# Forest Lake

**Vilas County, Wisconsin**

# Comprehensive Management Plan

**January 2019**

Sponsored by:

**Forest Lake Association, Inc. &**

**Town of Land O' Lakes**

WDNR Grant Program

AEPP-478-16

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Onterra LLC
Lake Management Planning

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Vilas County, Wisconsin

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January 2019

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Funded by: Forest Lake Association, Inc.
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## Acknowledgements

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

**Forest Lake Planning Committee**

| | | |
|---|---|---|
| Bruce Smit | Tom Janovsky | Tom Macak |
| John Reehl | Janine Smith | Steve Bablich |
| Colin Fitzgerald | | |

**Town of Land O' Lakes for sponsoring AIS-Education, Prevention, and Planning Grant**

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# 1.0 INTRODUCTION

Forest Lake, Vilas County, is a 469-acre seepage lake with a maximum depth of 53 feet and a mean depth of 24 feet. This oligo-mesotrophic lake has a relatively small watershed when compared to the size of the lake. Forest Lake contains 46 native plant species, of which fern-leaf pondweed is the most common plant. One exotic plant species is known to exist in Forest Lake.

**Field Survey Notes**

*Forest Lake is located in the township of Land O' Lakes. The lake has excellent water clarity and beautiful stretches of natural shoreland. Anecdotal data indicates that Forest Lake has experienced wide fluctuations in water levels.*

**Photograph 1.0-1 Forest Lake, Vilas County**

## Lake at a Glance – Forest Lake

| | |
|---|---|
| **Morphology** | |
| Acreage | 469 |
| Maximum Depth (ft) | 53 |
| Mean Depth (ft) | 24 |
| Shoreline Complexity | 5.5 |
| **Vegetation** | |
| Early Season AIS Survey Date | June 29, 2016 |
| Comprehensive Survey Date | July 27, 2016 |
| Number of Native Species | 46 |
| Threatened/Special Concern Species | - |
| Exotic Plant Species | Eurasian watermilfoil |
| Simpson's Diversity | 0.87 |
| Average Conservatism | 6.6 |
| **Water Quality** | |
| Trophic State | Oligo-mesotrophic |
| Limiting Nutrient | Phosphorus |
| Water Acidity (pH) | 8.0 |
| Sensitivity to Acid Rain | Low |
| Watershed to Lake Area Ratio | 1:1 |

Forest Lake is located approximately 8 miles west of Land O' Lakes, a popular tourist area in northern Wisconsin. The lake is a popular fishing spot and listed as a Wisconsin Area of Special Interest due to its naturally reproducing walleye population. The lake is accessed through a single boat landing meeting minimum requirements (approx. 10 spaces in addition to adjacent roadway parking) and via the Wilderness Lakes Trail System (biking and hiking).

Forest Lake's primary management unit is the Forest Lake Association, Inc. (FLA). FLA has partnered with the Town of Land O' Lakes to complete this project and the town is the sponsor of the grant.

# 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.

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

**Kick-off Meeting**

On August 6, 2016, a project kick-off meeting was held at the Land O' Lakes Pavilion to introduce the project to the general public. The meeting was announced through a mailing and personal contact by FLA board members. The approximately 66 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

**Planning Committee Meeting I**

The first Forest Lake Planning Committee meeting took place on July 19, 2017, included seven members of the committee, and lasted three hours. The primary objective of the meeting was to bring about a solid understanding of the data that was collected during the project and compiled from historical records. This was accomplished by Onterra providing the results sections of the primary study components (water quality, watershed, aquatic plants, and stakeholder survey) a week prior to the meeting and then going over the results in detail during the meeting. All committee questions were answered during the meeting as well as a very productive discussion by the group.

**Planning Committee Meeting II**

The second Forest Lake Planning Committee meeting was held on September 14, 2017 and lasted approximately two and half-hours. Four members of the committee were in attendance and discussion was centered on creating a framework of management goals and actions that would then be used by Onterra staff to create full, written implementation plan for Forest Lake. During the meeting the challenges that faced Forest Lake and the Forest Lake Association in managing the lake were discussed. Each of those challenges were then represented in one or more management goals. The committee then developed appropriate management actions to meet those goals.

**Project Wrap-up Meeting**
This will be completed by Planning Committee members during the 2019 Forest Lake Association Annual Meeting.

**Management Plan Review and Adoption Process**
The first draft of the implementation plan was provided to the Planning Committee in September 2018. The committee reviewed the plan and through the committee chair, provided several simple changes that they would like to see in the plan. Those changes were integrated within the plan and it was subsequently accepted by the committee.

During the spring of 2019, the Forest Lake Association Board of Directors will vote to accept the management plan following the integration of appropriate WDNR comments.

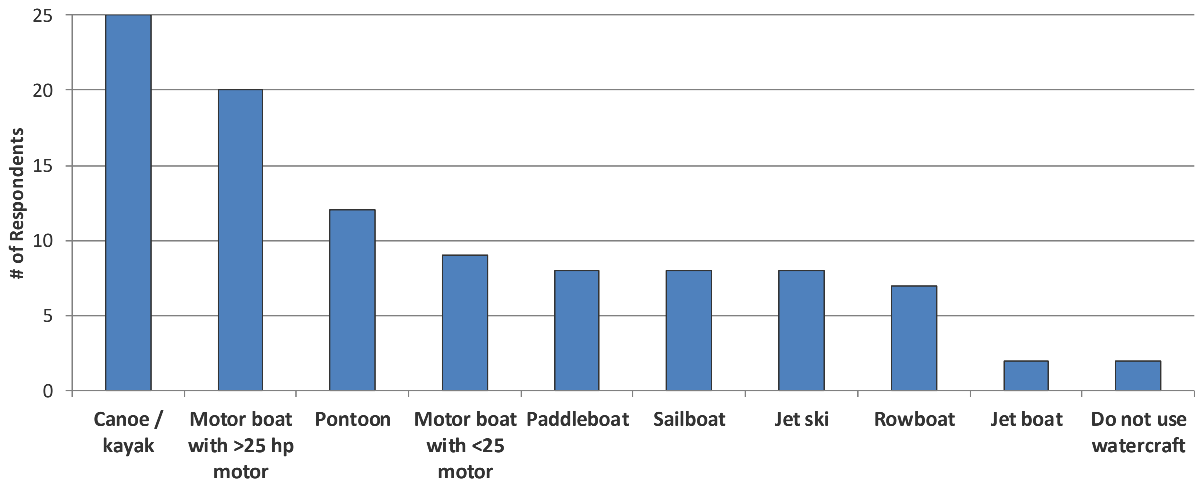
**Stakeholder Survey**
As a part of this project, a stakeholder survey was distributed to riparian property owners around Forest Lake. The survey was designed by Onterra staff and the FLA planning committee and reviewed by a WDNR social scientist. During November 2016, the eight-page, 35-question survey 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 FLA volunteer for analysis. Thirty-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 summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Forest Lake. The about a third of the stakeholders (34%) live on the lake during the summer months only, while 28% visit on weekends through the year, 16% are year-round residents, and 3% have undeveloped property. 69% of stakeholders have owned their property for over 15 years, and 41% have owned their property for over 25 years.

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

A concern of stakeholders noted throughout the stakeholder survey (see Questions 21-22 and survey comments – Appendix B) was aquatic invasive species introduction, excessive fishing pressure, and swimmer's itch in Forest Lake.

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




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

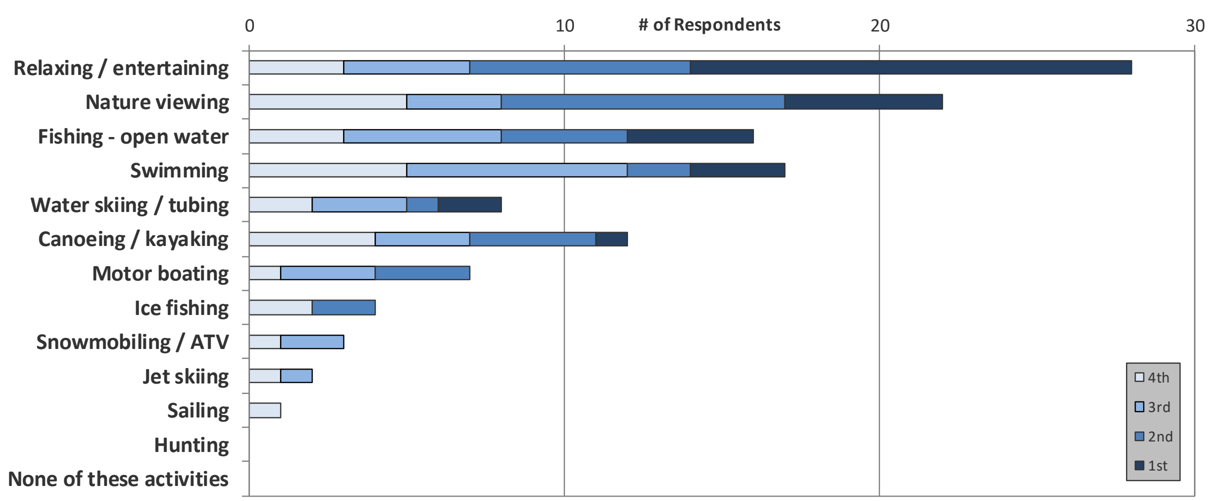
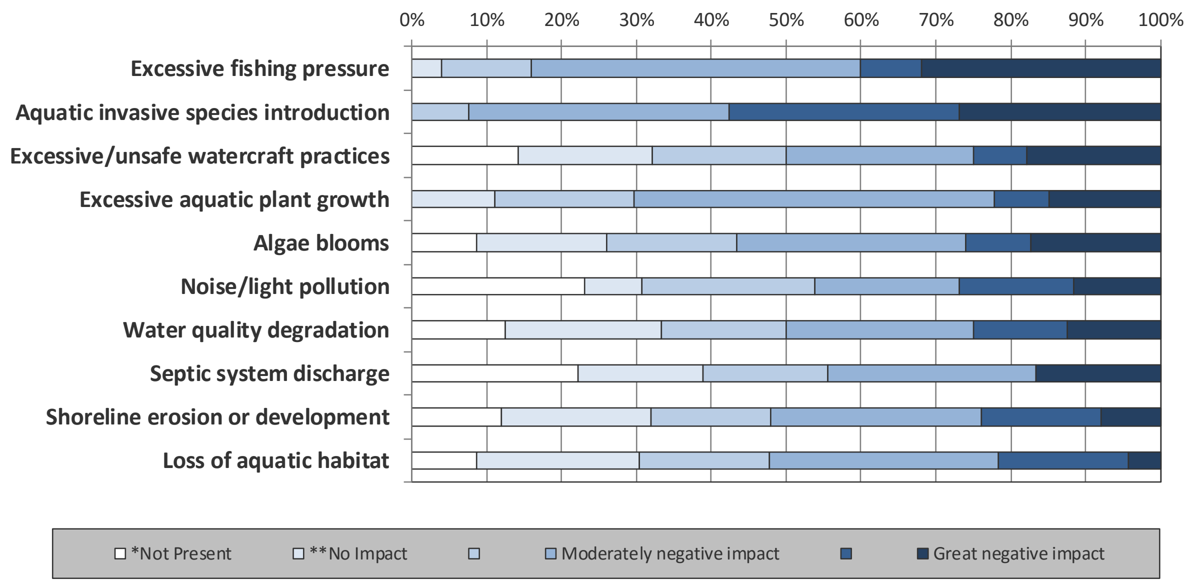



**Figure 2.0-1. Select survey responses from the Forest Lake Stakeholder Survey.** Additional questions and response charts may be found in Appendix B.

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




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

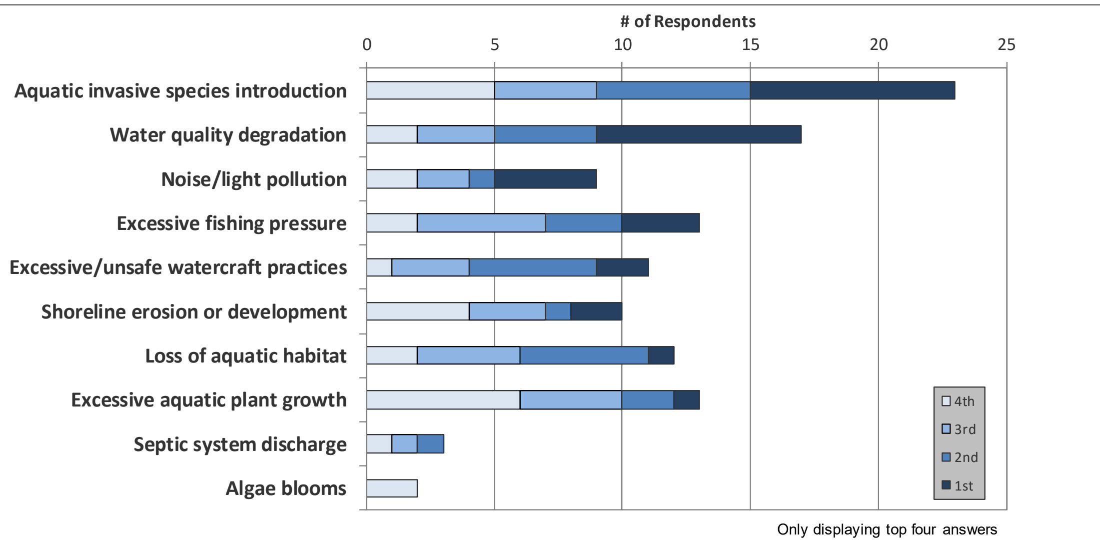



**Figure 2.0-2. Select survey responses from the Forest Lake Stakeholder Survey, continued.** Additional questions and response charts may be found in Appendix B.

# 3.0 RESULTS & DISCUSSION

## 3.1 Lake Water Quality

### *Primer on Water Quality Data Analysis and Interpretation*

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

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

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

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.

**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.

### Internal Nutrient Loading

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

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

**Non-Candidate Lakes**

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

**Candidate Lakes**

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

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

## Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) 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, small watershed and hydrology, Forest Lake is classified as a deep seepage lake (category 7 on Figure 3.1-1).

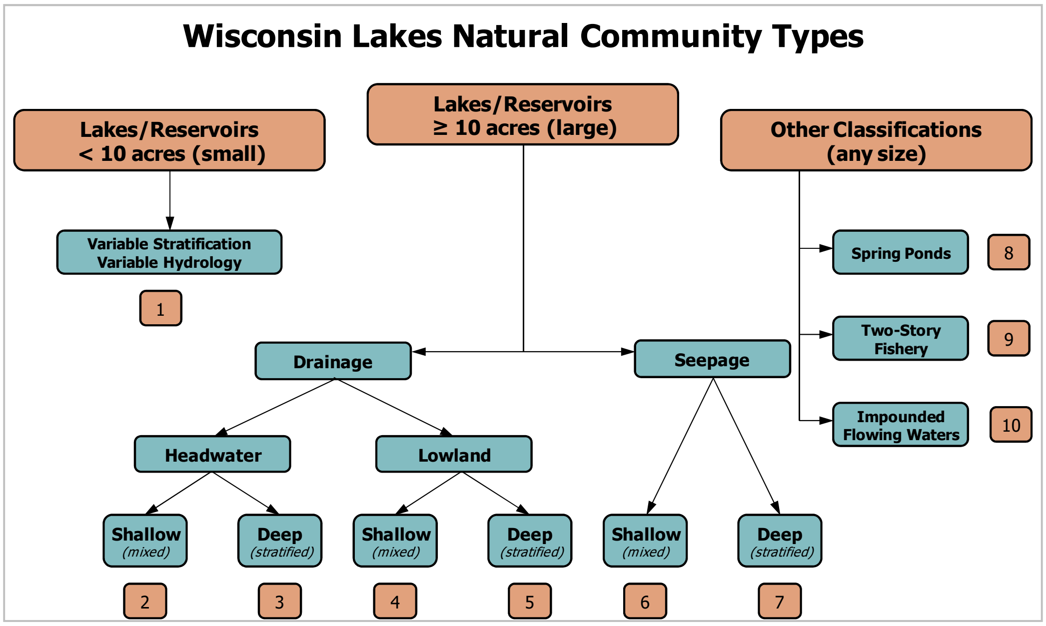



**Figure 3.1-1. Wisconsin Lake Natural Communities.** Forest Lake is considered a deep seepage lake, category 7. Adapted from WDNR 2013A.

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

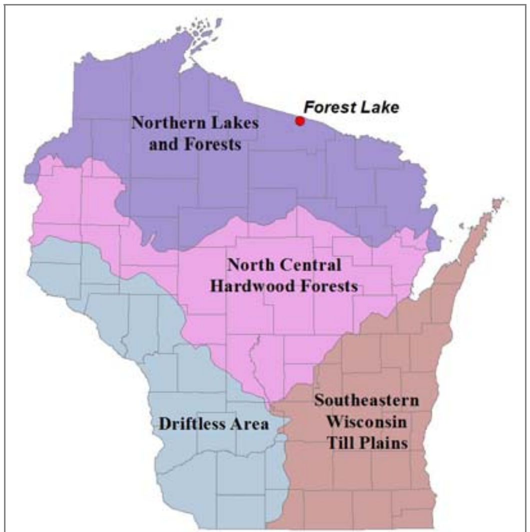



**Figure 3.1-2. Location of Forest Lake within the ecoregions of Wisconsin.** After Nichols 1999.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from Forest Lake is displayed in Figures 3.1-3 - 3.1-9. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

## *Forest Lake Water Quality Analysis*

### Forest Lake Long-term Trends

Near-surface total phosphorus data from Forest Lake are available annually from 1997 to 2016 (Figure 3.1-3). Average summer total phosphorus concentrations ranged from 8.0 µg/L in 2003 to 24.0 µg/L in 2006 and 2007. The weighted summer average total phosphorus concentration is 14.1 µg/L and falls into the *excellent* category for Wisconsin's deep seepage lakes and indicates Forest Lake's phosphorus concentrations are relatively similar to the majority of other deep seepage lakes in the state and lower than the majority of lakes within the NLF ecoregion.

Chlorophyll-*a* concentration data are available from Forest Lake annually from 1997 to 2016 (Figure 3.1-4). Average summer chlorophyll-*a* concentrations ranged from 0.9 µg/L in 2016 to 6.5 µg/L in 2014. The weighted summer chlorophyll-*a* concentration is 2.5 µg/L and falls within the *excellent* category for chlorophyll-*a* concentrations in Wisconsin's deep seepage lakes. The weighted summer average chlorophyll-*a* concentration falls below the median concentrations for deep seepage lakes in Wisconsin and all lake types within the NLF ecoregion. The 2016 summer chlorophyll-a concentration was below the weighted average, with an average concentration of 0.9 µg/L.

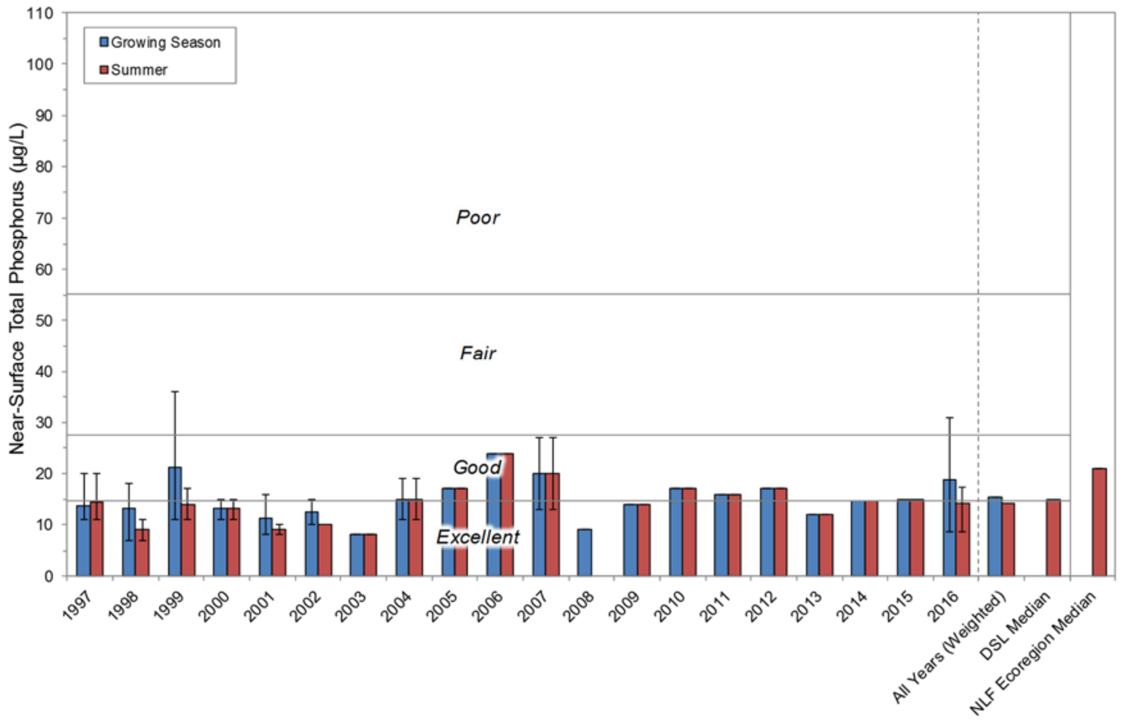



**Figure 3.1-3. Forest Lake, state-wide class 7 lakes, and regional total phosphorus concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

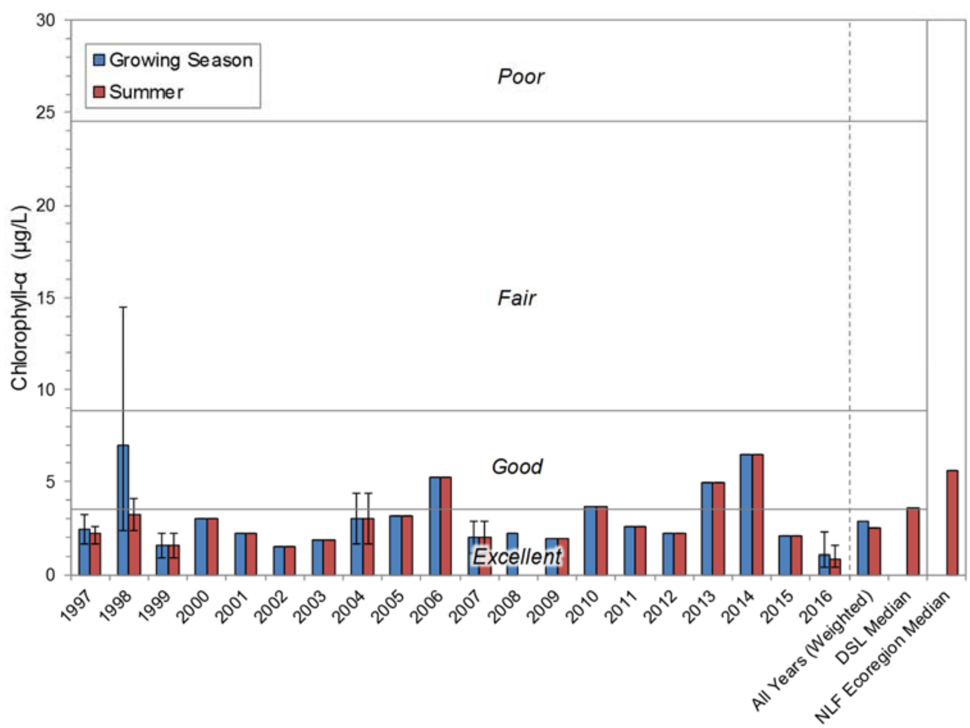



**Figure 3.1-4. Forest Lake, state-wide class 7 lakes, and regional chlorophyll-a concentrations.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Annual Secchi disk transparency data are available from Forest lake from 1990, 1996-2003, and intermittently from 2008 to 2016 (Figure 3.1-5). Average summer Secchi disk depth ranged from 10.8 feet in 1999 to 23 feet in 2011. The weighted summer average Secchi disk depth is 17.3 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 Wisconsin and all lake types within the NLF ecoregion. Forest Lake has higher water clarity than the majority of other deep seepage lakes in Wisconsin and all lakes within the NLF ecoregion.

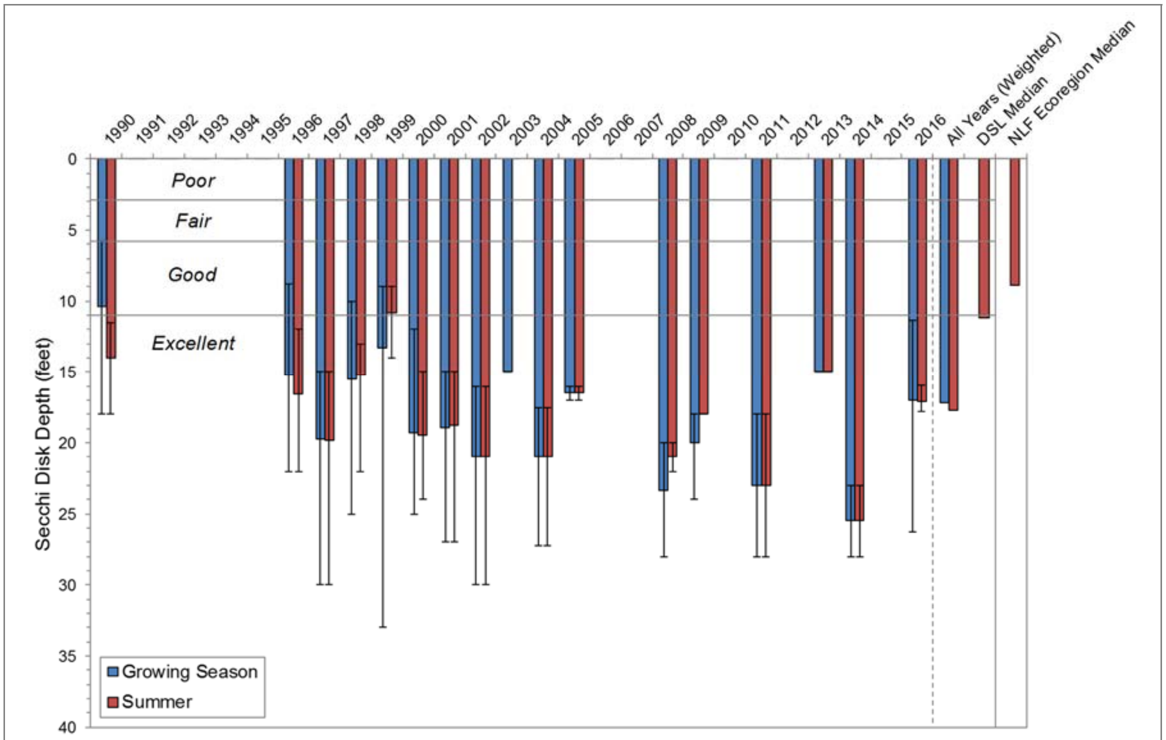



**Figure 3.1-5. Forest Lake, state-wide class 7 lakes, and regional Secchi disk clarity values.** Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading (discussed in the primer section) is a significant source of phosphorus in Forest Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom and near-surface total phosphorus concentrations are displayed in Figure 3.1-6 from five occasions from Forest Lake in 2016. As illustrated, in May of 2016 the near-bottom total phosphorus concentrations is similar to the concentration measured near the surface, but on all other occasions near-bottom concentrations are higher than near-surface concentrations and continue to increase throughout the summer. The higher concentrations of phosphorus near the bottom occurred when Forest Lake was stratified and the bottom layer of water (hypolimnion) was anoxic. These higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia. Figure 3.1-6 also displays the mass of phosphorus within the volume of the epilimnion and the hypolimnion as calculated with the concentrations shown on the chart.

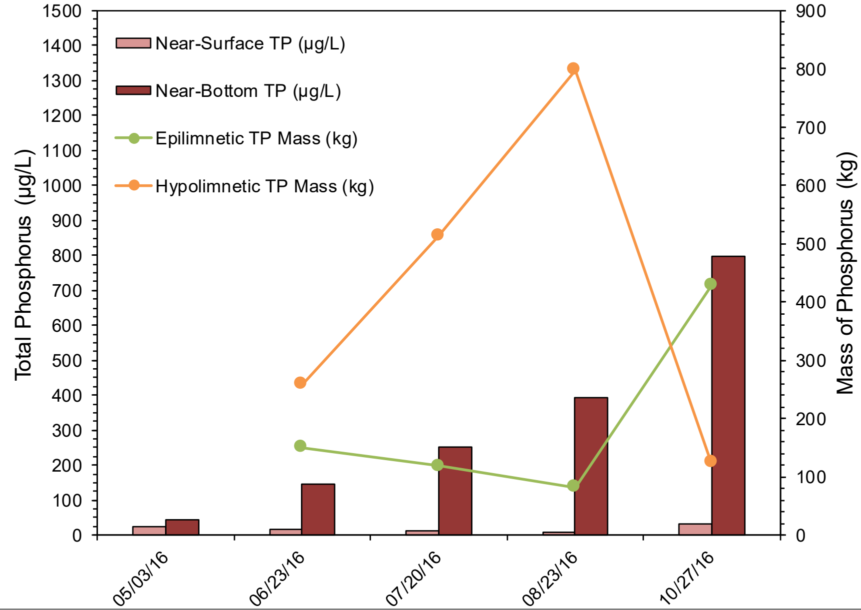



**Figure 3.1-6. Forest Lake near- surface and near-bottom total phosphorus concentrations and corresponding phosphorus mass in the epilimnion and hypolimnion.**

Forest Lake is dimitic lake; therefore, the lake only mixes twice each year during the spring and fall turnover events. During the summer in which the phosphorus is being released from the sediments, in this case, 2016, the phosphorus is not being utilized by algae because it is trapped in the hypolimnion, well below the depths the algae populate. In Figure 3.1-6, the October sample, which was collected as the lake was nearing complete turnover, a distinct increase in near-surface phosphorus concentrations and epilimnetic phosphorus mass is apparent. This pattern is also noticeable in Figure 3.1-7, which shows the changes in phosphorus, chlorophyll-*a*, and water transparency over the 2016 growing season, as well as Figure 3.1-8, which displays the averages of those parameters on a monthly basis utilizing the entire dataset available for Forest Lake. In Figure 3.1-8, on average, as phosphorus concentrations increase from the addition of the hypolimnetic phosphorus during fall turnover, the experiences a slight algae bloom as indicated by the increase in chlorophyll-*a*. In the same chart, it appears that average spring phosphorus concentrations are slightly higher than the fall, which is likely brought on by residual fall phosphorus levels brought on by the fall turnover and increased runoff resulting from snow melt and spring rains.

Overall, it is apparent that internal nutrient loading is occurring in Forest Lake, as it does in many lakes in Wisconsin. Further, the lake is experiencing higher algae biomass, especially in the fall, as a result of the internal load. However, while the increase is noticeable in the data used in this study, it is likely not noticeable to riparians in most years.

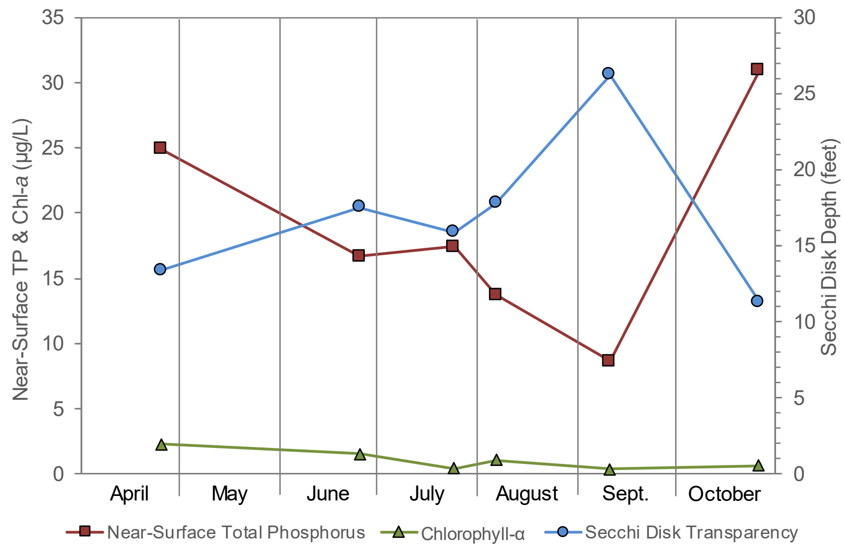



**Figure 3.1-7. Forest Lake 2016 average monthly near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency.**

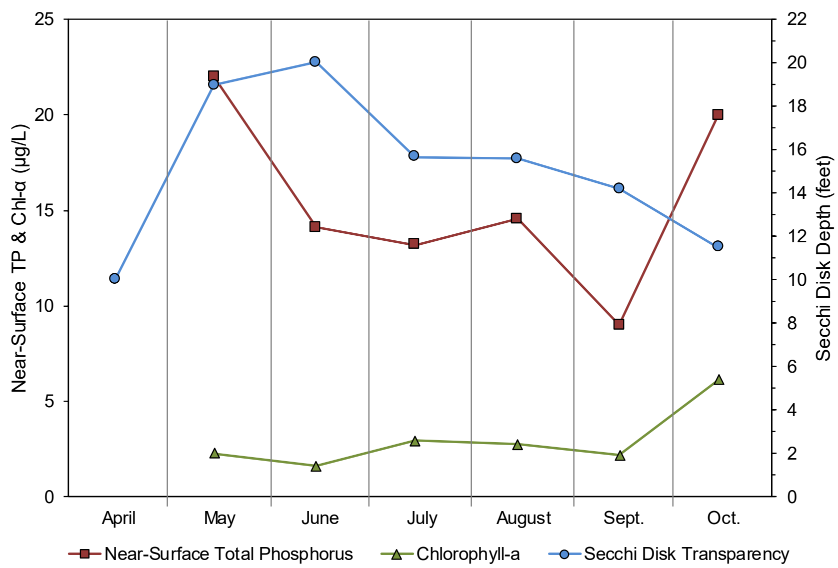



**Figure 3.1-8. Forest Lake average monthly near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency using all available data.**

## Limiting Plant Nutrient of Forest Lake

Using midsummer nitrogen and phosphorus concentrations from Forest Lake, a nitrogen:phosphorus ratio of 40:1 was calculated. This finding indicates that Forest Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes and that phosphorus is the primary nutrient regulating phytoplankton production. If phosphorus inputs to Forest Lake were to increase, phytoplankton production would likely also increase.

## Forest Lake Trophic State

Figure 3.1-8 contains the 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 along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Forest Lake indicate the lake is at present in an oligo-mesotrophic state. Forest Lake's productivity is lower when compared to both other deep seepage lakes in Wisconsin and other lakes within the NLF ecoregion.

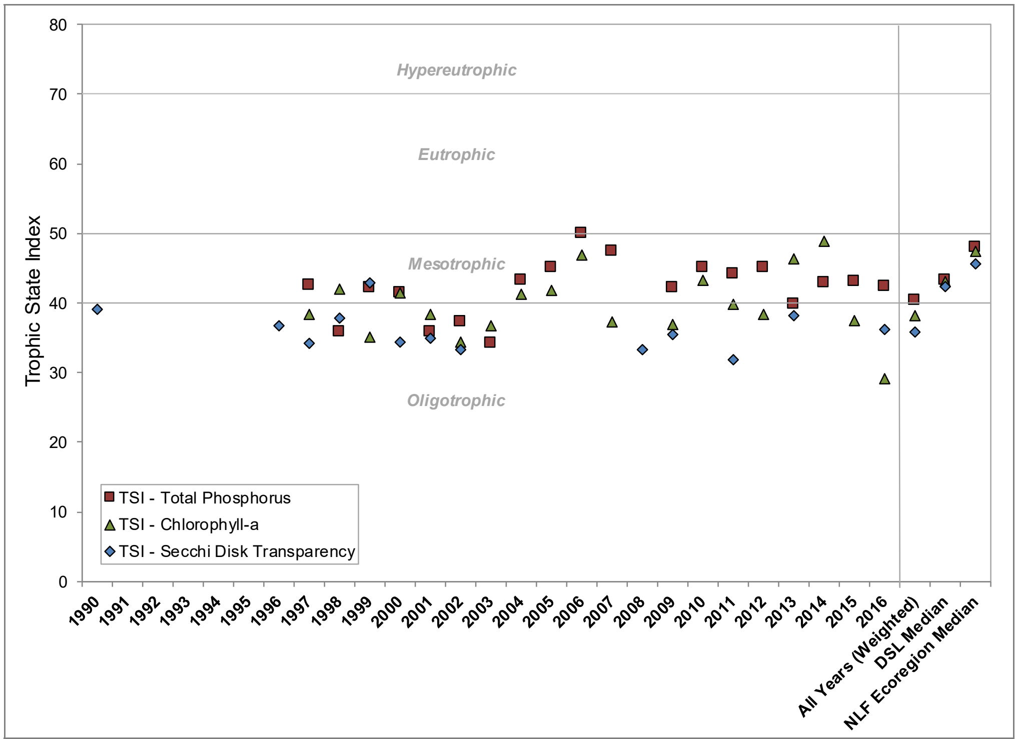



**Figure 3.1-8. Forest Lake, state-wide class 7 lakes, and regional Trophic State Index values.** Values calculated with summer month surface sample data using WDNR PUB-WT-193.

## Dissolved Oxygen and Temperature in 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 3.1-9. These data indicate that Forest Lake stratifies during the summer, but only the water near the bottom becomes anoxic. The data also indicates that there was sufficient oxygen throughout most of the water column under the ice to support the fishery during late-winter sampling.

Forest Lake has a positive *heterograde* profile [an increase in dissolved oxygen in the metalimnion due to phytoplankton photosynthesis] and is experiencing a metalimnetic oxygen maxima during the summer. This type of profile occurs because there is a large algal community in the metalimnion. Lakes that exhibit this profile need to have good water clarity in the epilimnion so that sufficient light reaches the metalimnion to support photosynthesis. Algae thrive in this deeper water because there is sufficient light and higher amounts of nutrients, e.g. phosphorus, in these deeper waters. If there is sufficient light reaching the metalimnion, but there is not a large algal community, this indicates that nutrient levels are low in this part of the water column.

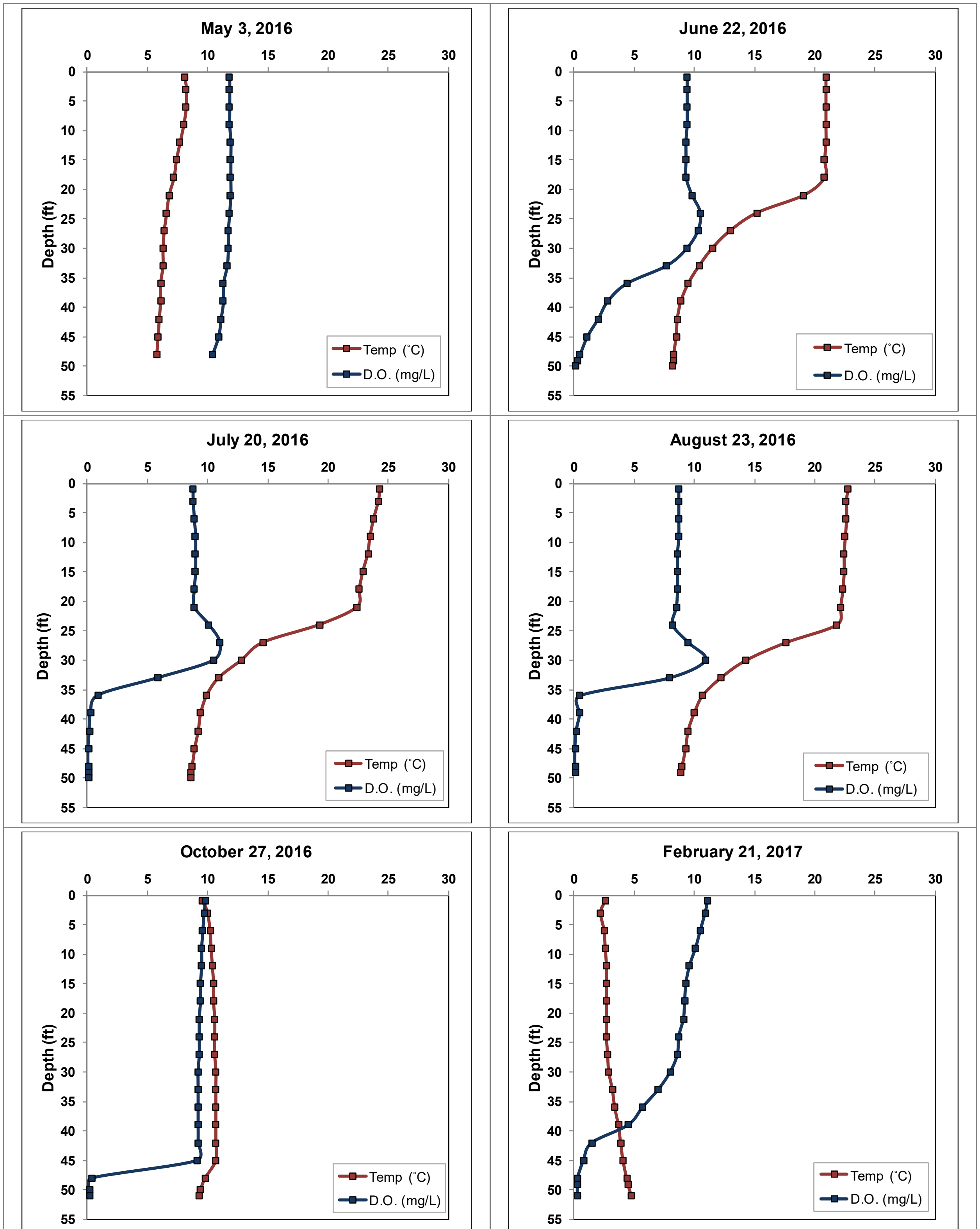



**Figure 3.1-9. Forest Lake dissolved oxygen and temperature profiles.**

## 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 pH of the water in Forest Lake was found to be near neutral with a value of 8.0, and falls within the normal range for Wisconsin Lakes.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate ($HCO_3^-$) and carbonate ($CO_3^-$), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Forest Lake was measured at 32 (mg/L as $CaCO_3$), indicating that the lake has sufficient capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Forest Lake's pH of 8.1 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Forest Lake was found to be 8.3 mg/L, falling below the optimal range for zebra mussels.

Zebra mussels (*Dreissena polymorpha*) are a 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 not suitable for mussel establishment. Plankton tows were completed by Onterra ecologists in Forest Lake in 2016 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys.

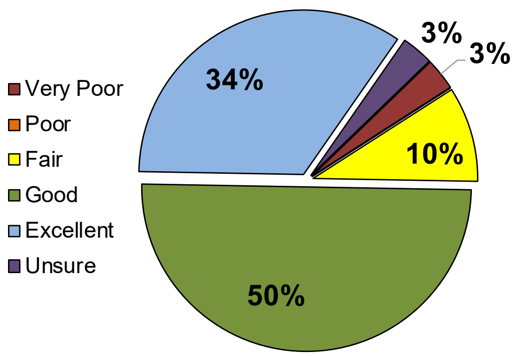
### *Stakeholder Survey Responses to Forest Lake Water Quality*

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Of the 87 surveys distributed, 32 (37%) were returned. Without a response rate of 60% or higher, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of water quality in Forest Lake but cannot be stated with statistical confidence.

Figure 3.1-10 displays the responses of members of Forest Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Forest Lake. When asked how they would describe the current water quality of Forest Lake, 50% of respondents indicated *good*, 34% indicated *excellent*, 10% indicated *fair*, 3% indicated *very poor*, and 3% indicated that they were *unsure*.

When asked how they believe the current water quality has changed since they first visited the lake, the largest proportion of respondents, 53%, indicated it has *remained the same*, 28% indicated it has *somewhat degraded*, 13%, indicated they were *unsure*, and 6% indicated it has *severely degraded* (Figure 3.1-10). As discussed in the previous section, given the intermittent data over the available time period, it is difficult to determine if there has been a trend in water clarity over time in Forest Lake. The proportion of stakeholders who indicated Forest Lake's water quality has somewhat or severely degraded may be taking into account Eurasian watermilfoil growth in the lake or may have observed increases in aquatic plant abundance within the lake. But again, historical data indicate water quality has not been degrading over time in Forest Lake.

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




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

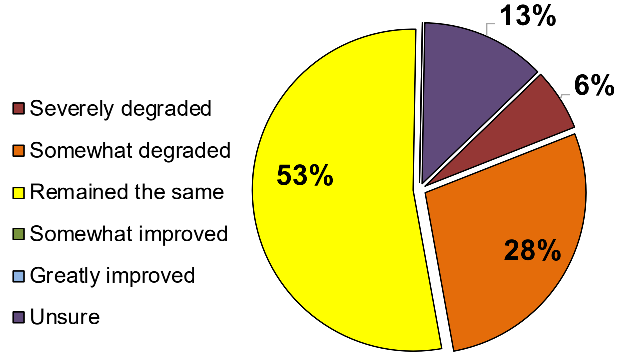



**Figure 3.1-10. Forest Lake stakeholder survey responses to questions regarding perceptions of lake water quality.**

## 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

As discussed in the Water Quality section (3.1), Forest Lake is classified as a deep seepage lake and does not possess a tributary inlet or outlet. Forest Lake's total watershed encompasses approximately 1,087 acres (1.7 square miles), yielding a watershed to lake area ratio of 1:1 (Map 2). In other words, approximately one acre of land drains to every one acre of Forest Lake. Approximately 43% of Forest Lake's watershed is composed of the lake surface, 41% of forest, 12% of wetlands, and 4% of pasture/grass (Figure 3.2-1, left frame). According to WiLMS modeling, the lake's water is completely replaced approximately once every 12 years (residence time) or 0.08 times a year (flushing rate); however, the residence time is likely shorter than estimated as Forest Lake is primarily fed by groundwater and WiLMS only uses surface runoff to estimate residence time.

As discussed earlier, the land cover within watersheds of lakes with watershed to lake area ratios of 10-15:1 or less has a greater influence on the water quality of a lake. Using the landcover data described above, WiLMS was utilized to estimate the annual potential phosphorus load from Forest Lake's watershed. It was estimated that approximately 189 pounds of phosphorus are delivered to the lake from its watershed on an annual basis (Figure 3.2-1, right frame). Phosphorus loading from septic systems was also estimated using data obtained from the 2016 stakeholder survey of riparian property owners. Of the estimated 189 pounds of phosphorus being delivered annually to Forest Lake 66% is estimated to originate from direct atmospheric deposition into the lake, 19% from forest, 11% from wetlands, and 3% from riparian septic systems.

Using predictive equations, WiLMS estimates that based on the potential annual phosphorus load, Forest Lake should have a growing season mean (GSM) total phosphorus concentration of approximately 14 μg/L. This predicted concentration is relatively similar to the measured GSM total phosphorus concentration of 15 µg/L. This indicates the lake's watershed and phosphorus inputs were modeled fairly accurately and the measured phosphorus concentrations in Forest Lake are near expected levels based on the lake's watershed size and land cover composition. There are no indications that significant sources of unaccounted phosphorus are being loaded to the lake.

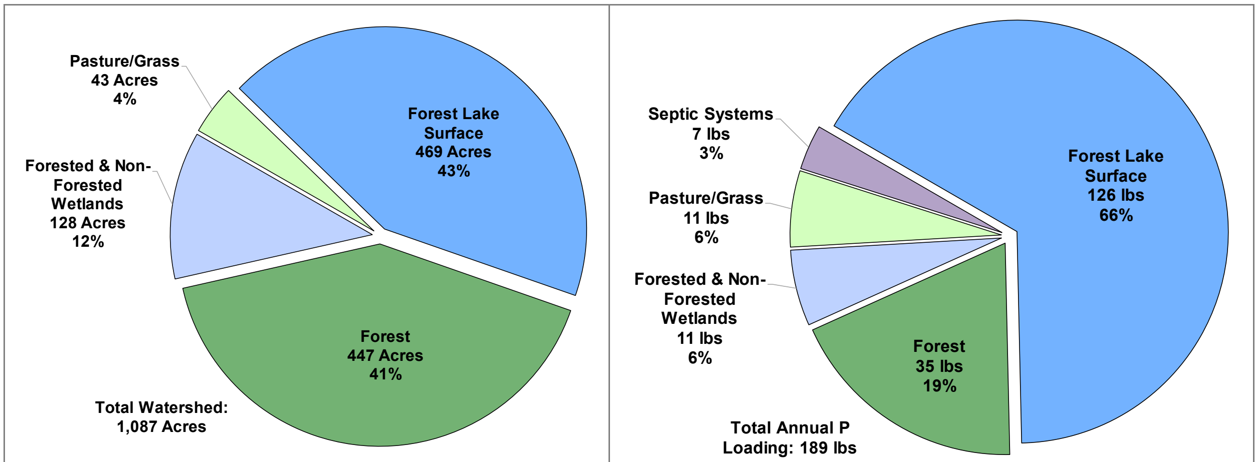



**Figure 3.2-1. Forest Lake watershed land cover types in acres and phosphorus loading in pounds.** Watershed land cover type based upon National Land Cover Database (NLCD – Fry et. al 2011). Phosphorus loading based upon Wisconsin Lake Modeling Suite (WiLMS).

As discussed in the Watershed Modeling section above, in systems with lower WS:LA ratios like Forest Lake, small changes in the watershed can lead to significant changes in water quality. To illustrate this, a scenario was modeled converting 25% of the forest in the Forest Lake's watershed to row crop agriculture. WiLMS estimates that the GSM total phosphorus concentration would increase to be approximately 17 µg/L. Using predictive equations developed by Carlson (1977), average chlorophyll-*a* and Secchi disk transparency values can be estimated using the average growing season surface phosphorus value. If 25% of forested land were converted to row crop agriculture, the estimated GSM concentration for chlorophyll-*a* would increase to 5 µg/L, which is about 2 µg/L higher than the average measured GSM chlorophyll-*a* concentration of 3 µg/L. The estimated GSM Secchi disk depth is estimated to decline to approximately 10 feet, which is approximately 7-foot reduction in the average measured GSM Secchi depth of 17 feet.

## 3.3 Shoreland Condition

### *The Importance of a Lake's Shoreland Zone*

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

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

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

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

### Shoreland Zone Regulations

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

**Wisconsin-NR 115: Wisconsin's Shoreland Protection Program**

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

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

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

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

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

## Wisconsin Act 31

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

## Shoreland Research

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

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

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

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.

### Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do nott allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

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

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

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

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

## *Forest Lake Shoreland Zone Condition*

### Shoreland Development

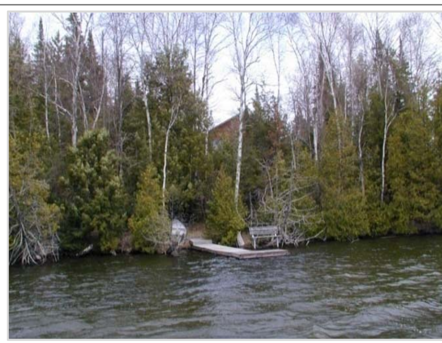
Forest Lake's shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, 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 the Fall of 2016, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Forest Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.5 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 0.9 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.

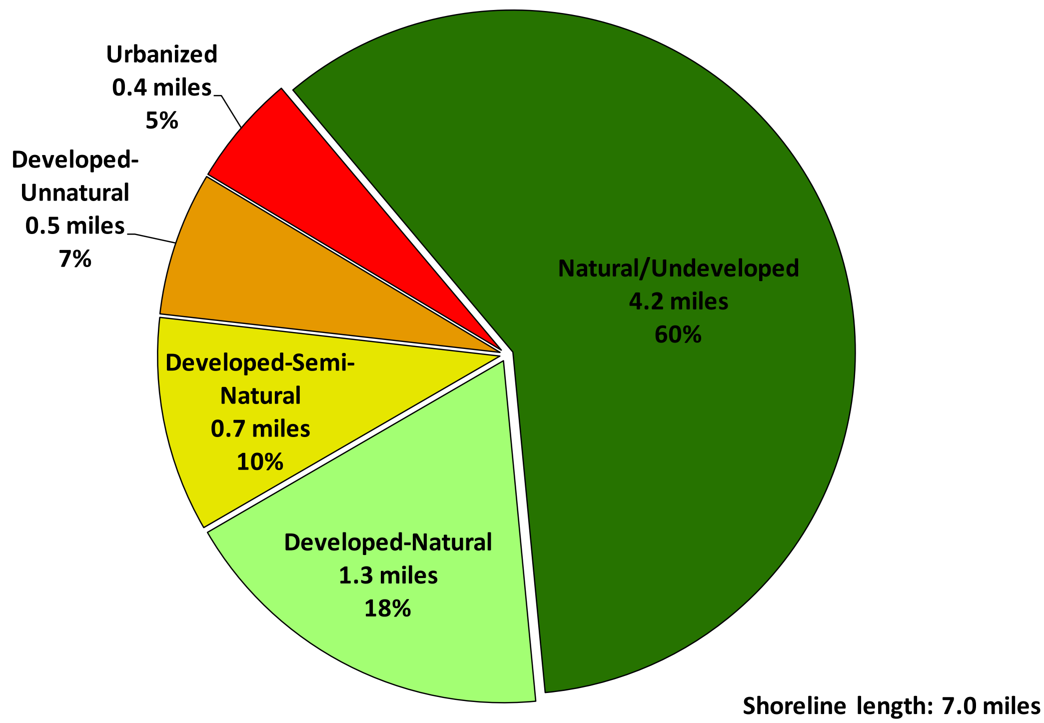



**Figure 3.3-2. Forest Lake shoreland categories and total lengths.** Based upon a Fall 2016 survey. Locations of these categorized shorelands can be found on Map 3.

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

## Coarse Woody Habitat

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

During this survey, 158 total pieces of coarse woody habitat were observed along seven miles of shoreline, which gives Forest Lake a coarse woody habitat to shoreline mile ratio of 22:1. Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

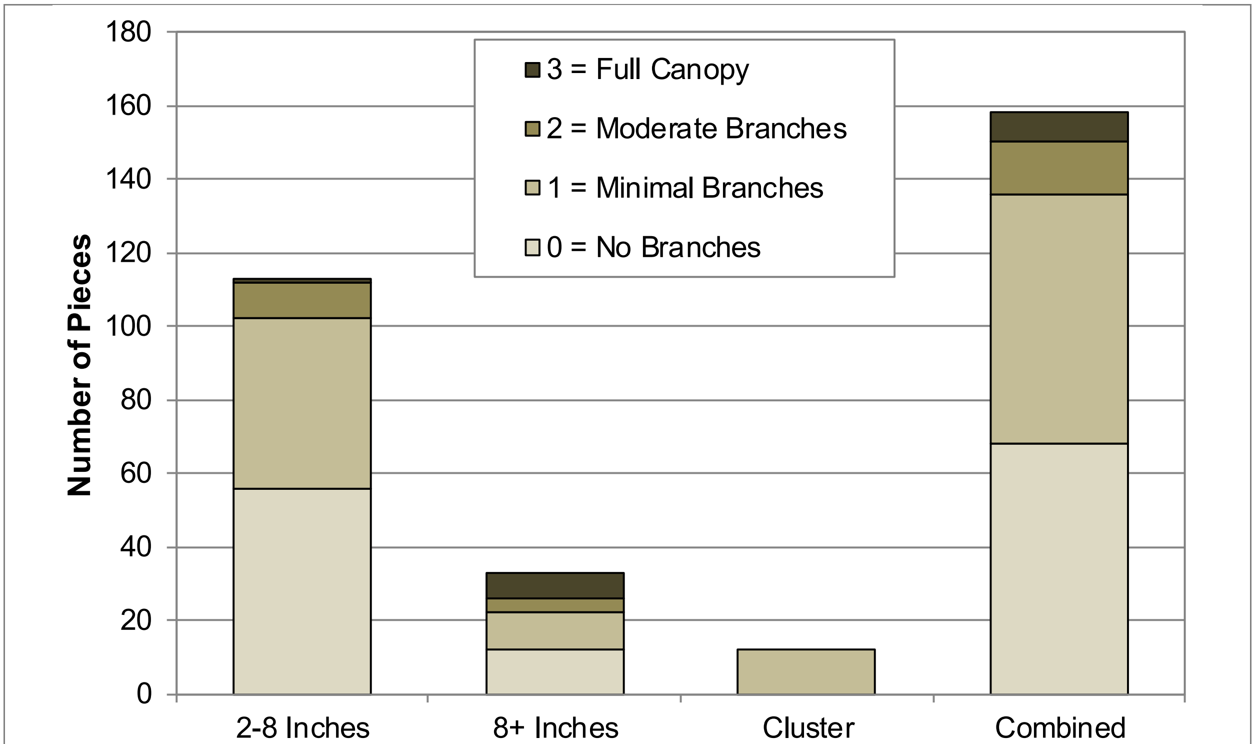



**Figure 3.3-3. Forest Lake coarse woody habitat survey results.** Based upon a Fall 2016 survey. Locations of Forest Lake coarse woody habitat can be found on Map 4.

## 3.4 Aquatic Plants

### Introduction

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

**Photograph 3.4-1. Example of emergent and floating-leaf communities.**

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced predation by predator fish, which could result in a stunted pan-fish population. Exotic plant species, such as Eurasian watermilfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These species will be discussed further in depth in the Aquatic Invasive Species section. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

## Aquatic Plant Management and Protection

> **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

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

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants. These techniques can be utilized by the property owner or a contractor of the property owner as long as the rules in NR 109.06(2) are followed.

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

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

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Very cost effective for clearing areas around docks, piers, and swimming areas.<br>• Relatively environmentally safe if treatment is conducted after June 15$^{th}$.<br>• Allows for selective removal of undesirable plant species.<br>• Provides immediate relief in localized area.<br>• Plant biomass is removed from waterbody. | • Labor intensive.<br>• Impractical for larger areas or dense plant beds.<br>• Subsequent treatments may be needed as plants recolonize and/or continue to grow.<br>• Uprooting of plants stirs bottom sediments making it difficult to conduct action.<br>• 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.<br>• Long-term costs are low.<br>• Excellent for small areas and around obstructions.<br>• Materials are reusable.<br>• Prevents fragmentation and subsequent spread of plants to other areas. | • Installation may be difficult over dense plant beds and in deep water.<br>• Not species specific.<br>• Disrupts benthic fauna.<br>• May be navigational hazard in shallow water.<br>• Initial costs are high.<br>• Labor intensive due to the seasonal removal and reinstallation requirements.<br>• Does not remove plant biomass from lake.<br>• Not practical in large-scale situations. |

## Water Level Drawdown

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

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

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

## Mechanical Harvesting

**Photograph 3.4-3. Mechanical harvester.**

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

### Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as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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.<br>• Plant biomass and associated nutrients are removed from the lake.<br>• Select areas can be treated, leaving sensitive areas intact.<br>• Plants are not completely removed and can still provide some habitat benefits.<br>• Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.<br>• Removal of plant biomass can improve the oxygen balance in the littoral zone.<br>• Harvested plant materials produce excellent compost. | • Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.<br>• Multiple treatments are likely required.<br>• Many small fish, amphibians and invertebrates may be harvested along with plants.<br>• There is little or no reduction in plant density with harvesting.<br>• Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.<br>• Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels. |

### Herbicide Treatment


**Photograph 3.4-4. Granular herbicide application.**

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

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

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

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

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

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

| 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; Eurasian water milfoil control when mixed with auxin herbicides |
| | | Diquat | Inhibits photosynthesis & destroys cell membranes | Nusiance natives species including duckweeds, targeted AIS control when exposure times are low |
| Systemic | Auxin Mimics | 2,4-D | auxin mimic, plant growth regulator | Submersed species, largely for Eurasian water milfoil |
| | | Triclopyr | auxin mimic, plant growth regulator | Submersed species, largely for Eurasian water milfoil |
| | In Water Use Only | Fluridone | Inhibits plant specific enzyme, new growth bleached | Submersed species, largely for Eurasian water milfoil |
| | Enzyme Specific (ALS) | Penoxsulam | Inhibits plant-specific enzyme (ALS), new growth stunted | New to WI, potential for submergent and floating-leaf species |
| | | Imazamox | Inhibits plant-specific enzyme (ALS), new growth stunted | New to WI, potential for submergent and floating-leaf species |
| | Enzyme Specific (foliar use only) | Glyphosate | Inhibits plant-specific enzyme (ALS) | Emergent species, including purple loosestrife |
| | | Imazapyr | Inhibits plant-specific enzyme (EPSP) | Hardy emergent species, including common reed |

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

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

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

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

**Cost**

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

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| • Herbicides are easily applied in restricted areas, like around docks and boatlifts.<br>• Herbicides can target large areas all at once.<br>• 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.<br>• Some herbicides can be used effectively in spot treatments.<br>• 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.<br>• Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly.<br>• 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.<br>• Many aquatic herbicides are nonselective.<br>• Some herbicides have a combination of use restrictions that must be followed after their application.<br>• Overuse of same herbicide may lead to plant resistance to that herbicide. |

## Biological Controls

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

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

**Cost**

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

| *Advantages* | *Disadvantages* |
|---|---|
| • Milfoil weevils occur naturally in Wisconsin.<br>• Likely environmentally safe and little risk of unintended consequences. | • Stocking and monitoring costs are high.<br>• This is an unproven and experimental treatment.<br>• 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.<br>• Once released, considerably less effort than other control methods is required.<br>• Augmenting populations many lead to long-term control. | • Although considered "safe," reservations about introducing one non-native species to control another exist.<br>• Long range studies have not been completed on this technique. |

## *Analysis of Current Aquatic Plant Data*

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

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

### *Frequency of Occurrence*

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

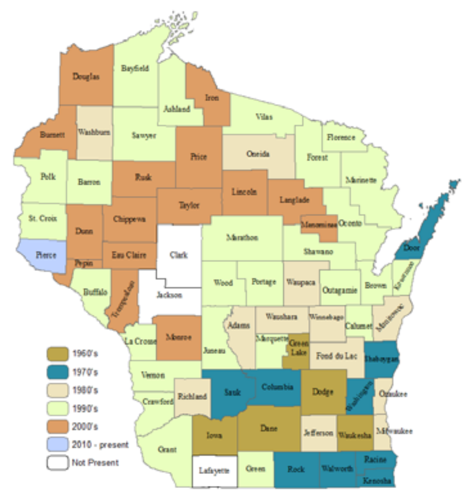



**Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties.** WDNR Data 2011 mapped by Onterra.

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

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

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

### *Aquatic Plant Survey Results*

During the aquatic plant surveys completed on Forest Lake in 2016, a total of 48 species of plants were located, one of which is considered a non-native, invasive species: Eurasian watermilfoil (Table 3.4-1). The aquatic plant species list also contains species recorded during whole-lake point-intercept surveys completed in 2005 and 2013. Changes in species' abundance between these three surveys are discussed later in this section. On June 29, 2016, an Early-Season AIS Survey was completed on Forest Lake that focused on locating and mapping potential occurrences of curly-leaf pondweed. This meander-based visual survey did not locate any occurrences of this non-native plant. At present, curly-leaf pondweed either does not occur in Forest Lake or exists at an undetectable level. Because the Eurasian watermilfoil in Forest Lake has the ability to negatively impact lake ecology, recreation, and aesthetics, the population of this plant is discussed in detail within the subsequent Non-Native Aquatic Plants Section.

The whole-lake aquatic plant point-intercept survey and emergent/floating-leaf aquatic plant community mapping survey were conducted on Forest Lake on July 27, 2016 by Onterra. On August 30 and 31, 2016, Onterra ecologists completed an acoustic survey on Forest Lake. The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Forest Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey revealed that the majority of Forest Lake contains harder substrates (rock and sand), while softer, flocculent sediments can be found in sheltered bays and deeper areas of the lake (Figure 3.4-2 and Map 5). On average, the hardest substrates were found within 10 to 36 feet of water. Overall, there was little variation in average substrate hardness throughout Forest Lake. Figure 3.4-2 illustrates the spatial distribution of substrate hardness in Forest Lake. Lakes in Wisconsin vary in their morphology, water chemistry, substrate composition, recreational use, and management, and all of these factors influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

**Table 3.4-1. Aquatic plant species located on Forest Lake during 2005 WDNR, 2013 WDNR, and 2016 Onterra surveys.**

| Growth Form | Scientific Name | Common Name | Coefficient of Conservatism (C) | 2005 (WDNR) | 2013 (WDNR) | 2016 (Onterra) |
|---|---|---|---|---|---|---|
| Emergent | *Bolboschoenus fluviatilis* | River bulrush | 5 | | | I |
| | *Carex comosa* | Bristly sedge | 5 | | | I |
| | *Carex lasiocarpa* | Narrow-leaved woolly sedge | 9 | | | I |
| | *Carex pseudocyperus* | Cypress-like sedge | 8 | | | I |
| | *Carex stricta* | Common tussock sedge | 7 | | | I |
| | *Carex utriculata* | Common yellow lake sedge | 7 | | | I |
| | *Dulichium arundinaceum* | Three-way sedge | 9 | | | X |
| | *Eleocharis palustris* | Creeping spikerush | 6 | | X | X |
| | *Glyceria borealis* | Northern manna grass | 8 | | | I |
| | *Glyceria canadensis* | Rattlesnake grass | 7 | | | I |
| | *Iris versicolor* | Northern blue flag | 5 | | | I |
| | *Juncus effusus* | Soft rush | 4 | | X | |
| | *Sagittaria latifolia* | Common arrowhead | 3 | | | I |
| | *Sagittaria rigida* | Stiff arrowhead | 8 | | X | I |
| | *Sagittaria* sp. | Arrowhead sp. | N/A | X | | |
| | *Schoenoplectus tabernaemontani* | Softstem bulrush | 4 | | X | X |
| | *Scirpus cyperinus* | Wool grass | 4 | | | I |
| | *Scirpus pedicellatus* | Stalked woolgrass | 6 | | | I |
| | *Sparganium americanum* | American bur-reed | 8 | | | X |
| | *Sparganium androcladum* | Shining bur-reed | 8 | | | X |
| | *Typha latifolia* | Broad-leaved cattail | 1 | | X | |
| FL | *Brasenia schreberi* | Watershield | 7 | | | X |
| | *Nuphar variegata* | Spatterdock | 6 | | | I |
| | *Nymphaea odorata* | White water lily | 6 | X | X | X |
| | *Persicaria amphibia* | Water smartweed | 5 | | | X |
| | *Sparganium angustifolium* | Narrow-leaf bur-reed | 9 | X | | X |
| Submergent | *Bidens beckii* | Water marigold | 8 | X | X | X |
| | *Chara* spp. | Muskgrasses | 7 | X | X | X |
| | *Elodea canadensis* | Common waterweed | 3 | X | X | X |
| | *Elodea nuttallii* | Slender waterweed | 7 | X | | |
| | *Heteranthera dubia* | Water stargrass | 6 | | X | X |
| | *Isoetes* spp. | Quillwort spp. | 8 | X | X | I |
| | *Myriophyllum sibiricum* | Northern watermilfoil | 7 | X | X | X |
| | *Myriophyllum spicatum* | Eurasian watermilfoil | Exotic | | X | I |
| | *Najas flexilis* | Slender naiad | 6 | X | X | X |
| | *Nitella* spp. | Stoneworts | 7 | | X | |
| | *Potamogeton alpinus* | Alpine pondweed | 9 | | X | I |
| | *Potamogeton amplifolius* | Large-leaf pondweed | 7 | X | X | X |
| | *Potamogeton berchtoldii* | Slender pondweed | 7 | | | X |
| | *Potamogeton foliosus* | Leafy pondweed | 6 | | | I |
| | *Potamogeton gramineus* | Variable-leaf pondweed | 7 | X | X | X |
| | *Potamogeton illinoensis* | Illinois pondweed | 6 | | X | I |
| | *Potamogeton natans* | Floating-leaf pondweed | 5 | | | I |
| | *Potamogeton obtusifolius* | Blunt-leaved pondweed | 9 | X | X | X |
| | *Potamogeton praelongus* | White-stem pondweed | 8 | | | X |
| | *Potamogeton praelongus X P. richardsonii* | White-stem X clasping-leaf pondweed | N/A | X | X | I |
| | *Potamogeton pusillus* | Small pondweed | 7 | X | X | |
| | *Potamogeton robbinsii* | Fern-leaf pondweed | 8 | X | X | X |
| | *Potamogeton spirillus* | Spiral-fruited pondweed | 8 | X | X | X |
| | *Potamogeton zosteriformis* | Flat-stem pondweed | 6 | X | X | X |
| | *Utricularia vulgaris* | Common bladderwort | 7 | | | I |
| | *Vallisneria americana* | Wild celery | 6 | | X | X |
| S/E | *Eleocharis acicularis* | Needle spikerush | 5 | X | X | X |
| | *Sagittaria cristata* | Crested arrowhead | 9 | | X | X |

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

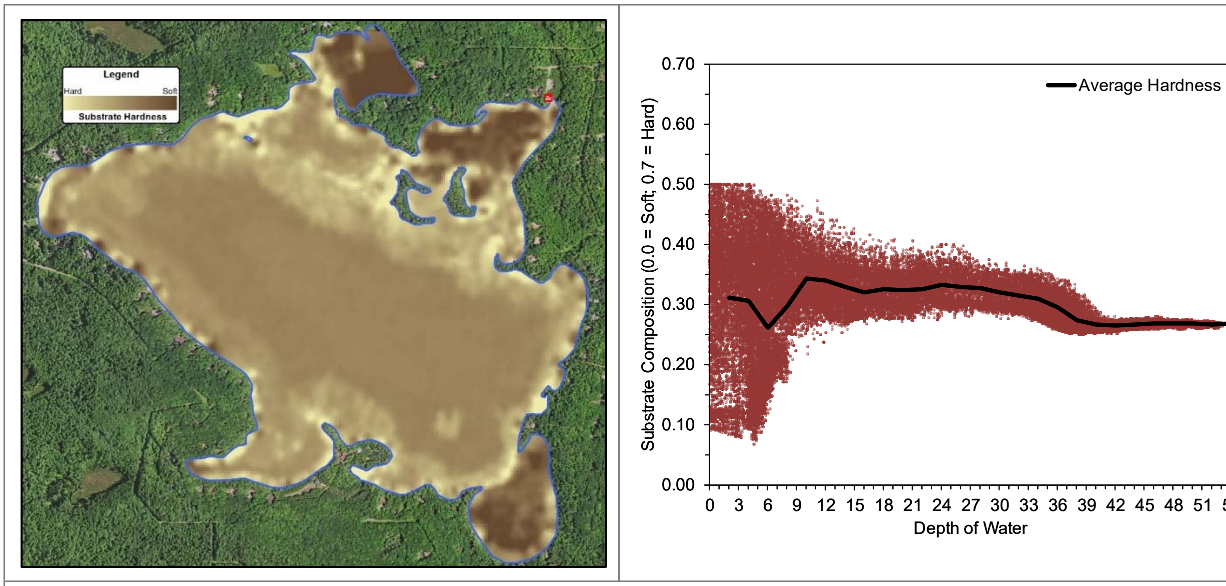



**Figure 3.4-2. Forest Lake spatial distribution of substrate hardness (top) and substrate hardness across water depth (bottom).** Individual data points are displayed in red. Created using data from August 2016 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 3.4-3 and Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2016 whole-lake point-intercept survey and acoustic survey found aquatic plants growing to a maximum depth of 21 feet, a testament to the high water clarity found in Forest Lake. However, the majority of aquatic plant growth occurs within the first 8 feet of water, and the presence of aquatic plants quickly diminished beyond 15 feet. Overall, the 2016 acoustic survey indicates that approximately 30% of Forest Lake contains aquatic vegetation (Figure 3.4-3). The remaining area of the lake is too deep and does not receive adequate light to support aquatic plant growth. The green areas in the middle portion of the lake are most likely an error from the acoustic data processing software but could also be very flocculant sediment sometimes found in deep water.

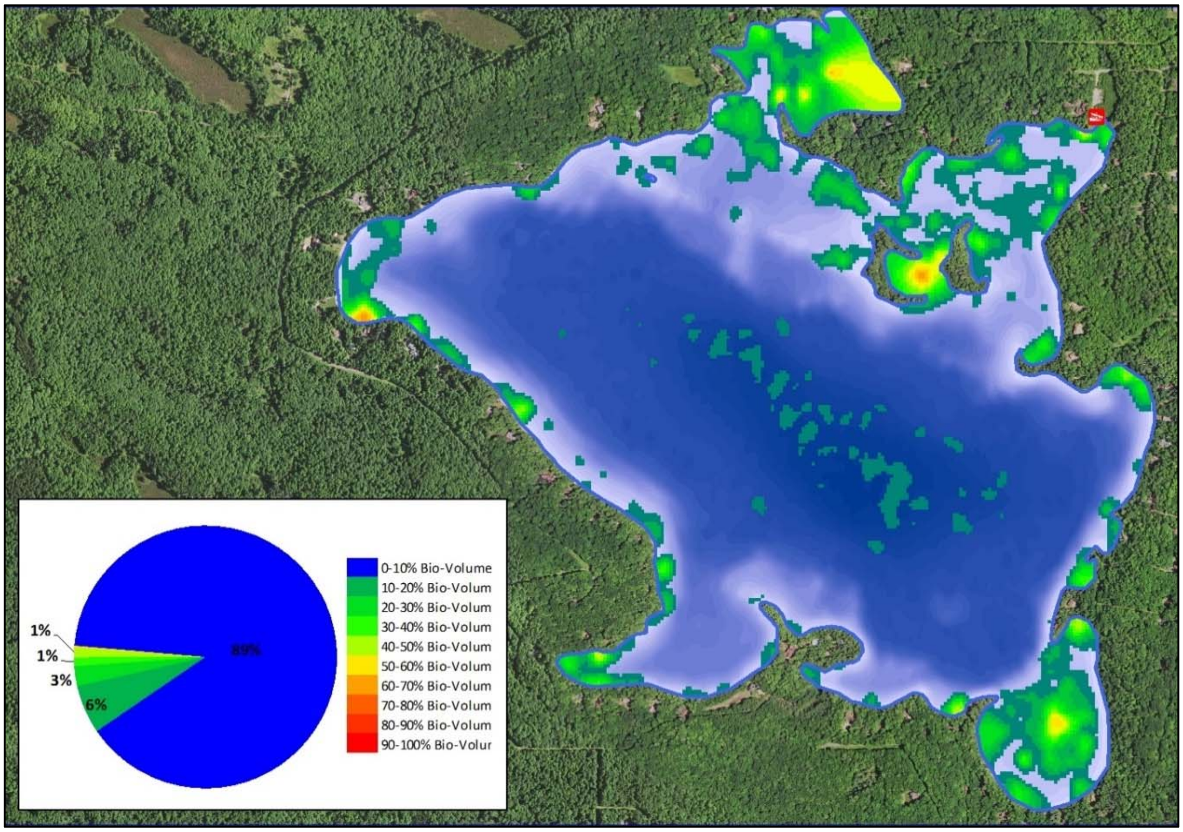



**Figure 3.4-3. Forest Lake 2016 aquatic plant bio-volume.** Created using data from August 2016 acoustic survey.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species comprise the aquatic plant community. Whole-lake point-intercept surveys are used to quantify the abundance of individual plant species within the lake. Of the 385 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone) in 2016, approximately 66% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 33% of the 385 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 16% had a TRF rating of 2, and 17% had a TRF rating of 3 (Figure 3.4-4). The TRF data indicates that where aquatic plants are present in Forest Lake, they are of low density.

Of the 48 aquatic plant species located in Forest Lake in 2016, 28 were encountered directly on the rake during the whole-lake point intercept survey. The remaining 20 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of these 28 species, fern-leaf pondweed was the most frequently encountered, followed by common waterweed, muskgrasses, and slender naiad (Figure 3.4-5).

Fern-leaf pondweed was the most abundant aquatic plant in Forest Lake in 2016 with a littoral frequency of occurrence of approximately 31%. As its name indicates, this plant resembles a terrestrial fern frond in appearance and is often a dominant species in plant communities of northern Wisconsin lakes. Fern-leaf pondweed is generally found growing in thick beds over soft substrates, where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. In 2016, fern-leaf pondweed was abundant throughout littoral areas of Forest Lake but was less abundant in near shore areas.

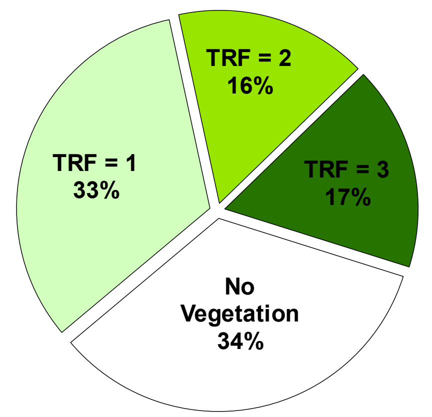



**Figure 3.4-4. Forest Lake 2016 aquatic vegetation total rake fullness (TRF) ratings within littoral areas.** Created from data collected during the 2016 whole-lake aquatic plant point-intercept survey.

Common waterweed was the second-most frequently encountered species with a littoral frequency of occurrence of approximately 16% (Figure 3.4-5). It is often one of the more dominant aquatic plants in Wisconsin's lakes and can be found throughout North America. Common waterweed is able to tolerate low-light conditions and obtain the majority of its nutrients directly from the water, and can thrive in more productive lakes. Because of its prevalence in many of Wisconsin's lakes, common waterweed is an important component of many aquatic ecosystems where it provides structural habitat and absorbs nutrients that would otherwise be available to free-floating algae. In Forest Lake, common waterweed was most abundant between 11 and 17 feet of water.

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin. In 2016, muskgrasses had a littoral frequency of occurrence of approximately 12% and was the third-most encountered species in Forest Lake (Figure 3.4-5). 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 form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). In Forest Lake, muskgrasses were abundant across littoral depths in 2016.

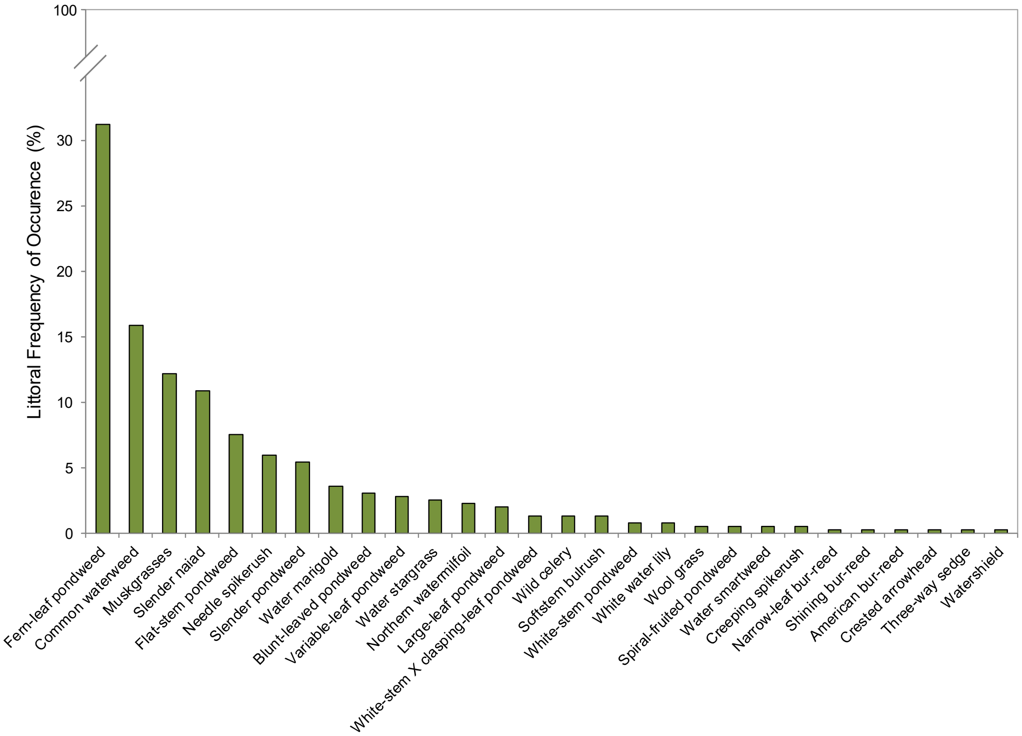



**Figure 3.4-5. Frequency of occurrence at littoral depths for several Forest Lake plant species.** Created using data from July 2016 aquatic plant point-intercept survey.

Slender naiad, the fourth-most frequently encountered aquatic plant in 2016 with a littoral frequency of occurrence of 11% (Figure 3.4-5), is a submersed, annual plant that produces numerous seeds. Slender naiad is considered to be one of the most important sources of food for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. In Forest Lake, slender naiad was most prevalent between 2.0 and 8.0 feet of water.

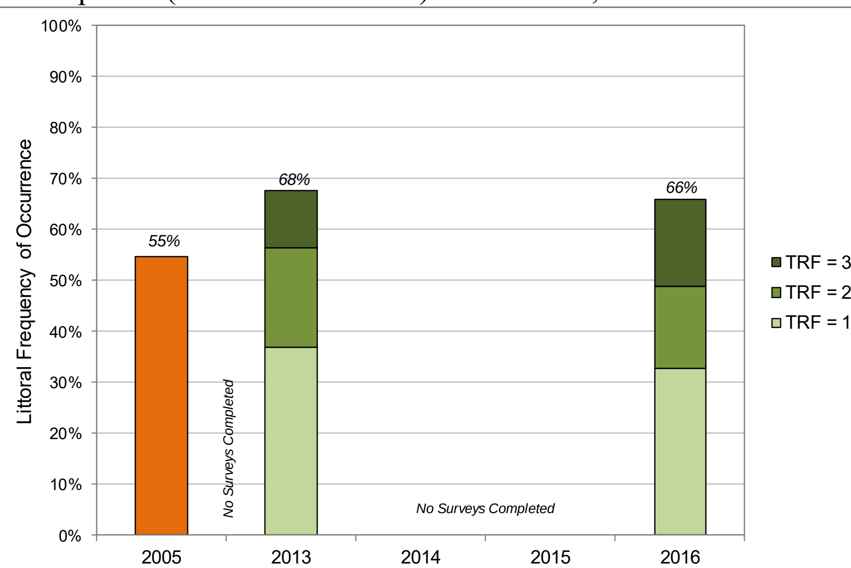



**Figure 3.4-6. Aquatic plant littoral frequency of occurrence and total rake fullness (TRF) ratings in Forest Lake from the 2005, 2013 and 2016 surveys.** TRF data was not collected in 2005. Change in occurrence from 2005 to 2013 were statistically different, change occurrence from 2013 to 2016 was not statistically valid and 2005 to 2016 were significantly different (Chi-square α = 0.05).

Aquatic plant point-intercept datasets are also available from 2005 and 2013 on Forest Lake, and the methodology and sampling locations were the same as the survey completed in 2016. The datasets from 2005, 2013, and 2016 can be statistically compared to determine if any significant changes in the overall occurrence of vegetation or in species' abundance have occurred over this time period. Comparison between these three surveys indicates that the littoral frequency of occurrence of all vegetation within Forest Lake has increased from 55% in 2005 to 68% in 2013 and 66% in 2016. The increase in occurrence from 2005 to 2013 represents a statistically valid increase in the occurrence of aquatic vegetation between these two surveys (Chi-square $\alpha = 0.05$). The occurrence of vegetation in 2016 was not statistically different from the occurrence measured in 2013 (Chi-square $\alpha = 0.05$). Figure 3.4-6 displays the littoral frequency of occurrence of vegetation from the 2005, 2013 and 2016 point-intercept surveys. Total rake fullness (TRF) data were not collected in 2005.

Figure 3.4-7 displays the individual littoral frequency of species which had a littoral frequency of occurrence of at least 5% in at least one of the three surveys. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of small pondweed (*P. pusillus*) and slender pondweed (*P. berchtoldii*) were combined for this analysis. In total, seven aquatic plant species exhibited statistically valid changes in their littoral frequency of occurrence between 2005 and 2016 (Figure 3.4-7). Fern-leaf pondweed, muskgrasses, flat-stem pondweed, and needle spikerush saw statistically valid increases in their littoral occurrences from 2005-2016, Fern-leaf pondweed statistically increased from 2005 to 2013 by 57.4% then again from 2013 to 2016 by 32.3%. Muskgrasses statistically increased from 2013 to 2016 by 711.8% and flat-stem pondweed statistically increased from 2005 to 2013 by 849.6%. Needle spikerush increased statistically, from 2005 to 2013, by 322.1%. Slender naiad saw a 43.5% statistically valid decline from 2005-2016.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, water levels, changes in clarity, herbivory, competition, and disease among other factors. Certain native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants; however, the treatment completed to control Eurasian watermilfoil in Forest Lake have been relatively small and are not believed to have been able to impact native plant populations on a lake-wide level. Rather, these observed reductions and increases in occurrence of certain species are believed to be due to varying interannual environmental conditions. Water level fluctuations can have impacts on aquatic vegetation. Forest Lake has experienced some large water fluctuations over the years which may have led to changes in aquatic plant abundance. Ongoing collection of aquatic plant data from Wisconsin's lakes shows that aquatic plant populations have the capacity to fluctuate widely on an interannual basis under natural conditions. It is not known what has driven the changes observed in Forest Lake, but it is likely the result of a combination of primarily natural factors. Having a species-rich plant community like that found in Forest Lake is important as when conditions are unfavorable for some species, other species can fill in to fulfill their ecological role.

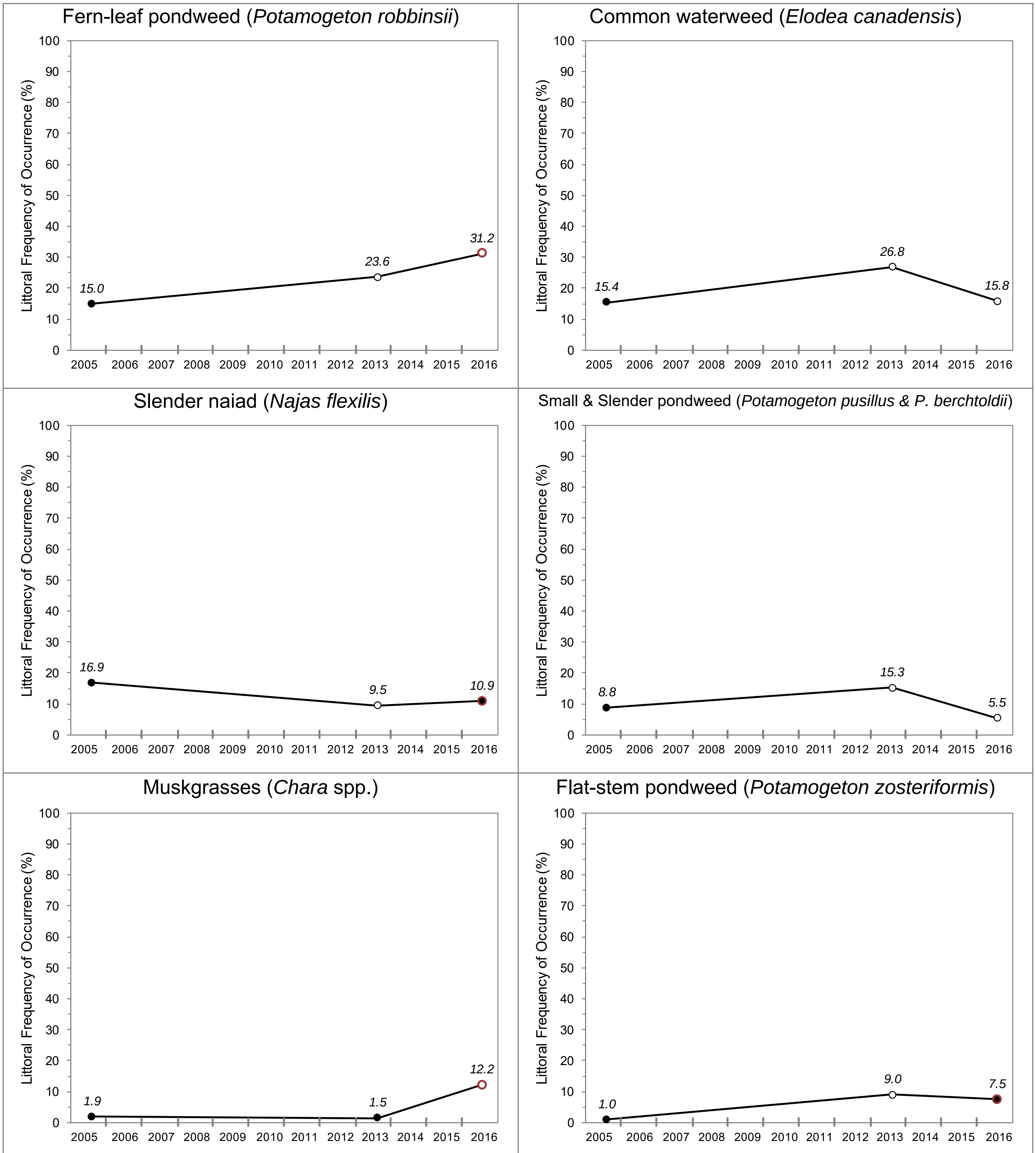



**Figure 3.4-7 . Littoral frequency of occurrence of select native aquatic plant species in Forest Lake from 2005-2016.** Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from WDNR 2005 (N = 421), WDNR 2013 (N = 399) and Onterra 2016 (N = 385) whole-lake point-intercept surveys.

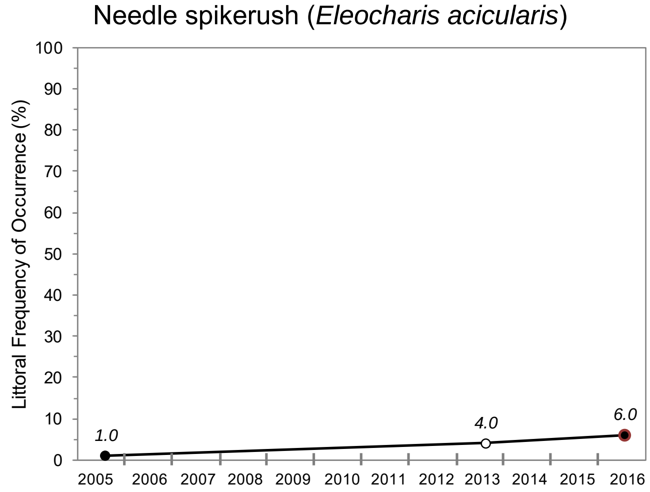



**Figure 3.4-7 continued. Littoral frequency of occurrence of select native aquatic plant species in Forest Lake from 2005-2016.** Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Circle outlined with red indicates 2016 littoral occurrence was statistically different from littoral occurrence in 2005 (Chi-Square α = 0.05). Species displayed had a littoral occurrence of at least 5% in one of the three surveys. Created using data from WDNR 2005 (N = 421), WDNR 2013 (N = 399) and Onterra 2016 (N = 385) whole-lake point-intercept surveys.

As described above, aquatic plant communities are dynamic and can vary from year to year. In 1993, concerns about a loss of aquatic plants and reduced warm water fish populations were brought forward by Dr. Ken Smigielski. In response, Forest Lake was visited by aquatic community ecologist Sandy Engel and fishery manager Harland Carlson. Similarly, it was determined that water level changes in the lake were likely influencing plant population changes and that fish populations would return with submergent plant growth. It was recommended that residents along Forest Lake transplant native pondweeds in the lake; however, without historic plant data from this time, it is impossible to determine if planting efforts in the lake were successful.

As discussed in the primer section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while a total of 48 native aquatic plant species were located in Forest Lake during the 2016 surveys, 28 were directly encountered on the rake during the point-intercept survey. Forest Lake's native aquatic plant species richness in 2016 exceeded the 75th percentile value for lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and for lakes throughout Wisconsin (Figure 3.4-8). The species richness recorded in 2016 (29) was also higher than that recorded during the 2005 (21) and 2013 (28) point-intercept surveys. Given Forest Lake has not seen significant changes in water quality or seen major disturbances over this period, the differences in species richness between these surveys are likely due to differences in the surveyors' aquatic plant identification abilities. The differences in the aquatic plant species list between these surveys can be viewed in Table 3.4-1.

The average conservatism of the 28 native aquatic plants recorded on the rake in 2016 was 6.8, falling just above the median value (6.7) for lakes within the NLFL ecoregion and above the median value (6.3) for lakes throughout Wisconsin (Figure 3.4-8). This indicates that Forest Lake has a slightly higher number of native aquatic plant species with high conservatism values when compared to the majority of lakes within the NLFL ecoregion. Average conservatism in 2016 was lower when compared to the average conservatism values recorded in 2005 (6.9) and higher than 2013 (6.6).

Using Forest Lake's 2016 native aquatic plant species richness and average conservatism to calculate the Floristic Quality Index value yields a high value of 35.9, exceeding the 75th percentile values for lakes within the NLFL ecoregion and the state. This indicates that Forest Lake's aquatic plant community is of higher quality in terms of species richness and community composition than the majority of lakes within the ecoregion and the state. Given that native species richness and was higher in 2016 when compared to 2005 and 2013 and the average conservatism was higher in 2016 than 2013, the 2016 Floristic Quality Index value was also higher than those calculated for 2005 and 2013.

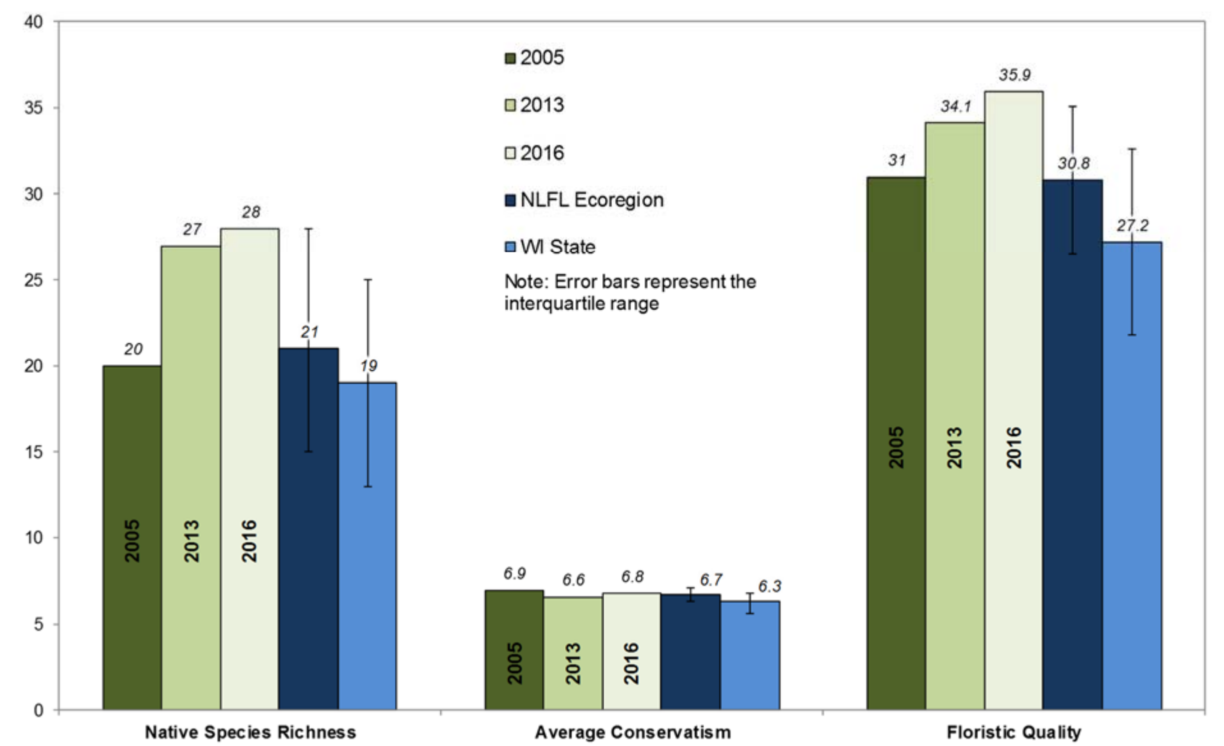



**Figure 3.4-8. Forest Lake Floristic Quality Analysis.** Created using data from WDNR 2005 (N = 421), WDNR 2013 (N = 399) and Onterra 2016 (N = 385) whole-lake point-intercept surveys. Analysis follows Nichols (1999).

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

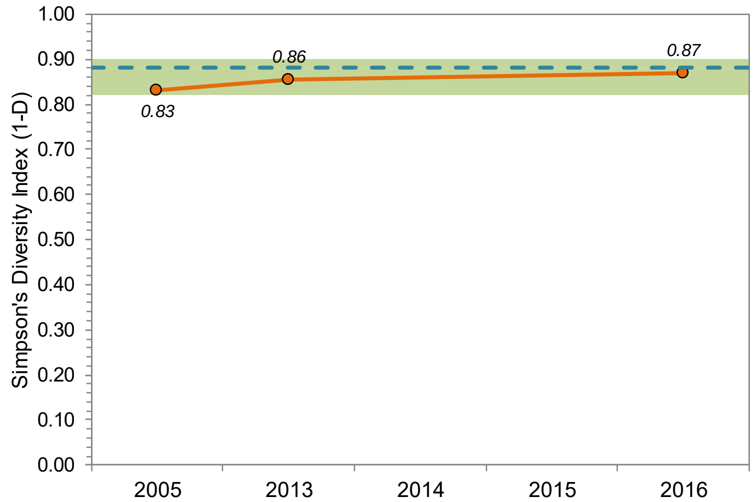



**Figure 3.4-9. Forest Lake species diversity index.** Created using data from 2005, 2013, and 2016 aquatic plant surveys. Ecoregion data from 212 NLFL lakes collected by WDNR Science Services and Onterra.

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 value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 3.4-9). Using the data collected from the 2005, 2013, and 2016 point-intercept surveys, Forest Lake's aquatic plant community is shown to have relatively low species diversity. Simpson's Diversity Index values were 0.83 in 2005, 0.86 in 2013, and 0.87 in 2016. These diversity value fall near the median or below the median value of 0.88 for lakes in the NLFL ecoregion.

While Forest Lake contains a high number of aquatic plant species, the majority of the plant community is comprised of just four species. One way to visualize Forest Lake's moderate species diversity is to look at the relative occurrence of aquatic plant species. Figure 3.4-10 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey and illustrates the relatively uneven distribution of aquatic plant species within the community. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population).

For instance, while fern-leaf pondweed had a littoral frequency of occurrence of 31%, its relatively frequency of occurrence was 27%. Explained another way, if 100 plants were sampled from Forest Lake, 27 would be fern-leaf pondweed. Figure 3.4-10 illustrates that 62% of Forest Lake's aquatic plant community was comprised of just four species in 2016: fern-leaf pondweed, common waterweed, muskgrasses, and slender naiad. Despite having a higher number of aquatic plant species (species richness), the dominance of the plant community by a few number of species results in the average species diversity.

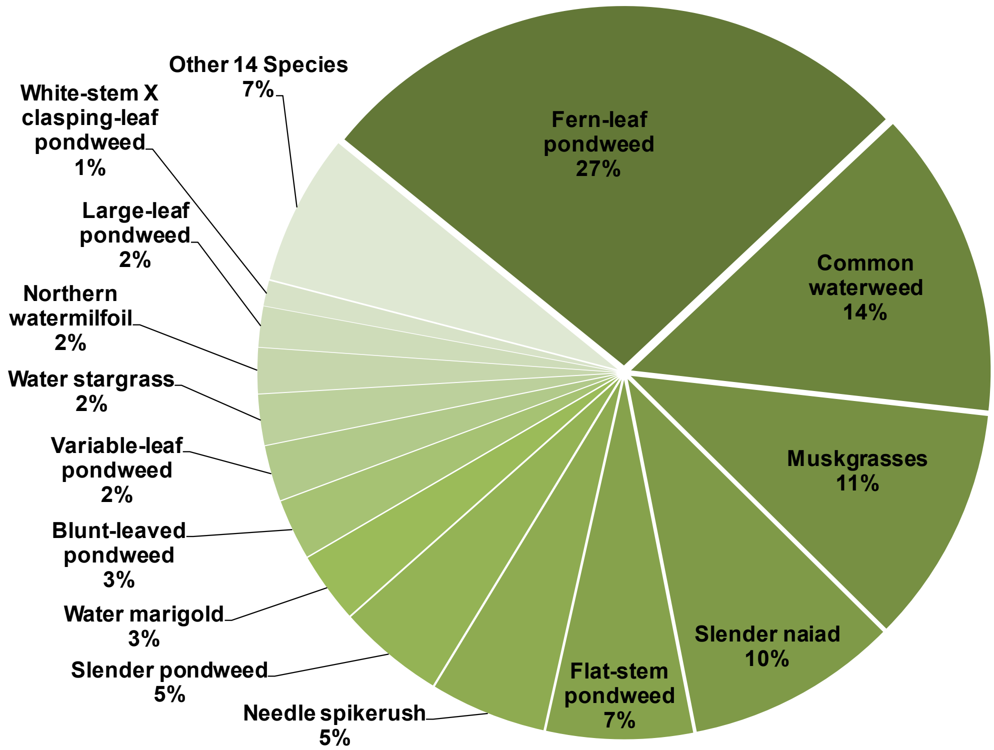



**Figure 3.4-10. 2016 relative frequency of occurrence of aquatic plants in Forest Lake** Created using data from 2016 point-intercept survey.

The quality of Forest Lake's plant community is also indicated by the high number of native emergent and floating-leaf aquatic plant species located in 2016 (Table 3.4-1). The 2016 community mapping survey found that approximately 9.2 acres (2%) of the 469 acre-lake contain these types of plant communities (Table 3.4-2 and Map 7). Twenty-three floating-leaf and emergent species were located on Forest Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

**Table 3.4-2. Forest Lake acres of plant community types.** Created from July 2016 community mapping survey.

| Plant Community | Acres |
|---|---|
| Emergent | 2.6 |
| Floating-leaf | 1.5 |
| Mixed Emergent & Floating-leaf | 5.0 |
| **Total** | 9.2 |

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

## Non-native Plants in Forest Lake

### Eurasian watermilfoil

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

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first documented in Forest Lake during the early summer of 2001. The Forest Lake Association (FLA) initiated volunteer-based hand-harvesting activities and coordinated an herbicide treatment which was subsequently conducted in late-August 2001 using an ester formulation of granular 2,4-D (Navigate ®). The herbicide treatment was determined to be highly effective and continued volunteer-based hand-harvesting has occurred since, seemingly maintaining the EWM population at low levels. In 2013 and 2014, FLA supplied over 575 volunteer hours monitoring and hand-harvesting the EWM population. During those same years, the group paid for 230 hours of harvesting by professionals. Still, with all of this effort, sufficient EWM was located in the northern portion of the lake to warrant an 8-acre treatment during the spring of 2015, which was paid solely with FLA funds

The Late-Summer EWM Peak-Biomass survey was conducted in August of 2015 to qualitatively assess the herbicide treatment as well as to understand the peak growth (peak-biomass) of the EWM population throughout the lake. No EWM was visible within the treatment areas and numerous rake tows in the previously known EWM colonies yielded only native plants within the treatment areas. This 100% reduction in EWM following treatment exceeded the qualitative success criteria for this treatment. During the survey of the rest of the littoral areas of the Forest Lake, only a *single* EWM plant was found between two of the islands on the lake. With the currently low levels of EWM in Forest Lake, no herbicide treatment was warranted for 2016. In July 2016, hand removal efforts by FLA volunteers occurred. Continued monitoring and volunteer hand-removal will likely be the most appropriate control strategy for maintaining the low EWM population in the lake in the future.

Onterra ecologists completed a Late-Summer EWM Peak-Biomass Survey on Forest Lake on September 7, 2016. During this survey, EWM was found to have expanded since 2015 but the overall lake-wide levels were still low (Figure 3.4-11). In 2015, one *single plant* of EWM was found between the two islands on the north side of the lake. In 2016, *single or few plants*, *clumps of plants*, and *small plant colonies* were found (Figure 3.4-11).

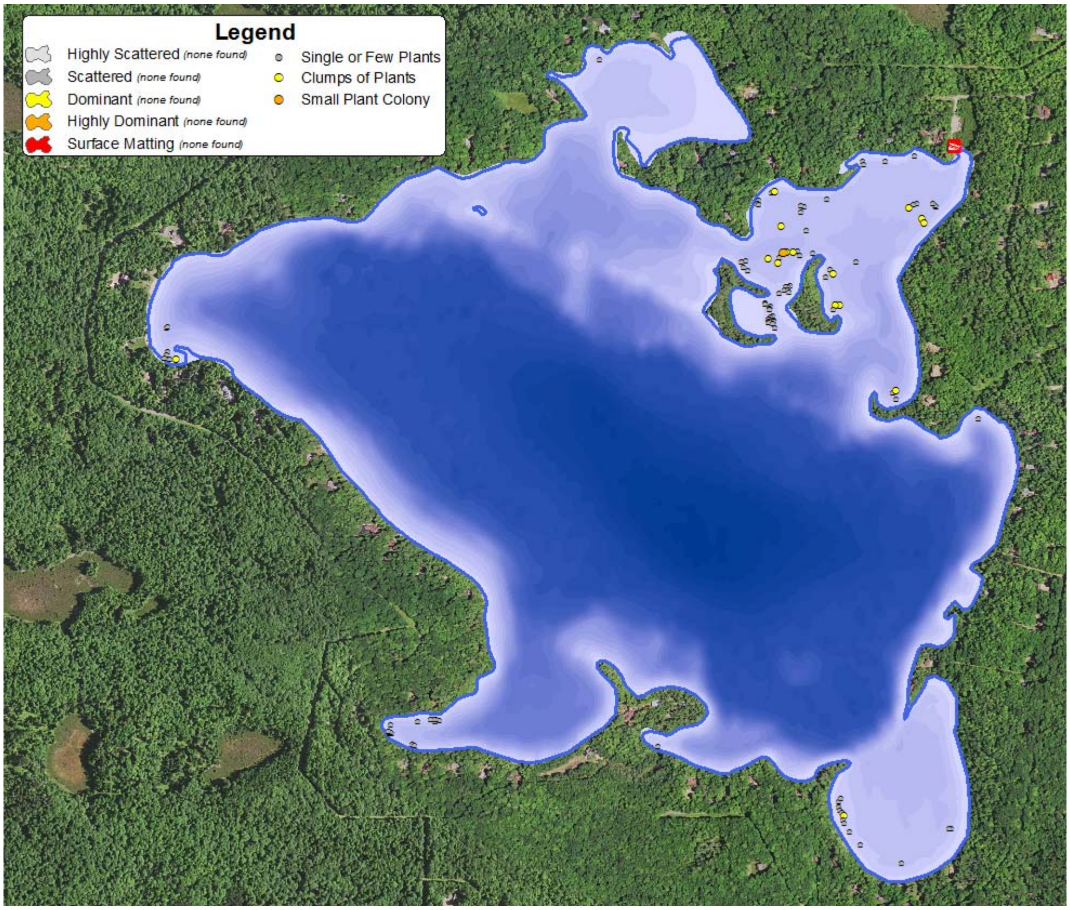



**Figure 3.4-11. Forest Lake 2016 Eurasian watermilfoil locations.** Locations mapped during survey completed on September 7, 2016.

Onterra ecologists completed a Late-Summer EWM Peak-Biomass Survey on Forest Lake on September 6, 2017. During this survey, EWM was found to have expanded since 2016 but the overall lake-wide levels were still low (Figure 3.4-12). S*ingle or few plants*, *clumps of plants*, and *small plant colonies* were found between and around the two islands on the north side of the lake. S*ingle or few plants* were found in the small bays on the south side of the lake and s*ingle or few plants* and *clumps of plants* were found in the northernmost bay on the north shore and on the northwestern shoreline. At present, EWM it as at a level at which it is not having adverse impacts to lake ecology, recreation, or aesthetics. However, continued monitoring and active management will ensure that EWM population in Forest Lake remains at low levels.

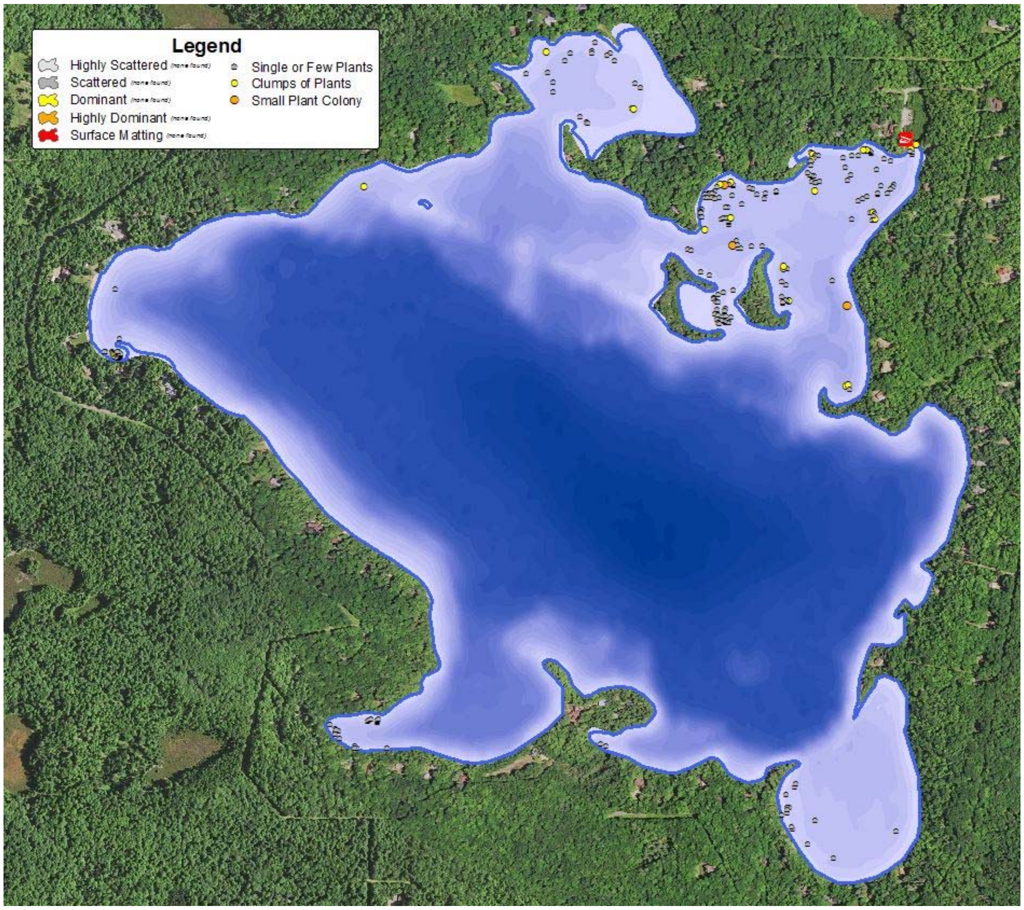
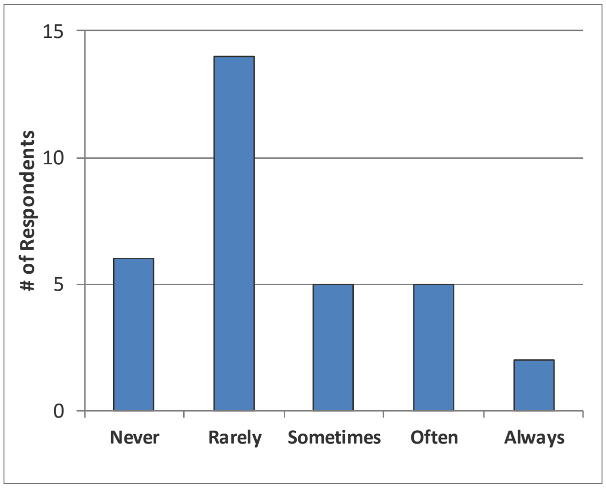
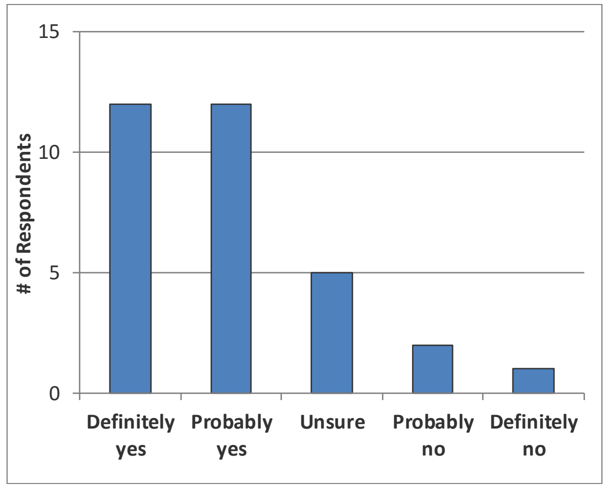



**Figure 3.4-12. Forest Lake 2017 Eurasian watermilfoil locations.** Locations mapped during survey completed on September 6, 2017.

### *Stakeholder Survey Responses to Aquatic Vegetation within 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. Figures 3.4-13 and 3.4-14 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, the majority of stakeholder survey respondents (63%) indicated *rarely* or *never*, 16% indicated *sometimes*, 16% indicated *often*, and 5% indicated *always* (Figure 3.4-13).

When asked if they believe aquatic plant control is needed on Forest Lake, 75% of respondents indicated *definitely yes* and *probably yes*, 16% indicated that they were *unsure*, and 9% indicated *probably no* or *definitely no.* The presence of AIS within Forest Lake is well-known knowledge for the stakeholders so while aquatic plants probably do not generally impact user's enjoyment of the lake, stakeholders believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in Forest Lake is discussed within the Implementation Plan Section (Section 5.0).

| | |
|---|---|
|   |   |
| **Figure 3.4-13. Stakeholder survey response Question #23.** During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of Forest Lake? | **Figure 3.4-14. Stakeholder survey response Question #24.** Do you believe aquatic plant control is needed on Forest Lake? |

## 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 2 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 | Eurasian watermilfoil | *Myriophyllum spicatum* | Section 3.4 – Aquatic Plants |
| Invertebrates | Banded mystery snail | *Viviparus georgianus* | Section 3.5 - Aquatic Invasive Species |

Figure 3.5-1 displays the nine 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*

#### Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

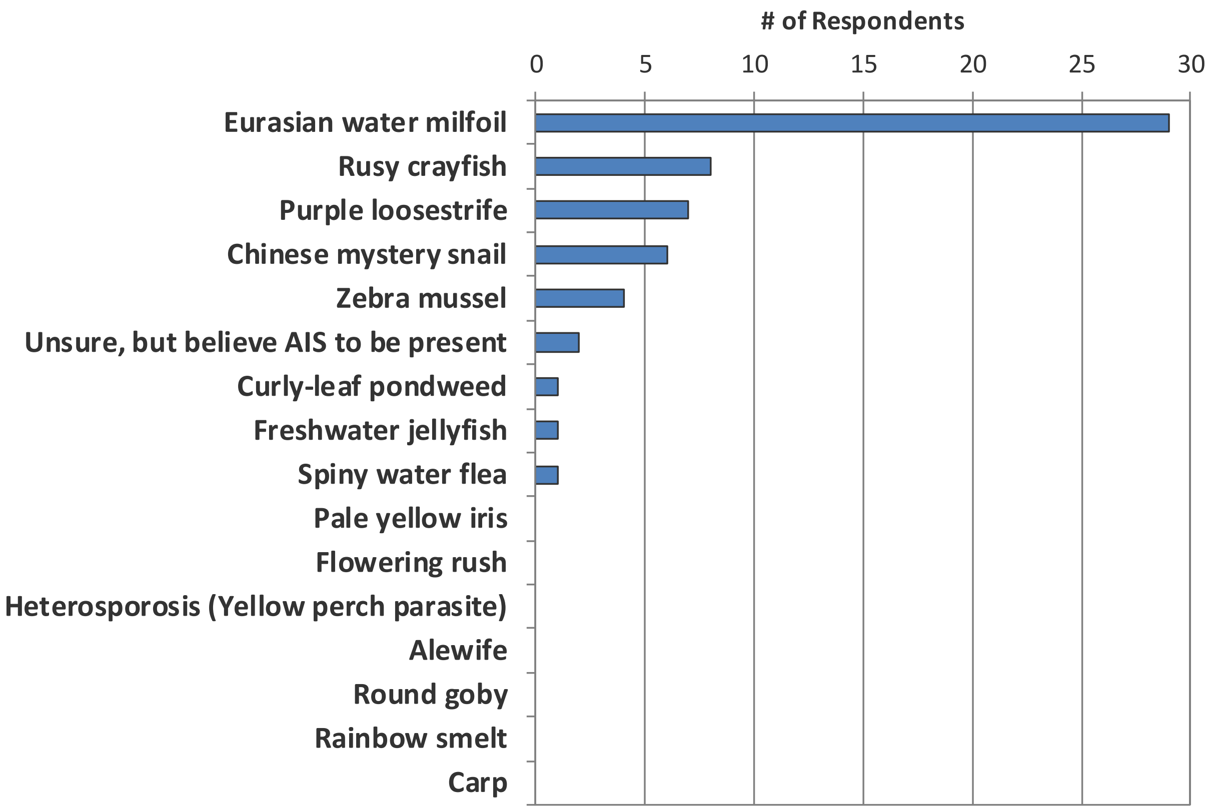



**Figure 3.5-1. Stakeholder survey response Question #20.** Which aquatic invasive species do you believe are in Forest Lake?

## 3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Forest Lake. The goal of this section is to provide an overview of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR), the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologists Hadley Boehm and Steve Gilbert (WDNR 2017 & GLIFWC 2016).

### *Forest Lake Fishery*

#### Forest Lake Fishing Activity

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 piscovorous 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.

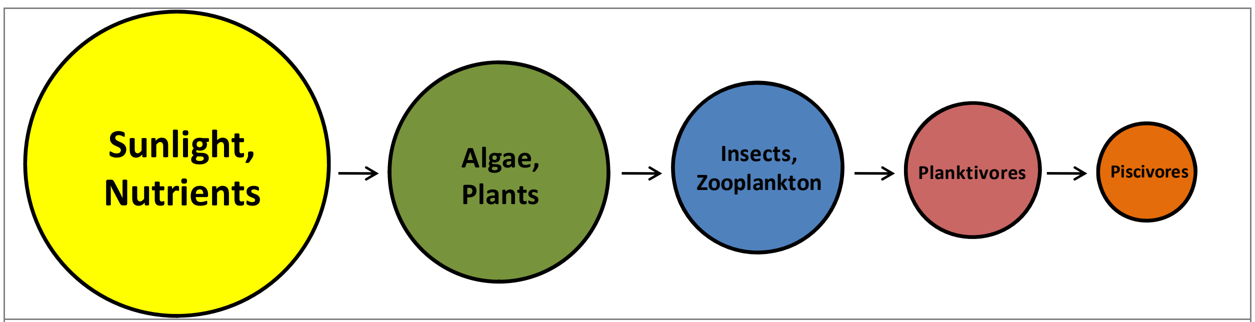



**Figure 3.6-1. Aquatic food chain.** Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Forest Lake is oligotrophic, meaning it has high water clarity, but a low amount of nutrients and thus low primary productivity. Simply put, this means it is difficult for the lake to support a large population of predatory fish (piscivores) because the supporting food chain is relatively small. Table 3.6-1 shows the popular game fish present in the system. Additionally, Forest Lake includes one of the most abundant white sucker (*Catostomus* *commersonii*) populations of Vilas County. Beginning in 1992, the WDNR has collected white sucker eggs to incubate and raise as an early food source for muskellunge reared at the hatchery. These eggs are an essential part to the muskellunge WDNR rearing program (Gilbert 2006).

**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 |
|---|---|---|---|---|
| Bluegill (*Lepomis macrochirus*) | 11 | Late May - Early August | Shallow water with sand or gravel bottom | Fish, crayfish, aquatic insects and other invertebrates |
| Cisco (*Coregonus artedii*) | 22 | Late November - Early December | No clear substrate preference. | Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates. |
| 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) |
| Rock Bass (*Ambloplites rupestris*) | 13 | Late May - Early June | Bottom of course sand or gravel, 1 cm - 1 m deep | Crustaceans, insect larvae, and other invertebrates |
| Smallmouth Bass (*Micropterus dolomieu*) | 13 | Mid May - June | Nests more common on north and west shorelines over gravel | Small fish including other bass, crayfish, insects (aquatic and terrestrial) |
| Walleye (*Sander vitreus*) | 18 | Mid April - Early May | Rocky, wavewashed shallows, inlet streams on gravel bottoms | Fish, fly and other insect larvae, crayfish |
| Yellow Perch (*Perca flavescens*) | 13 | April - Early May | Sheltered areas, emergent and submergent veg | Small fish, aquatic invertebrates |

## Survey Methods

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

The other commonly used sampling method is electroshocking (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, *galvanotaxis* (stimulation of the nervous system in response to an electric current) transpires and involuntarily causes the fish to swim toward the electrodes. When the fish are in the vicinity of the electrodes, they undergo *narcosis* (stunned), making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell fish generally recover within minutes.

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

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

## Fish Stocking

**Photograph 3.6-2. Fingerling Walleye.**

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 3.6-2). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Forest Lake has been stocked as early as the 1930s with variable fish species. As of 2006, sustainable natural reproduction was occurring for all major fish species and there was no need to stock any species (Gilbert 2006). Stocking efforts done by the WDNR, for Forest Lake, are displayed in Table 3.6-3.

**Table 3.6-3. WDNR fisheries stocking data for Forest Lake (1936-1977).**

| Year | Species | Strain (Stock) | Age Class | # Fish Stocked | Avg Fish Length (in) |
|---|---|---|---|---|---|
| 1952 | Largemouth bass | Unspecified | Fingerling | 2,330 | Unspecified |
| 1950 | Largemouth bass | Unspecified | Fingerling | 700 | Unspecified |
| 1949 | Largemouth bass | Unspecified | Fingerling | 9,300 | Unspecified |
| 1944 | Largemouth bass | Unspecified | Fingerling | 250 | Unspecified |
| 1940 | Largemouth bass | Unspecified | Fry | 3,000 | Unspecified |
| 1939 | Largemouth bass | Unspecified | Fry | 2,800 | Unspecified |
| 1937 | Largemouth bass | Unspecified | Fingerling | 3,000 | Unspecified |
| 1977 | Walleye | Unspecified | Fingerling | 22,000 | 3 |
| 1967 | Walleye | Unspecified | Fingerling | 5,775 | Unspecified |
| 1966 | Walleye | Unspecified | Fingerling | 24,000 | Unspecified |
| 1965 | Walleye | Unspecified | Fingerling | 47,000 | Unspecified |
| 1938 | Bluegill | Unspecified | Adult | 1,600 | Unspecified |
| 1936 | Bluegill | Unspecified | Yearling | 80 | Unspecified |
| 1938 | Yellow Perch | Unspecified | Adult | 200 | Unspecified |
| 1936 | Yellow Perch | Unspecified | Yearling | 320 | Unspecified |

## Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), Forest Lake stakeholders enjoy catching walleye the most (Figure 3.6-2). Approximately 60% of stakeholders who fish Forest Lake believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 50% of landowners who fish Forest Lake believe that the quality of fishing has gotten worse since they have started fishing the lake (Figure 3.6-4).

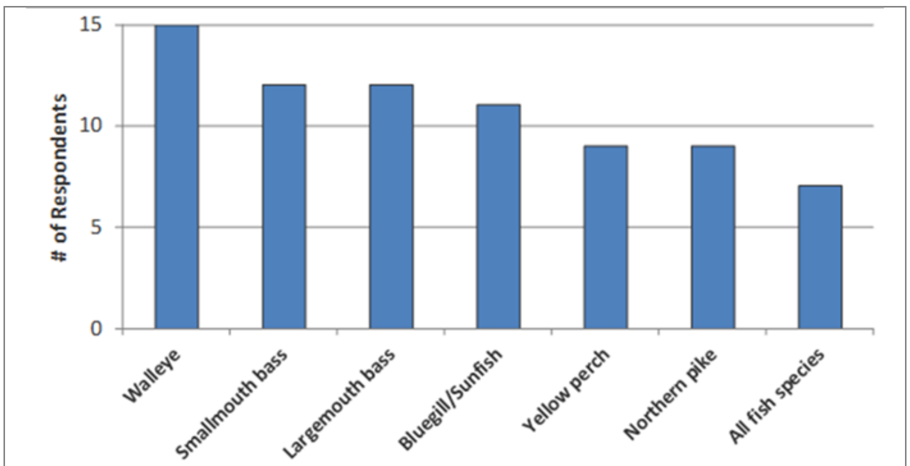



**Figure 3.6-2. Stakeholder survey response Question #9.** What species of fish do you like to catch on Forest Lake?

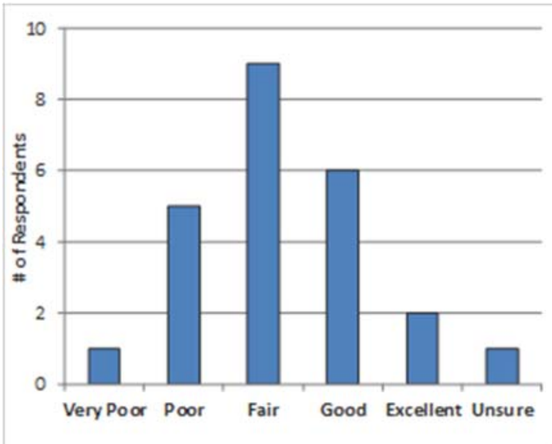



**Figure 3.6-3. Stakeholder survey response Question #10.** How would you describe the current quality of fishing on Forest Lake?

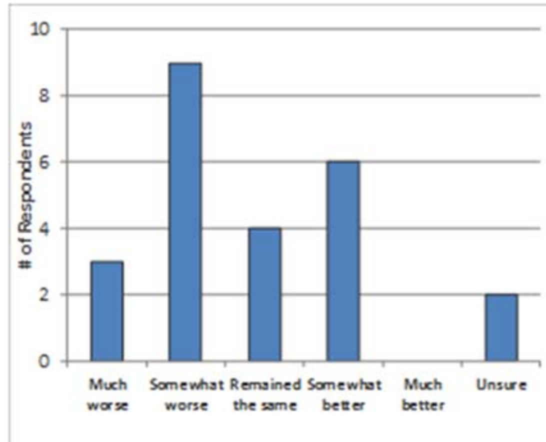



**Figure 3.6-4. Stakeholder survey response Question #11.** How has the quality of fishing changed on Forest Lake since you started fishing the lake?

## *Forest Lake Spear Harvest Records*

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-5). Forest Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level" or 12% of a lake's estimated walleye population. Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The


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

safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration (termed "declared quota" later on in this report), and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

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

Walleye open water spear harvest records are provided in Figure 3.6-6 from 1999 to 2017, however records extend to 1989. As many as 219 walleye have been harvested from the lake in the past (2016), but the average harvest is roughly 118 fish in a given year. Spear harvesters on average have taken 83% of the declared quota.

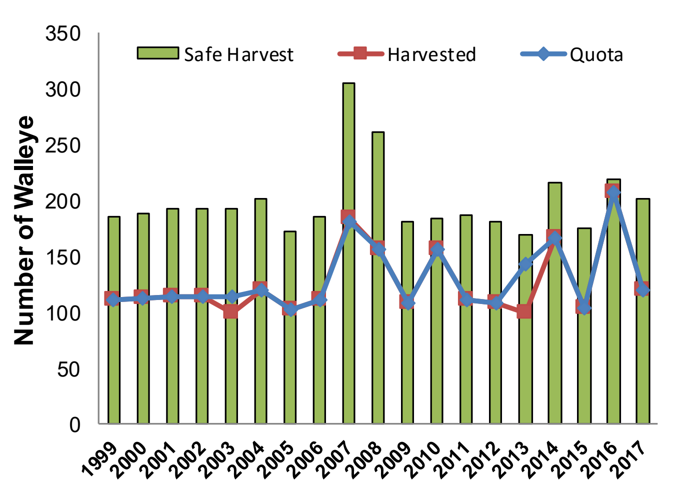



**Figure 3.6-6. Forest Lake walleye spear harvest data.** Annual total walleye harvest statistics are displayed since 1999 from GLIFWC annual reports for Forest Lake.

## Forest Lake Fish Habitat

### Two-Story Fishery

Forest Lake is unique compared to most lakes in Wisconsin in that it is a two-story fishery. A two-story fishery is capable of supporting both a warm water and cold water fishery. The top-story supports warmer water species such as bass and pike. The lower-story is colder, deeper, well oxygenated and can support species such as cisco or lake trout. A 2014 survey conducted by the WDNR found cisco (*Coregonus* spp.) in Forest Lake in low relative abundance (Lyons, et al 2015).

### Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2016, 43% of the substrate sampled in the littoral zone of Forest Lake was sand, 36% was soft sediments and 21% composed of rock.

### Coarse Woody Habitat & Fish Sticks Program

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

**Photograph 3.6-2. Fish Stick Example.**
(Photo courtesy of WDNR 2013)

The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 survey documented 158 pieces of coarse woody along the shores of Forest Lake, resulting in a ratio of approximately 22 pieces per mile of shoreline. Forest Lake may be an excellent candidate to consider enhancing coarse woody habitat through the deployment of fish sticks.

## *Regulations and Management*

Current (2017-2018) regulations for Forest Lake gamefish species are displayed in Table 3.6-4. 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 3.6-4. WDNR fishing regulations for Forest Lake (2018-2019).**

| Species | Daily bag limit | Length Restrictions | Season |
|---|---|---|---|
| Panfish | 25 | None | Open All Year |
| Largemouth bass and smallmouth bass | 1 | 18" | June 16, 2018 to March 3, 2019 |
| Smallmouth bass | Catch and release only | Catch and release only | May 5, 2018 to June 15, 2018 |
| Largemouth bass | 1 | 18" | May 5, 2018 to June 15, 2018 |
| Muskellunge and hybrids | 1 | 40" | May 26, 2018 to November 30, 2018 |
| Northern pike | 5 | None | May 5, 2018 to March 3, 2019 |
| Walleye | 3 | Only walleye less than 14" may be kept except, one fish may be over 18" | May 5, 2018 to March 3, 2019 |

## Mercury Contamination and Fish Consumption Advisories

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

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

**Fish Consumption Guidelines for Most Wisconsin Inland Waterways**

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

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

**Figure 3.6-7. Wisconsin statewide safe fish consumption guidelines.** Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (*http://dnr.wi.gov/topic/fishing/consumption/*)

Additional restrictions may be found at these WDNR weblinks.

WDNR online query: *http://dnr.wi.gov/FCSExternalAdvQry/FishAdvisorySrch.aspx*
WDNR fish consumption homepage: *http://dnr.wi.gov/topic/fishing/consumption/*

# 4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the 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 needs to be completed to protect and enhance them.

Overall, Forest Lake is a very healthy lake. Nutrient levels are lower in Forest Lake compared to similar lakes in the state and all lakes in the Northern Lakes and Forests Ecoregion. This leads to lower algal abundance and excellent water clarity in Forest Lake as well. The lake is considered to have low to moderate productivity and be in an oligotrophic-mesotrophic state. There is some evidence of internal nutrient loading from bottom sediments in Forest Lake. Internal nutrient loading is a natural occurrence in many deep lakes and there is no evidence that this phenomenon is impacting the lake's water quality in a noticeable manner at present.

Forest Lake is considered to be a deep seepage lake, meaning that the lake has a small surface watershed and groundwater, which is typically very low in nutrient content, is significant in the lake's hydrologic budget. Of the lake's total surface watershed, the lake itself makes up approximately 40% with forested areas adding about the same. The remaining area is made up of wetlands and grassed areas. All-in-all, the surface watershed of Forest Lake adds little phosphorus to the lake and is the driving factor in its excellent water quality.

The floristic quality of Forest Lake is considered higher than most lakes in the state and in the ecoregion and is another indicator of the lake's good ecological health. While the lake has a high native species richness, its diversity is moderate because the population is highly dominated by fern pondweed and moderately dominated by three additional species, common waterweed, muskgrasses, and slender naiad. Studies completed in 2005, 2013, and 2016 indicate that the overall aquatic plant abundance increased from 2005 to 2013 and remained approximately the same in 2016. Seepage lakes like Forest Lake can experience fluctuations in water levels as the groundwater regime in the area changes from year-to-year. Forest Lake is no exception; therefore, the lake's photic zone also changes, expanding and contracting areas of the lake bottom available to plant establishment as the water levels rise and fall. Although Forest Lake's species diversity, as mentioned above, would be considered moderate, it is sufficient to allow the aquatic plant population to alter with the environmental changes brought on by the fluctuating water levels.

Eurasian watermilfoil was first documented in Forest Lake in 2001 and remained at a very low occurrence through 2014, likely attributable to the diligent hand-harvesting efforts for the FLA. In 2015, the population had expanded in the northern portion of the lake and the FLA sponsored an herbicide treatment of the area utilizing 2,4-D. No EWM was located in the treatment area that summer and its occurrence remained low there and in other areas of the lake. The FLA has continued its diligent hand-harvesting efforts using professional and volunteer services since the last treatment, but unfortunately the FLA has seen EWM density increase in the areas it has typically occupied throughout the years. On October 16, 2018, Onterra ecologists visited Forest Lake to completed a focused late-season AIS survey. The survey crew only visited areas of the lake that were known to have EWM based upon volunteer survey data supplied by the FLA. The results of that survey are displayed in Map 8 and when compared to earlier mapping efforts completed in 2016 and 2017 (Figures 3.4-11 and 3.4-12), it is apparent that the EWM has increased in density and area in several locations around the lake. Still, on a lake-wide basis, the EWM population would be considered to be very low. Balancing the cost, time, and environmental risk of managing EWM is a difficult task. The Implementation Plan (Section 5.0) will be used as a guide to assist the FLA in balancing those factors and managing the EWM in Forest Lake with the ultimate goal of keeping the population low.

While EWM may seem like the biggest challenge facing the FLA in managing Forest Lake, it likely is not. When considering the overall health of Forest Lake, the most daunting challenge is the impacts by human beings as they alter the landscape around the lake and recreate on the lake itself. Fortunately, those that first developed property around the lake created certain deed restrictions that ease some of those impacts to the lake's health. Further, the current FLA membership is highly involved in the monitoring and management of the lake's health. The challenge facing the FLA is to maintain that involvement and awareness in its members so in the long-run, the lake's overall health remains as high as it is now. This challenge is also addressed with several goals and actions contained in the Implementation Plan below.

# 5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the FLA Planning Committee and ecologist/planners from Onterra. It represents the path the FLA 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.

## *Management Goal 1: Control Existing and Prevent Further Aquatic Invasive Species Infestations within Forest Lake*

| | |
|---|---|
| **Management Action:** | Continue Clean Boats Clean Waters watercraft inspections at public access location |
| **Timeframe:** | Continuation of current effort |
| **Facilitator:** | FLA Board of Directors |
| **Potential Grant:** | WDNR AIS-Clean Boats Clean Waters Grant |
| **Description:** | Currently the FLA monitors the Forest Lake public boat landing using training provided by the Clean Boats Clean Waters program. Forest Lake is a popular destination by recreationists and anglers, making the lake vulnerable to new infestations of exotic species. The intent of the boat inspections would not only be to prevent additional invasive species from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasive species that are present in Forest Lake. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread.<br><br>The FLA has set a goal of 200 hours of annual watercraft inspections utilizing a combination of volunteer and paid inspectors. Volunteers would focus upon high-use periods such as weekends and holidays. The long-term goal is permanent monitoring, given the financial capacity to do so. |
| **Action Steps:** | |
| | See description above as this is an established program. |

| **Management Action:** | Coordinate annual volunteer monitoring of EWM. |
|---|---|
| **Timeframe:** | Continuation of current effort |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | Continue volunteer-based AIS monitoring as the primary guide to volunteer and/or professional hand-harvesting efforts. Professional monitoring would be utilized on an as-needed basis as determined by the findings of the volunteer monitors. – If the volunteer AIS monitoring coordinator believes that EWM levels have increased significantly or if additional AIS are verified in the lake, professional AIS monitoring services would be solicited to map AIS and assist the FLA with determining the proper management strategy.<br><br>A coordinator should be recruited and be the primary contact with the Lake Management Planning Committee and Forest Lake Association. |
| **Action Steps:** | |
| | See description above as. |

| **Management Action:** | Conduct EWM population control using hand-harvesting (including DASH) and/or herbicide spot treatments. |
|---|---|
| **Timeframe:** | Continuation of current effort |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | The proactive EWM management strategy that has occurred in Forest Lake since its detection has kept the EWM population at low levels. At these low levels, the EWM population is likely not causing measurable negative ecological impacts to the system nor diminishing the navigability, recreation, or aesthetics of the lake. The FLA would like to continue on a proactive management approach to EWM to keep the population low within the lake, preferably with non-herbicide control options.<br><br>*Hand-Harvesting*<br>If the early summer volunteer surveys reveal areas of EWM that are comprised of *single plants* or *clumps of plants* and are not 'colonized', the FLA will organize efforts to hand-remove the plants. Depending on the level of volunteerism and size of the EWM occurrences, the FLA will determine if volunteer- or professional-based methods would be solicited.<br><br>Hand-harvesting would occur following the early summer survey in roughly mid-June to mid-September. Conducting hand-harvesting earlier or later in the year can reduce the effectiveness of the strategy, as plants are more brittle and extraction of the roots more difficult. |

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|---|---|
| | If a Diver Assisted Suction Harvest (DASH) component is utilized, the FLA and contracted firm would be responsible for the WDNR permit procedures. The contracted firm would be guided with GPS data from the early summer survey and would track their efforts (when, where, time spent, quantity removed) for post assessments.<br><br>Herbicide Spot Treatment<br>If the following trigger is met, the FLA would initiate pretreatment monitoring and begin discussions, including consultation with WDNR staff, regarding conducting herbicide spot treatments: "colonized (polygons) areas where a sufficiently large treatment area can be constructed to hold concentration and exposure times." It is believed that these areas are too large to be controlled using hand-harvesting techniques. It is likely that these areas would need to be targeted with herbicides that require short exposure times (diquat, florpyrauxifen-benzyl [ProcellaCOR™]) or herbicide combinations (diquat/endothall, 2,4-D/endothall, etc.). Larger areas (>5 acres) or sites in protected parts of the lake are to be targeted with an herbicide spot treatment, more traditional systemic herbicides like 2,4-D may be appropriate and considered. If populations exceed spot-treatment thresholds, large-scale herbicide strategies may be given consideration.<br><br>In late-winter, an herbicide applicator firm would be selected and a conditional permit application would be applied for from the WDNR. The herbicide treatment would occur when surface water temperatures are roughly below 60°F and active growth tissue is confirmed on the target plants. A pretreatment survey, a week or so prior to treatment, would be used to finalize the permit, potentially with adjustments, and dictate approximate ideal treatment timing.<br><br>Overall, the FLA will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen. Any financial cost will first be approved by the Forest Lake Association Board of Directors. |
| **Action Steps:** | |
| | See description above |

| **Management Action:** | Conduct periodic quantitative vegetation monitoring on Forest Lake. |
|---|---|
| **Timeframe:** | Point-Intercept Survey every 3-5 years, Community Mapping every 7-10 years |
| **Possible Grant:** | Small-Scale Lake Planning Grant or AIS-Education, Prevention, and Planning in <$10,000 category. |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | As part of the ongoing AIS management program, a whole-lake point-intercept survey will be conducted at a minimum once every 3-5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Forest Lake. A point-intercept survey was conducted on Forest Lake in 2016; therefore, the next point-intercept survey will be completed between 2019 and 2021, depending on the level of AIS management being completed.<br><br>In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Forest Lake, a community mapping survey would be conducted every 7-10 years. A community mapping survey was conducted on Forest Lake in 2016 as a part of this management planning effort. The next community mapping survey will be completed between 2022 and 2026. |
| **Action Steps:** | |
| | See description above. |

| **Management Action:** | Initiate rapid response plan following detection of new AIS |
|---|---|
| **Timeframe:** | If/When Necessary |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | If volunteer or professional surveys locate a suspected new AIS within Forest Lake, the location would be marked (e.g. GPS, maker buoy) and a specimen would be taken to the WDNR Lake Coordinator (Kevin Gauthier), or to the Vilas County Land Conservation Department for verification. If the suspected specimen is indeed a non-native species, the WDNR will fill out an incident form and develop a strategy to determine the population level within the lake. The lake would be professionally surveyed, either by agency personnel or a private consulting firm during that species' peak growth phase.<br><br>If the AIS is a NR40 prohibited species (i.e. red swamp crayfish, starry stonewort, hydrilla, etc.), the WDNR may take an active role in the response.<br><br>If the AIS is a NR40 restricted species (i.e. purple loosestrife, curly-leaf pondweed, etc.), the FLA would need to reach out to a consultant to develop a formal monitoring and/or control strategy. The WDNR would be able to help financially through the AIS Grant Program's Early Detection and Response program. This grant program is non- |

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|---|---|
| | competitive and doesn't have a specific application deadline, but is offered on a first-come basis to the sponsor of project waters that contain new infestations (found within less than 5% of the lake and officially documented less than 5 years from grant application date). Currently this program will fund up to 75% percent of monitoring and control costs, up to $20,000. |
| **Action Steps:** | |
| | See description above |

## *Management Goal 2: Maintain Current Water Quality Conditions*

| | |
|---|---|
| **<u>Management Action:</u>** | Monitor water quality through WDNR Citizens Lake Monitoring Network. |
| **Timeframe:** | Continuation of current effort. |
| **Facilitator:** | FLA Board of Directors |
| **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.<br><br>Volunteer water quality monitoring is currently being 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. The FLA currently monitors the deep hole site within as a part of the advanced CLMN program. This includes collecting Secchi disk transparency and sending in water chemistry samples (chlorophyll-a, and total phosphorus) to the Wisconsin State Laboratory of Hygiene for analysis. The samples are collected three times during the summer and once during the spring. It is important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).<br><br>It will be the Board of Directors responsibility to ensure that a volunteer is prepared to communicate with WDNR representatives and collect water quality samples each year. |
| **Action Steps:** | |
| 1. | Trained CLMN volunteer(s) collects data and report results to WDNR and to association members during annual meeting. |
| 2. | CLMN volunteer and/or FLA Board of Directors would facilitate new volunteer(s) as needed |

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| 3. | Coordinator contacts Sandra Wickman (715.365.8951) to acquire necessary materials and training for new volunteer(s) |

## Management Goal 3: Improve Lake and Fishery Resource by Protection and Restoring Shoreland Condition

| **Management Action:** | Educate stakeholders on the importance of shoreland condition and shoreland restoration on Forest Lake. |
|---|---|
| **Timeframe:** | Initiate 2019 |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects.<br><br>Approximately 11% of Forest Lake's shoreline is considered completely urbanized or developed unnatural (Figure 3.3-2). This limits shoreland habitat, but it also reduces natural buffering of shoreland runoff and allows nutrients to enter the lake. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, the FLA has decided to take the following steps to increase shoreland restoration on Forest Lake:<br><br>1. Educate riparians about the importance of healthy and natural shorelands.<br>2. Solicit 3 or more riparians to allow shoreland restoration and storm water runoff designs for their property.<br>3. The FLA will work with Vilas County (Quita Sheehan) or private entity to create design work. Small-scale WDNR grants may be sought to offset design costs.<br>4. Designs can be shared with FLA members to provide further education of shoreland restoration projects.<br>5. Move forward with implementing shoreland restoration per the designs that were developed for those riparians that wish to. Project funding would be available through the WDNR's Healthy Lakes Initiative Grants (see below).<br>6. The FLA's goal would be to have at least 1 shoreland restoration sites to serve as demonstrations sites to encourage other riparians to follow same path of shoreland restoration. |

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| | The WDNR's Healthy Lakes Initiative Grant program 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 Oconto County.<br>• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance<br>• Maximum of $1,000 per 350 $ft^2$ of native plantings (best practice cap)<br>• Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances<br>• Must be at least 350 $ft^2$ of contiguous lakeshore; 10 feet wide<br>• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years<br>• Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available |
| **Action Steps:** | |
| 1. | Recruit facilitator from Planning Committee |
| 2. | Facilitator contacts the Vilas County Land Conservation department to gather information on initiating and conducting shoreland restoration projects. If able, the county staff member would be asked to speak to FLA members about shoreland restoration at their annual meeting. |
| 3. | The FLA would encourage property owners that have restored their shorelines to serve as demonstration sites. |

| **<u>Management Action:</u>** | Coordinate with WDNR and private landowners to expand coarse woody habitat in Forest Lake |
|---|---|
| **Timeframe:** | Initiate 2019 |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | FLA stakeholders realize the complexities and capabilities of Forest Lake ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition |

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| | Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.<br><br>The WDNR's Healthy Lakes Initiative Grant allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.<br>• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance<br>• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)<br>• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances<br>• Buffer area (350 $ft^2$) at base of coarse woody habitat cluster must comply with local shoreland zoning or:<br>    o The landowner would need to commit to leaving the area un-mowed<br>    o The landowner would need to implement a native planting (also cost share through this grant program available)<br>• Coarse woody habitat improvement projects require a general permit from the WDNR<br>• 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 Lakes Coordinator and WDNR Fisheries Biologist to gather information on initiating and conducting coarse woody habitat projects. |
| 3. | The FLA will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites. |

## *Management Goal 4:* Increase the FLA'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 |
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| **Timeframe:** | Continuation of current efforts |
| **Facilitator:** | FLA Board of Directors |
| **Description:** | Education represents an effective tool to address many lake issues. The FLA annually distributes a newsletter to its membership, maintains a closed Facebook Group, and has developed a website, which is the official repository of the FLA information. These mediums allow for communication with association members, but increasing the level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings.<br><br>The FLA has a strong commitment to keeping Forest Lake healthy; therefore, it is a requirement of a FLA board member to contact any and all new lake property owners regarding the deed restrictions, the importance of maintaining the lake water quality, and any other pertinent information relating to the lake.<br><br>The FLA will continue to make the education of lake-related issues a priority. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support.<br><br>*Example Educational Topics*<br>• History and summary of Forest Lake Lot Restrictions<br>• Specific topics brought forth in other management actions<br>• Aquatic invasive species identification<br>• Basic lake ecology<br>• Impacts of drought and low water levels<br>• Sedimentation<br>• Boating safety (promote existing guidelines, Lake Use Information handout)<br>• Swimmers itch<br>• Shoreline habitat restoration and protection<br>• Fireworks use and impacts to the lake<br>• Noise and light pollution<br>• Fishing regulations and overfishing<br>• Minimizing disturbance to spawning fish<br>• Recreational use of the lakes |
| **Action Steps:** | |

| | |
|---|---|
| | See description above as this is an established program. |

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

**Table 5.0-1 Management Partner List.**

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| **Town of Land O' Lakes** | General Town Chair (Daniel Balog,715.547.3255, town.landolakes@gmail.com) | Oversees ordinances, funding, and other items pertaining to town | As needed. | Involved in lake management activities, monitoring, implementation, funding, volunteer recruitment. May be contacted regarding ordinance questions, and for information on community events. |
| **Great Lakes Indian Fish and Wildlife Commission** | General (715.682.6619) | Resource management within Ceded Territory | As needed. | Collaborate on lake related studies, AIS management, inform of meetings, etc. |
| **Vilas County Lakes & Rivers Association (VCLRA)** | President (Tom Ewing, president@vclra.us) | Protects Vilas Co. waters through facilitating discussion and education. | Twice a year or as needed. | Become aware of training or education opportunities, partner in special projects, or networking on other topics pertaining to Vilas Co. waterways. |

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| **Vilas County Land and Water Conservation Department** | Lake Conservation Specialist (Mariquita (Quita) Sheehan, 715.479.3721, mashee@co.vilas.wi.us) | Oversees conservation efforts for lake grants and projects. | Twice a year or more as needed. | Contact for shoreland remediation/restoration techniques and cost-share procedures, wildlife damage programs, education and outreach documents. |
| | Lake Conservation Specialist (Cathy Higley, 715.479.3738, cahigl@co.vilas.wi.us) | Oversees AIS monitoring and education activities county-wide. | Twice a year or more as issues arise. | AIS training and ID, monitoring techniques, CBCW training, report summer activities. |
| **Wisconsin Department of Natural Resources** | Fisheries Biologist (Steve Gilbert, 715.356.5211) | Manages the fish populations and fish habitat enhancement efforts. | Once a year, or more as issues arise. | Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery. |
| | Lakes Coordinator (Kevin Gauthier – 715.365.8937) | Oversees management plans, grants, all lake activities. | As needed. | Information on planning/AIS projects, grant applications or to seek advice on other lake issues. |
| | Environmental Grant Specialist (Laura MacFarland, 715.365.8900) | Oversees financial aspects of grants. | As needed. | Information on grant financials and reimbursement, CBCW grant applications. |
| | Conservation Warden (Rich Thole, 715.605.2130) | Oversees regulations handed down by the state. | As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day). | Contact regarding suspected violations pertaining to recreational activity, include fishing, boating safety, ordinance violations, etc. |
| | Trout Lake Station staff (Susan Knight and Carol Warden 715.356.9494) | Conducts lake research on multiple levels | As needed. | Can be contacted for identification or consultation on AIS. |
| | Citizen Lake Monitoring Network (Sandy Wickman – 715.365.8951, sandra.wickman@wisconsin.gov) | Provides information, training, and equipment for CLMN volunteers. | As needed. | Contact of information regarding CLMN program, including training, equipment, and data entry into SWIMS |
| **Vilas County Sheriff Dept.** | 1.800.472.7290 or 715.479.4441 non-emergency, 911 emergencies only. | Perform law enforcement duties to protect lakes, especially pertaining to compliance with boating safety rules. | As needed. | Contact regarding suspected violations pertaining to boating safety rules on the lake. |

| Partner | Contact Person | Role | Contact Frequency | Contact Basis |
|---|---|---|---|---|
| | | | | |
| **University of Wisconsin Extension Office** | Lakes Specialist (Pat Goggin, 715.365.8943, Patrick.Goggin@wisconsin.gov) | Provides guidance for lakes, shoreline restoration, and outreach/education. | As needed. | Contact for shoreland remediation/restoration techniques, outreach/education. |
| **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 | Those interested may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc. |

# 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 on the lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred once in spring and three times during the summer. In addition to the samples collected by Forest Lake Association, Inc. (FLA) members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although FLA members collected a spring total phosphorus sample, professionals also collected a near bottom sample to coincide with the bottom total phosphorus sample. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

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

| | Spring | | June | July | August | Fall | | Winter | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **S** | **B** | **S** | **S** | **S** | **S** | **B** | **S** | **B** |
| Total Phosphorus | ■♦ | ■ | ♦ | ♦ | ♦ | ■ | ■ | ■ | ■ |
| Dissolved Phosphorus | ■ | ■ | | | | | | ■ | ■ |
| Chlorophyll-*a* | ■ | | ♦ | ♦ | ♦ | ■ | | | |
| Total Kjeldahl Nitrogen | ■ | ■ | ● | ● | ● | ■ | | ■ | ■ |
| Nitrate-Nitrite Nitrogen | ■ | ■ | ● | ● | ● | ■ | | ■ | ■ |
| Ammonia Nitrogen | ■ | ■ | ● | ● | ● | ■ | | ■ | ■ |
| Laboratory Conductivity | ■ | ■ | | | | | | | |
| Laboratory pH | ■ | ■ | | | | | | | |
| Total Alkalinity | ■ | ■ | | | | | | | |
| Total Suspended Solids | ■ | ■ | | | | ■ | ■ | ■ | ■ |
| Calcium | ■ | | | | | | | | |

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

## Acoustic Survey

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

# 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)

# Aquatic Vegetation

## *Early Season AIS Survey*

An Early Season AIS Survey was completed on Forest Lake during a June 29, 2016 field visit, 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.

## *Comprehensive Macrophyte Surveys*

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 on July 27, 2016. A point spacing of 45 meters was used resulting in approximately 247 points.

### *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 GeoXT Global Positioning System (GPS) with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

Representatives of all plant species located during the point-intercept and community mapping survey were collected and vouchered by the University of Wisconsin – Steven's Point Herbarium. A set of samples was also provided to the FLA.

# 7.0 LITERATURE CITED

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

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.

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. 2010A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2010.

Great Lakes Indian Fish and Wildlife Service. 2010B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2010.

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.

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.

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.

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

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

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.

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: *www.glifwc.org/Accordian_Stories/GeorgeSpangler.pdf*

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

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.

Wisconsin Department of Natural Resources. 2002. 2002-2003 Ceded Territory Fishery Assessment Report. Administrative Report #59.

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. 2011. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed March 2011.

Wisconsin Department of Natural Resources (WDNR). 2013. Wisconsin 2014 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://www.glifwc.org/Biology/reports/reports.htm.

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