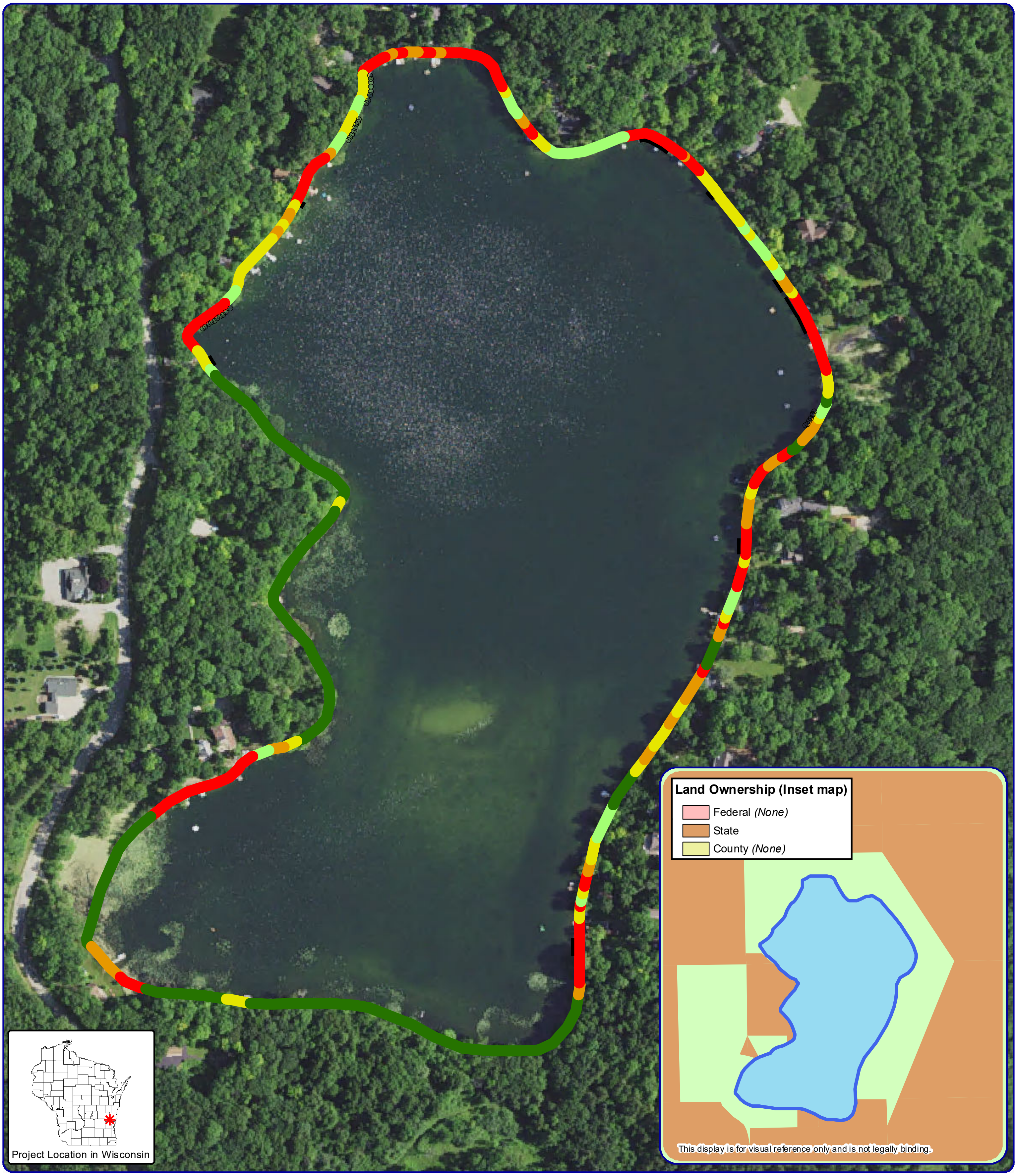
Sources:
Land Cover: NLCD, 2011
Orthophotography: NAIP, 2015
Hydro: WDNR
Map Date: February 15, 2019 JMB
Filename: ForestFDL_WS_2018.mxd

Map 2

Forest Lake

Fond du Lac County, Wisconsin

Watershed Boundaries & Land Cover Types



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Sources:
Roads and Hyrdo: WDNR
Shoreline Assessment: Onterra, 2017
Map Date: October 27, 2017
Filename: Forest_ShorelandCondition_2017.mxd

Legend

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

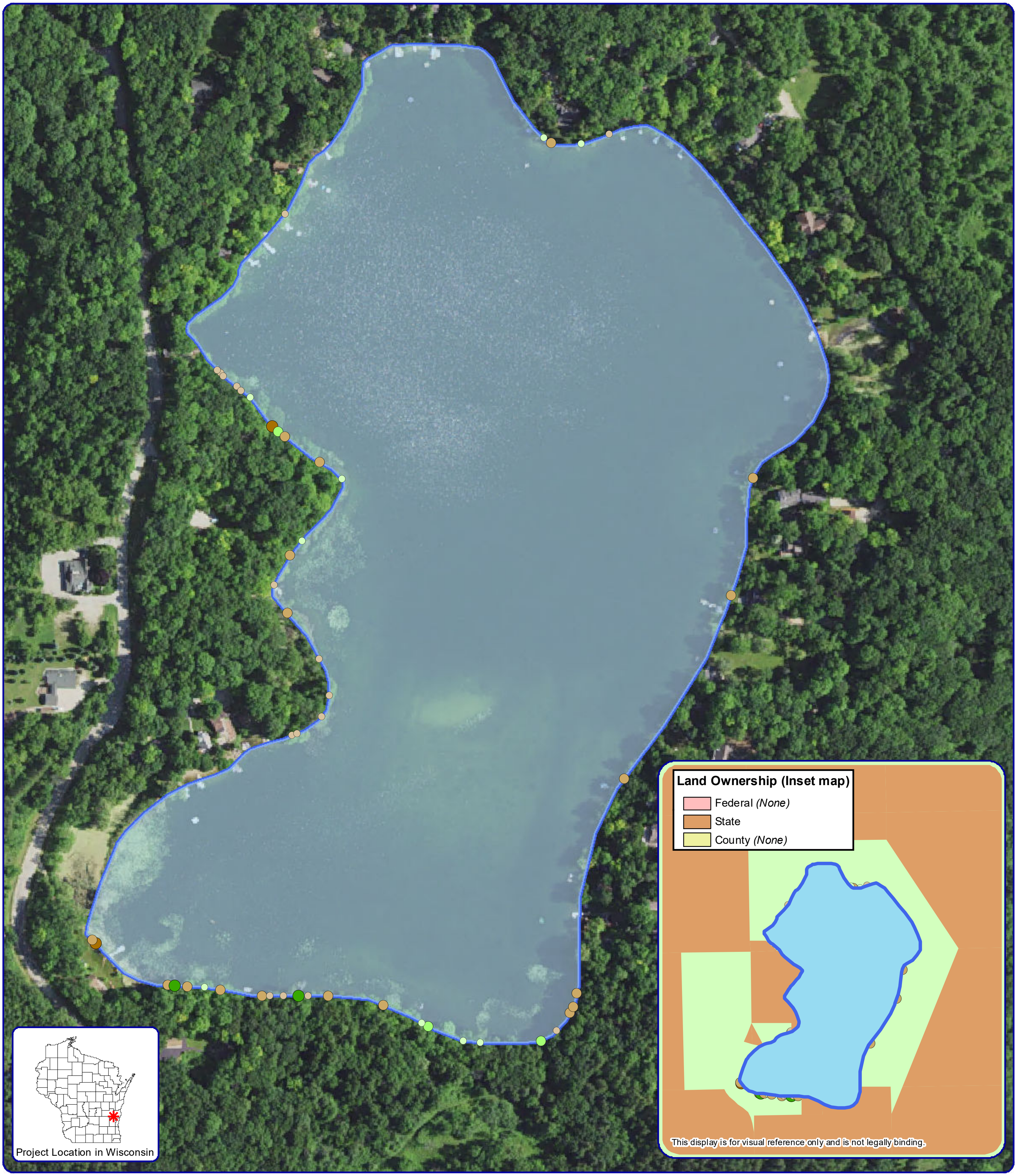
Seawall

- Masonry/Wood/Metal
- Rip-Rap

Map 3

Forest Lake
Fond du Lac County, Wisconsin

2017 Shoreline Condition Assessment



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Legend

2-8 Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy *(None)*

8+ Inch Pieces
- No Branches
- Minimal Branches
- Moderate Branches
- Full Canopy *(None)*

Cluster of Pieces
- No Branches *(None)*
- Minimal Branches *(None)*
- Moderate Branches *(None)*
- Full Canopy *(None)*

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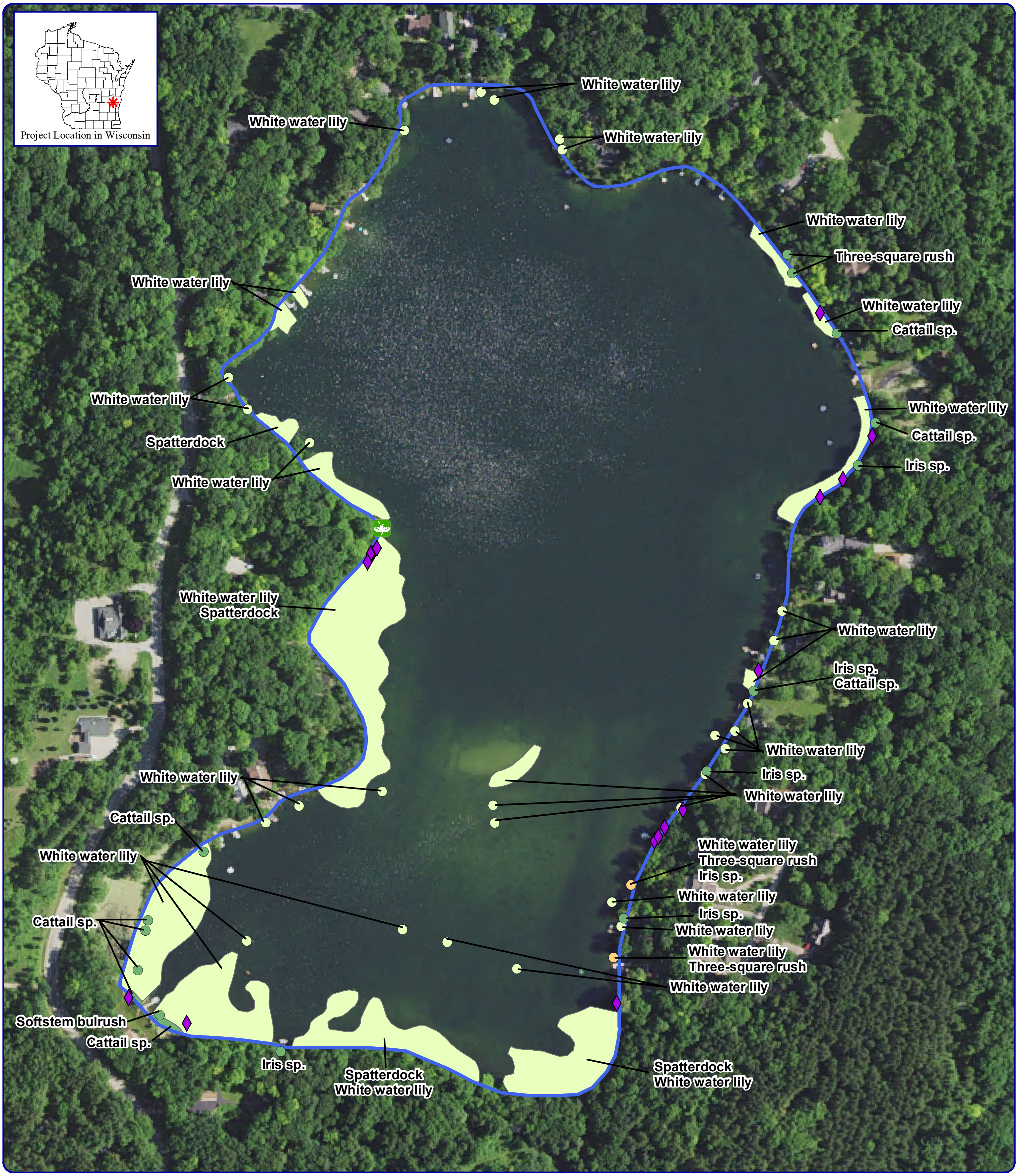
Sources:
Roads and Hyrdo: WDNR
CWH Survey: Onterra, 2017
Map Date: October 27, 2017
Filename: Forest_CWH_2017.mxd

Map 4
Forest Lake
Fond du Lac County, Wisconsin
2017 Coarse Woody Habitat Survey Results



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Legend

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

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

Exotic Plant Communities
- Purple Loosestrife

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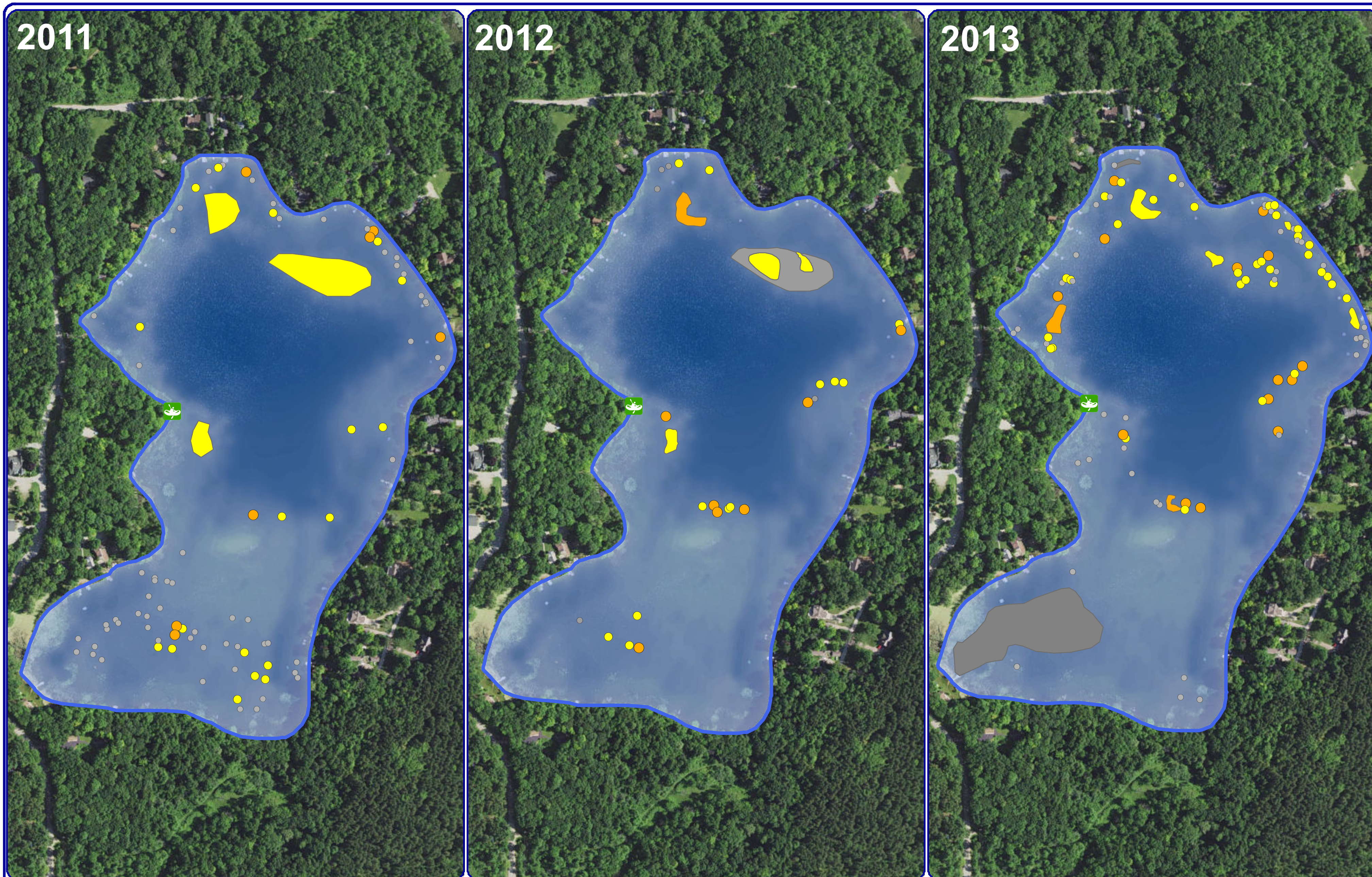
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2018
Orthophotography: NAIP, 2017
Map date: October 11, 2018 JLW
Filename: Forest_Comm_2018.mxd

Map 5
Forest Lake
Fond du Lac County, Wisconsin
Aquatic Plant Communities



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Feet

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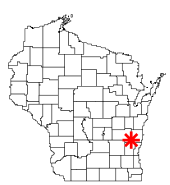
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2011-2013
Map Date: February 15, 2019
Filename: ForestFDL_EWMSeries_'11-13

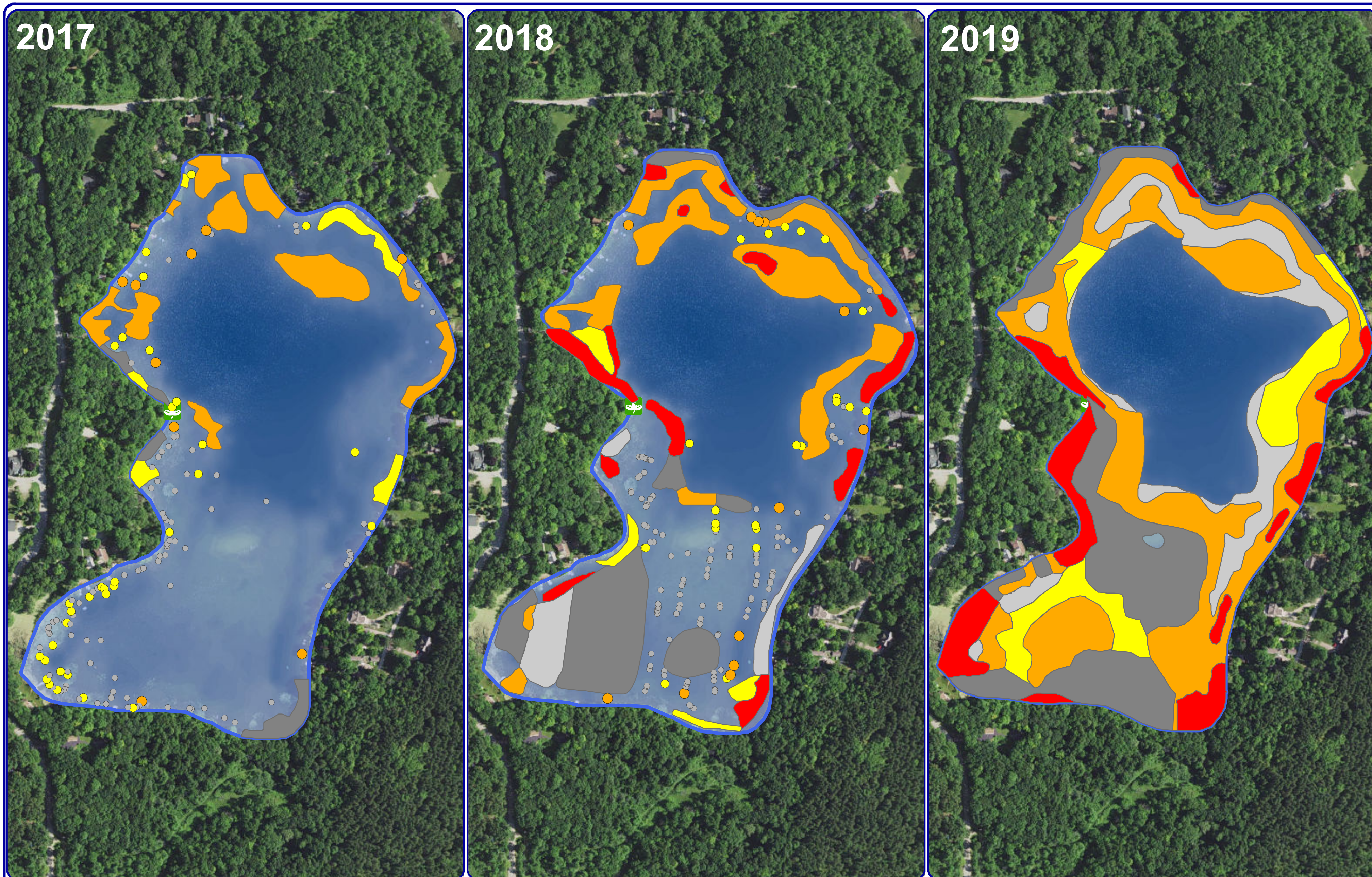

Project Location in Wisconsin

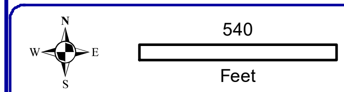
Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 6
Forest Lake
Fond Du Lac, Wisconsin

Late-Summer EWM Surveys: 2011-2013





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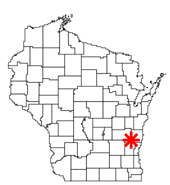
Sources:
Roads and Hydro: WDNR
Aquatic Plants: Onterra, 2011-2013
Map Date: February 15, 2019
Filename: ForestFDL_EWMSeries_'11-13



Project Location in Wisconsin

Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 7
Forest Lake
Fond Du Lac, Wisconsin

Late-Summer EWM Surveys: 2017-2019