Pine Lake

Forest County, Wisconsin

Comprehensive Management Plan

May 2013

Sponsored by:

Pine Lake Protection and Rehabilitation District

WDNR Grant Program

LPL-1292-09, LPL-1293-09, & LPL-1325-10

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

Onterra LLC
Lake Management Planning

Pine Lake

Forest County, Wisconsin

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Created by: Tim Hoyman, Eddie Heath & Dan Cibulka
Onterra, LLC
De Pere, WI

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

Pine Lake Planning Committee

James Gehl
Cyndi Ginder
Ann Kloehn
Terry Kloehn
Marilyn Pfeiffe
Dennis Schumacher
Mary Sprenger
Dick Tarcin
Gerald Wolf
Steve Ziesmann
Tom Ziolkowski

Wisconsin Dept. of Natural Resources

Kevin Gauthier

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1.0 INTRODUCTION

Pine Lake, Forest County (Map 1), is a drainage lake with a maximum depth of 15 feet and a surface area of nearly 1,684 acres. Pine Lake is the headwaters of the Wolf River which ultimately flows into the Lake Winnebago System. This eutrophic lake has a relatively moderately sized watershed when compared to the size of the lake. Pine Lake contains 33 native plant species, of which coontail is the most common plant. Two exotic plant species are known to exist in Pine Lake.

Field Survey Notes

Large lake, moderate depth with quite a few plants. Bushy pondweed found throughout lake and washed upon shoreline in numerous areas. Native plant abundance is high with scattered Eurasian water milfoil found throughout much of the littoral zone, but not at nuisance levels.

Photograph 1.0-1 Pine Lake, Forest County, WI

Lake at a Glance – Pine Lake

Morphology	
Acreage	1,684
Maximum Depth (ft)	15
Mean Depth (ft)	10
Vegetation	
Curly-leaf Survey Date	June 10, 2009
Comprehensive Survey Date	July 6 & 7, 2009
Number of Native Species	33
Threatened/Special Concern Species	None
Exotic Plant Species	Eurasian water milfoil, Curly-leaf pondweed
Simpson's Diversity	0.88
Average Conservatism	6.4
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Water Acidity (pH)	7.7
Sensitivity to Acid Rain	Not sensitive
Watershed to Lake Area Ratio	8:1

Pine Lake's shallow depth and dense aquatic vegetation population are major concerns of the Pine Lake Protection and Rehabilitation District (PLPRD). In the recent past, harvesting activities were used to increase recreational opportunities and remove excessive amounts of plant materials which have been attributed to low winter dissolved oxygen levels. Harvesting was completed with a district-owned harvester that was sold during 2009. The lake group also has concern regarding the establishment of two non-native aquatic plant species, curly-leaf pondweed and hybrid Eurasian-Northern water milfoil, the latter of which is present in nuisance levels within the lake. Additional non-native species found in Pine Lake include the Banded mystery snail, Chinese mystery snail, and Rusty crayfish. Pine Lake is a highly sought after location amongst recreationists and anglers. Being the second largest lake in Forest County and having over 400 property owners within the district, the lake receives considerable public use. These intense public use opportunities most likely contributed to Pine Lake becoming infested with the several exotic species it has now.

Pine Lake is classified as a drainage lake, meaning it has both an inlet (or inlets) and an outlet. Water flows out of Pine Lake at its south end, and begins the Wolf River which eventually reaches the Lake Winnebago system. The water level was naturally controlled until 1927, when the installation of culverts under a downstream railroad trestle occurred. A control structure was constructed in 1938 to maintain the lake near original levels and provide for greater recreation opportunities. This dam, originally owned and operated by Forest County, is now maintained and operated by the Town of Hiles. The dam is a small, earthen structure with a structural height of 5.7 feet and a hydraulic height of 1.5 feet. Previous court orders determined the dam is to be maintained within a one-foot range, from elevation 90.0 feet to 91.0 feet. Following a winter fish kill during 1964 – 1965, residents petitioned to have the dam raised to an elevation of 91.5 feet. A commission of Town of Hiles personnel, Wisconsin DNR and engineers determined that raising the water levels would potentially damage low lying riparian private and public property. Additionally, the fish kills occurred during a winter in which above-normal ice and snow cover was present on the lake. Because of the potential damage that might ensue and the extreme events that led to the fish kill, the commission concluded that the dam was to be maintained at its predetermined range (90.0 to 91.0 feet elevation).

The PLPRD sought this particular planning project for four main reasons: 1) to learn the extent of the exotic plants which occur in their lake, 2) to formulate an ecologically sound harvesting program to reduce nuisance levels of native plants that meets stakeholder's interests, 3) to understand their lake ecosystem more fully, and 4) to be eligible to receive additional WDNR grant funds to address AIS and other goals of lake stakeholders. The management plan that has resulted from this project is truly the combination of scientific study and the sociologic aspects of the lake and its stakeholders. The results of those studies will not only lead to better management decisions, but also act as a reference point for future studies and likely serve as groundwork for the restoration of important native habitat within and around Pine Lake. The implementation plan found near the end of the document will act as a guide for the PLPRD as they continue to advocate responsible management of this resource.

2.0 STAKEHOLDER PARTICIPATION

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

Kick-off Meeting

On October 3rd, 2009, a project kick-off meeting was held at the Hiles Town Hall to introduce the project to the general public. The meeting was announced through a mailing and personal contact by PLPRD board members. The approximately 12 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.

Stakeholder Survey

During June 2010, an eight-page, 29-question survey was mailed to 394 property owners in the Pine Lake watershed. About 56 percent of the surveys were returned and those results were entered into a spreadsheet by members of the Pine Lake Planning Committee. 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.

Planning Committee Meeting I

On December 13, 2010, Tim Hoyman of Onterra met with seven members of the Pine Lake Planning Committee for about four hours. In advance of the meeting, attendees were provided an early draft of the study report sections to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. All study components including aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed. The committee initiated further discussion about issues such as abundant floating plant mats, exotic plant species, and harvesting practices.

Planning Committee Meeting II

On January 14, 2011, Tim Hoyman met with eight members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Pine Lake management plan. Chris Hamerla, Lincoln, Langlade, and Forest County Aquatic Invasive Species Coordinator, and Kevin Gauthier, WDNR Water Resources Management Specialist, were also in attendance and participated in the discussion.

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, not all chemical attributes collected may have a direct bearing on the lake's ecology, but may be more useful as indicators of other problems. Finally, 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 analysis 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 ecology 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.

Comparisons with Other Datasets

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 similar lakes in the area. In this document, a portion of the water quality information collected in Pine Lake are compared to other lakes in the region and state (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 Pine Lake 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).

Lillie and Mason (1983) is an excellent source of data for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Forest County lakes are included within the study's Northeast (Figure 3.1-1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from Pine Lake are displayed in Figures 3.1-2 – 3.1-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) from the deepest location in Pine Lake (Map 1). 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 (see discussion under Internal Nutrient Loading on page 9). Surface samples in Pine Lake were collected at a depth of 3 feet.

Figure 3.1-1. Location of Pine Lake within the regions utilized by Lillie and Mason (1983).

Apparent Water Quality Index

Water quality, like beauty, is often in the eye of the beholder. A person from southern Wisconsin that has never seen a northern lake may consider the water quality of their lake to be good if the bottom is visible in 4 feet of water. On the other hand, a person accustomed to seeing the bottom in 18 feet of water may be alarmed at the clarity found in the southern lake.

Lillie and Mason (1983) used the extensive data they compiled to create the *Apparent Water Quality Index* (WQI). They divided the phosphorus, chlorophyll-*a*, and clarity data of the state's lakes into ranked categories and assigned each a "quality" label from "Excellent" to "Very Poor". The categories were created based upon natural divisions in the dataset and upon their experience. As a result, using the WQI as an assessment tool is very much like comparing a particular lake's values to values from many other lakes in the state. However, the use of terms like, "Poor", "Fair", and "Good" bring about a better understanding of the results than just comparing averages or other statistical values between lakes. The WQI values corresponding to the phosphorus, chlorophyll-*a*, and Secchi disk values for Pine Lake are displayed on Figures 3.1-2 – 3.1-4.

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. 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.

> **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.

Carlson (1977) presented a trophic state index that gained great acceptance among lake managers. Because Carlson developed his TSI equations on the basis of association among water clarity, chlorophyll-*a*, and total phosphorus values of a relatively small set of Minnesota Lakes, researchers from Wisconsin (Lillie et. al. 1993), developed a new set of relationships and equations based upon the data compiled in Lillie & Mason (1983). This resulted in the Wisconsin Trophic State Index (WTSI), which is essentially a TSI calibrated for Wisconsin lakes. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Citizen Lake Monitoring Network volunteers.

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

In lakes that support strong stratification, 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 the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae 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 screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. months 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.

Pine Lake Water Quality Analysis

Pine Lake Long-term Trends

The historic water quality data that exists for Pine Lake is largely from the last decade, so it is difficult to complete a reliable long-term trend analysis. While the data collected by volunteers since 2003 are a great start, it is unfortunate that there are not more data available because having an understanding of how the lake has changed over the years is always interesting and leads to sounder management decisions. As part of this study, stakeholders in the Pine Lake watershed were divided when asked to describe the current water clarity of the lake; roughly 47% responded with remarks less than "fair", and about 40% responded with a description of greater than "fair" (Appendix B, Question #14). No matter the situation now, about 80% of respondents did state that they believe the water clarity has degraded since they obtained their property near Pine Lake (Question #15).

As described above, three water quality parameters are of most interest; total phosphorus, chlorophyll-*a*, and Secchi disk transparency. Total phosphorus data from Pine Lake are displayed in Figure 3.1-2. The available averaged data indicates that concentrations are very comparable to similar lakes across the state, and also to lakes within the Northeast region. The data also shows that fluctuations do occur from year-to-year, as indicated by the averaged data from 2006 and 2008. These variances in lake total phosphorus concentration are likely due to various environmental factors, which may dictate the amount and timing of runoff that the lake receives on a given year. Overall, phosphorus levels in Pine Lake can be described as *Good* or *Fair*.

The second water quality parameter of interest is chlorophyll-*a*. The averaged chlorophyll-*a* data from Pine Lake has fluctuated greatly between 1994 and the past 7 years (Figure 3.1-3). It is important to note that the data from 1994 is not an average from that year, but a single mid-June sample. Again, this single, large value may be due to environmental circumstances unique for that year or could possibly have been the result of a faulty collection or analysis. If valid, differences between the 1994 datum and the more recent data must not be interpreted as a trend because of the substantial gap in data between these two periods, in which fluctuations of many levels may have occurred. The latter is the likely situation as total phosphorus values and water clarity readings do not support the high chlorophyll-*a* reading from that year. Regardless, a weighted average over all years of collected data is slightly below the average statewide, and only slightly higher than the regional average. A weighted average for years 2003-2009 is somewhat smaller than the average for all years (Figure 3.1-3).

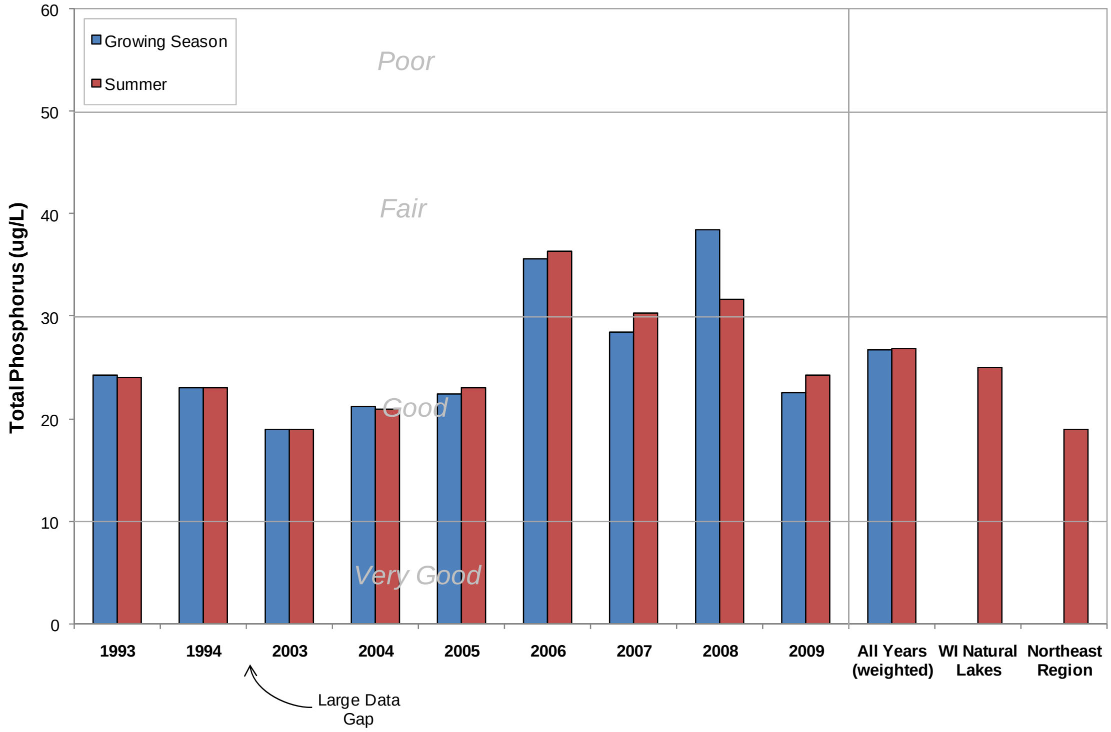

Figure 3.1-2. Pine Lake, regional, and state total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

The third and final water quality parameter of interest is Secchi disk clarity. As previously mentioned, Secchi disk clarity is a measurement of visibility into the water column, and both phosphorus concentration and chlorophyll-*a* concentration are major controllers of this value. Like the other parameters, Secchi disk clarity has fluctuated over the period of available data (Figure 3.1-4). However, a weighted average across all years is lower than averages for similar lakes both state-wide and regionally. The aforementioned relationship between phosphorous, chlorophyll-*a*, and Secchi disk clarity is apparent through the Pine Lake data. For example, in years 2003-2005, phosphorous concentrations were fairly low, resulting in a smaller algal biomass (and thus a smaller concentration of chlorophyll-*a* in the water column). As a result, the Secchi disk clarity was deeper, likely due to the reduced algae abundance. When phosphorous concentrations were found higher (2006-2008), chlorophyll-*a* concentrations increased as well, resulting in a decrease in Secchi disk clarity.

Limiting Plant Nutrient of Pine Lake

Using midsummer nitrogen and phosphorus concentrations from Pine Lake, a nitrogen:phosphorus ratio of 25:1 was calculated. This finding indicates that Pine Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

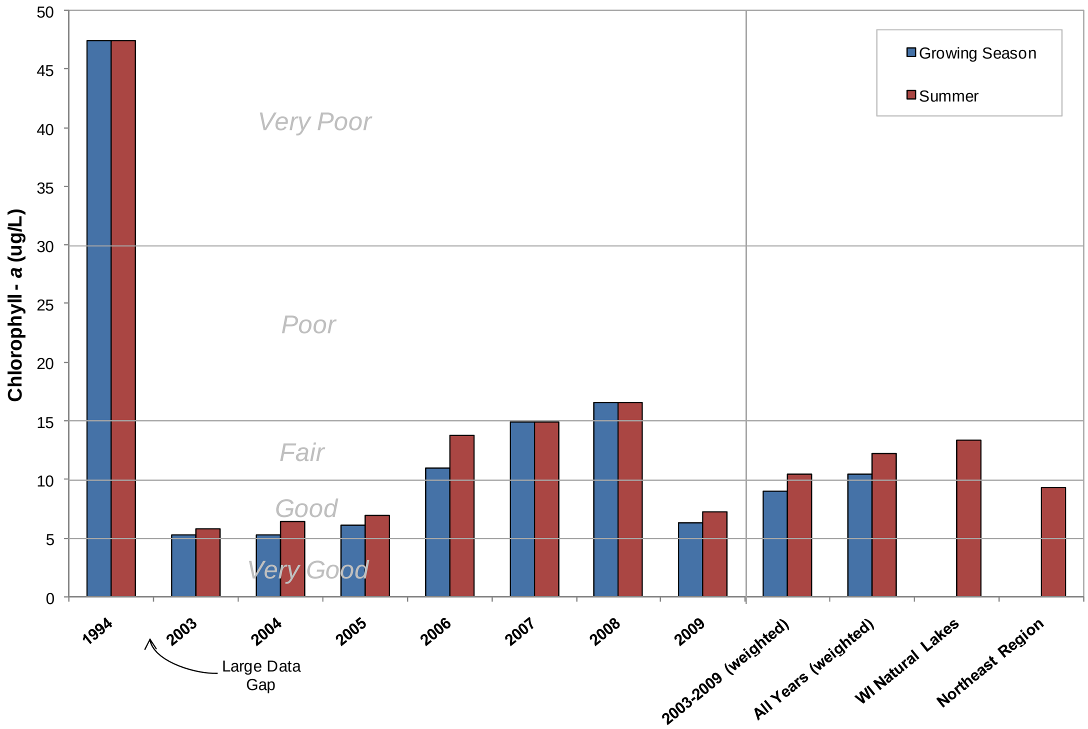

Figure 3.1-3. Pine Lake, regional, and state chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

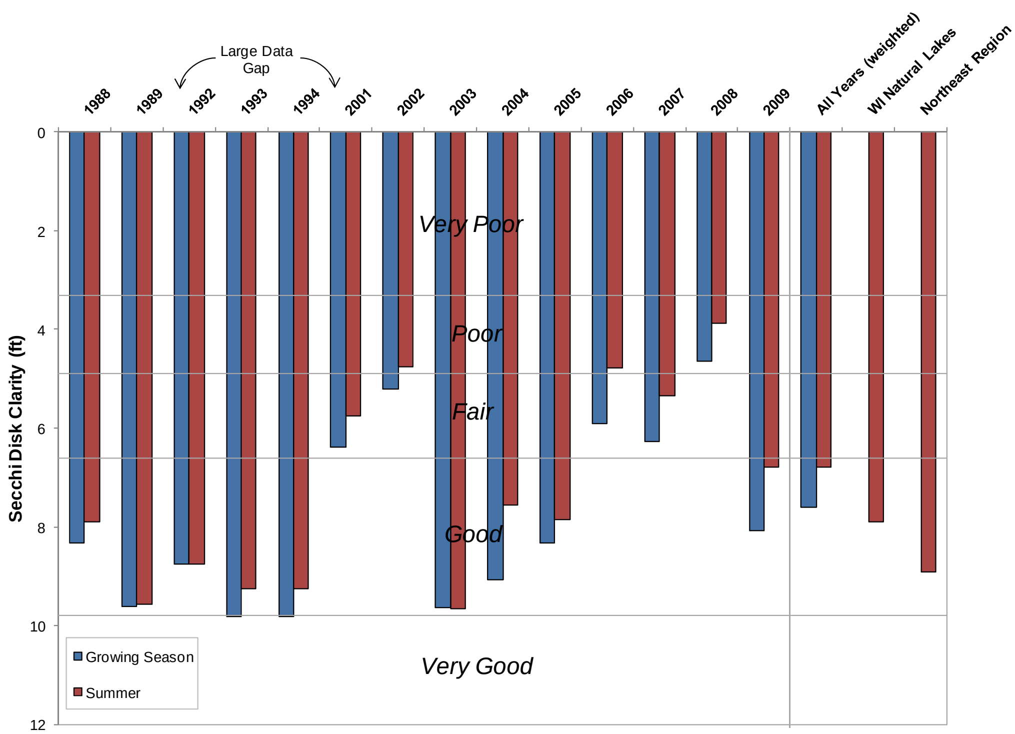

Figure 3.1-4. Pine Lake, regional, and state Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).

Pine Lake Trophic State

Figure 3.1-5 contain the WTSI values for Pine Lake. The WTSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from higher eutrophic to middle mesotrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* WTSI values, it can be concluded that Pine Lake is in middle eutrophic state.

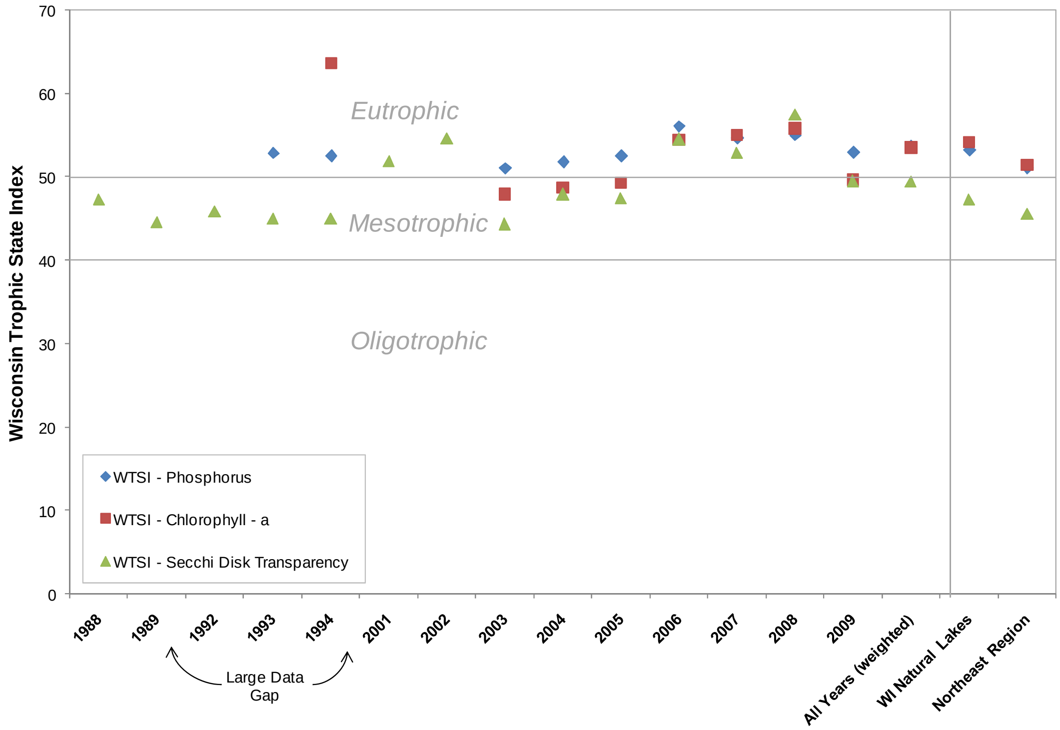

Figure 3.1-5. Pine Lake, regional, and state Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Dissolved Oxygen and Temperature in Pine Lake

As part of this project, Onterra and members of the district both collected temperature and dissolved oxygen data on Pine Lake throughout 2009 and once in winter of 2010. Profiles depicting these data are displayed in Figure 3.1-6. Pine Lake was found to not stratify thermally during the summer months. This is not uncommon in lakes that are large in size but fairly shallow in depth. Energy from the wind is sufficient to mix the lake from top to bottom, distributing oxygen throughout the epilimnion and hypolimnion and keeping water temperatures fairly constant within the water column. In the winter months, the lake stratifies thermally, with the warmer, denser water sinking to the bottom of the lake. The ice covered surface prevents any mixing by the winter winds. During this time, dissolved oxygen declines towards the hypolimnion, however oxygen levels remain sufficient (at least 3 mg/L) to support most aquatic life found in northern Wisconsin within the upper 7 feet of the water column.

The lack of strong summer stratification also reduces the likelihood that internal nutrient loading plays a large role in Pine Lake's nutrient budget. A limited amount of bottom phosphorus recycling may occur during the spring turnover as a result of winter stratification, but again, the amount would likely be small relative to the amount that enters from the watershed.

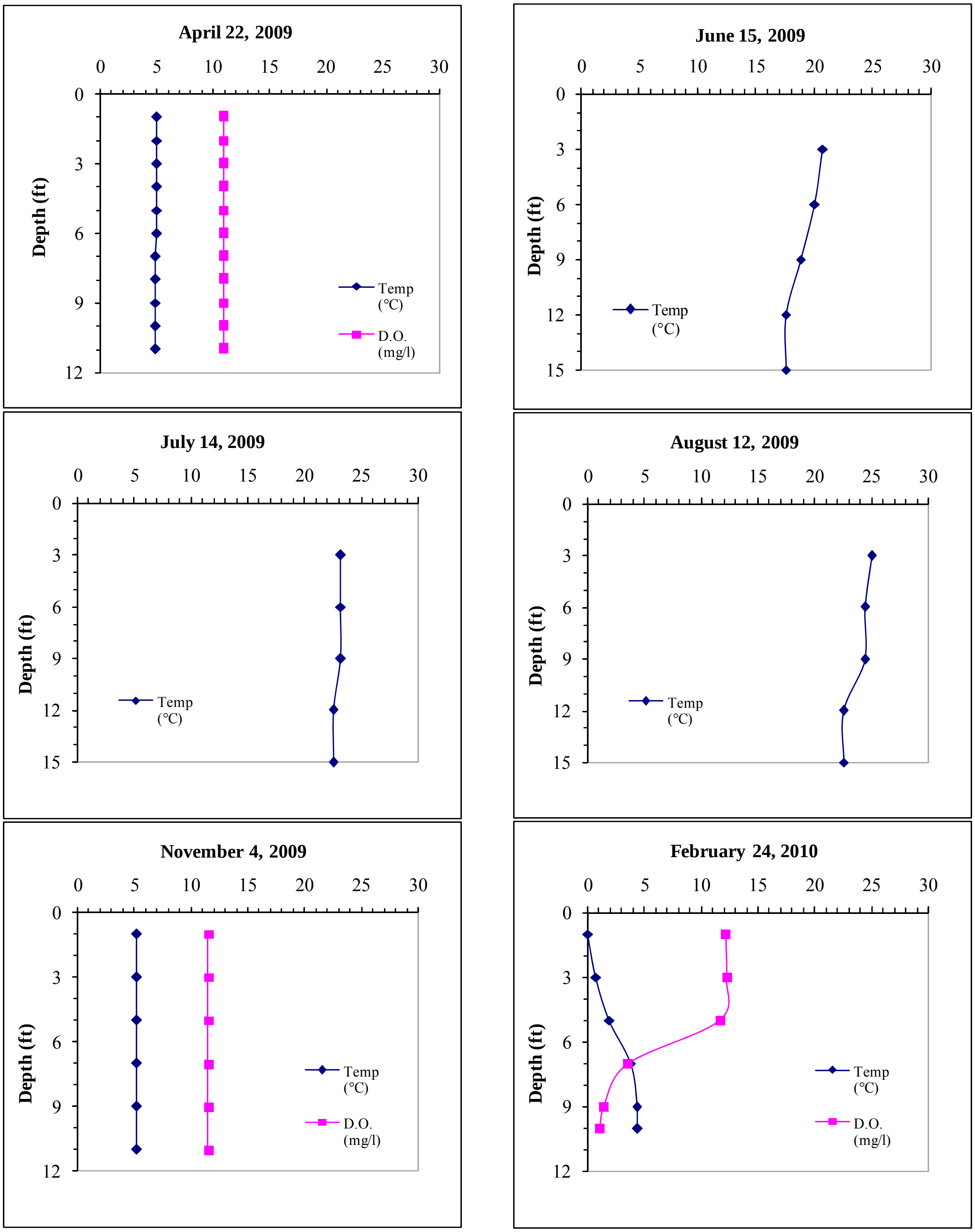

Figure 3.1-6. Pine Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Pine Lake

Alkalinity, pH, and calcium analyses were also performed on some of the water quality samples collected from Pine Lake. Alkalinity values ranged between 48 and 49 mg/l as $CaCO_3$ during the summer months indicating that the lake has a higher buffering capacity against acid rain. During the same time, the lake's pH hovered around 7.7 or slightly above neutral. The pH value is normal for a lake such as Pine Lake and is well within the optimal range for zebra mussels. However, calcium analysis from a sample collected during June 2009 returned a value of 11.9 mg/l, which is at the very low end for zebra mussels.

Pine Lake *Escherichia coli* (E. coli) monitoring

Fecal coliform bacteria are microorganisms found in the lower intestines of warm-blooded mammals. These bacteria are essential for mammals, as they play a role in the digestion of food within the intestines. However, when found in lake or stream water, some types may pose as a health risk to humans. Furthermore, these organisms are used as *indicator organisms*, or organisms that indicate the possible presence of other pathogenic bacteria or viruses that live in human and animal digestive systems. Essentially, the presence of fecal coliform bacteria in a waterbody indicates that fecal contamination (and possibly pathogenic microorganisms) might also be present, and that contact with this water may pose a health risk.

One type of coliform, *Escherichia coli* (E. coli), is commonly screened for in water quality samples as it is specific to fecal material from humans and other warm-blooded animals. Currently, the Environmental Protection Agency (EPA) recommends E. coli as the best indicator of health risk in recreational waters. Through the Clean Water Act Section 406(a), the EPA is required to publish monitoring and assessment guidelines and standards for coliform content on recreational beaches. These standards were adopted by the Wisconsin Beach Monitoring Program, and are as follows:

For single sample maximums,

- If the *E. coli* count is greater than 1000 MPN/100 mL, the beach is closed.
- If the *E. coli* count is greater than 235 MPN/100 mL but less than 1000 MPN/100 mL, an advisory is issued.
- If the *E. coli* count is under 235 MPN/100 mL, the beach has no advisories or warnings issued.

**MPN/100 mL – most probable number of colony forming units per 100 mL of water*

From 2001 until recent (2010), the US Forest Service has been sampling the public beach on the northwestern shores of Pine Lake for E. coli during the summer months of June, July and August. This effort has totaled 30 samples. Of this total, E. coli went undetected 5 times. In 24 of the remaining 25 samples, the concentration of E. coli was below 235 MPN/100 mL, the EPA level at which beach advisories are initiated (Figure 3.1-7). On a single sampling event, July 2008, E. coli levels reached past this advisory standard to 380 MPN/100 mL. With respect to month, average E. coli concentrations seem to be higher in July (average = 96 MPN/100mL) than in June (61 MPN/100 mL) and August (40 MPN/100mL). While it is troubling that E. coli is found on this public beach, the concentrations are fairly low and not a cause for alarm at this time. However, continued monitoring is recommended.

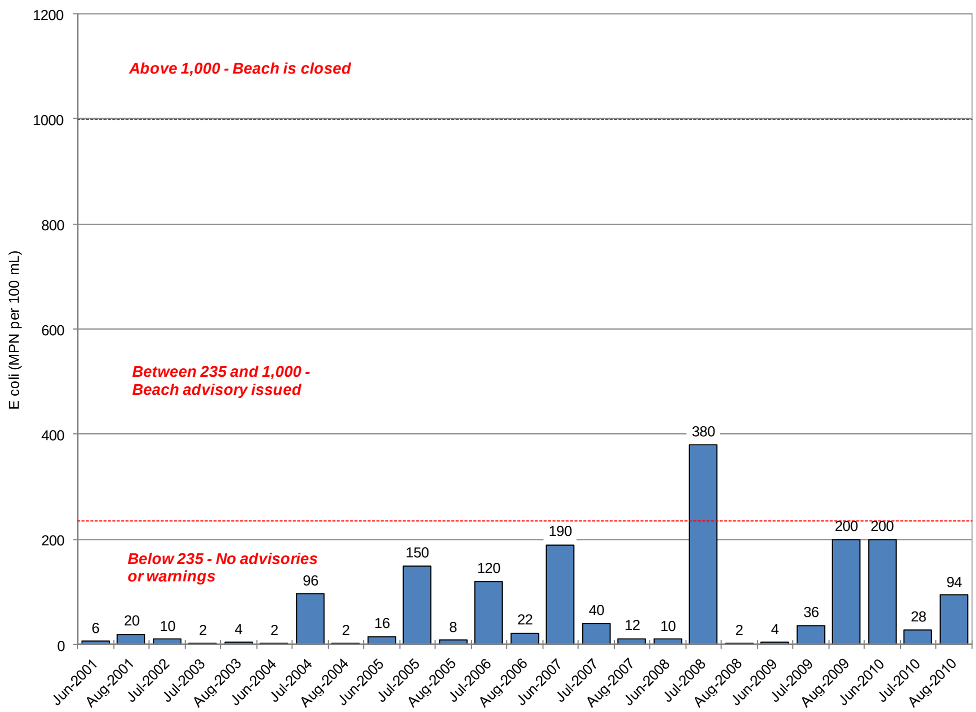

Figure 3.1-7. Pine Lake *Escherichia coli* monitoring data. Samples collected and analyzed by the US Forest Service, and graphically represented here by Onterra.

3.2 Watershed Assessment

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.

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 exceeding 10-15:1, 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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. 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 affect 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 can be 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.

Pine Lake's watershed is approximately 13,772 acres in size (Map 2). The watershed is dominated primarily by forested land (56% or 7,661 acres), but wetlands (27% or 3,755 acres) makes up a considerable portion of the watershed as well. The lake surface (12%) and pasture/grass (5%) make up smaller amounts of the watershed. Although medium density urban lands and row crop agricultural land are both found within the watershed, the amount of land they cover (34 and 21 acres, respectively) is less than 1% of the watershed (Figure 3.2-1). The watershed to lake area ratio is 8:1, which, as discussed earlier, indicates that the land cover types play an important role in the water quality of Pine Lake. Luckily, the land cover types included within the watershed are that which export minimal amounts of nutrients and other pollutants to the lake. The urban land and row crop agriculture that are found in the watershed are often a concern to the water quality of a lake; however, as mentioned earlier their contributions to the acreage in Pine Lake's watershed are minimal and as a result currently pose little threat to Pine Lake.

WiLMS modeling utilizing the land cover types and acreages found in Figure 3.2-1 results in an estimated annual phosphorus load of 1,597 lbs for Pine Lake. (Figure 3.2-2 and Appendix D). This is a moderate amount, given the size of Pine Lake and its watershed. Forested land, which occupies the majority of the watershed, is responsible for 39% of the phosphorus load. Because of its large surface area, Pine Lake captures 28% of the annual load through atmospheric deposition. Wetlands, the second largest land cover type in the watershed, contribute 21% of the annual phosphorus load, while pasture/grass land is responsible for 10% of the load. Not surprisingly, the smallest land cover types (medium density urban and row crops) export approximately 1% of the phosphorus load to the lake each.

Although pasture/grass land makes up 5% of the watershed, it is responsible for 10% of the phosphorus load. Further WiLMS modeling indicated that converting 50% of the 615 acres of pasture/grass land to forest would essentially reduce the overall phosphorus load by 3.7% (59 lbs), while a 100% conversion of pasture/grass to forest would reduce the annual load by 7.3% (117 lbs).

Along with holding minor amounts of urban and agricultural land within its watershed, Pine Lake is likely able to withstand larger phosphorus inputs because of its size and its hydrology. Pine Lake has several input streams and a single outlet, and because of this we can characterize the lake as being a drainage lake. As opposed to a seepage lake, which has no inlets or outlets, a drainage lake will recycle its water (or "flush" itself) at a quicker rate. WiLMS estimates that Pine Lake flushes 86% of its total water volume in a year's time (the *lake flushing rate*). The lake will flush itself completely in 1.2 years. This process helps to remove nutrients or pollutants which would otherwise accumulate in the system.

Overall, the situation in the Pine Lake watershed is close to ideal in terms of protecting the health of the lake. The land cover types that impose little risk to the lake are large, while the types that are known to negatively affect waterbodies are small. Additionally, the hydrology of the lake assists greatly in reducing pollutant build-up in the water. If restoration or protection efforts are to take place in the watershed, the area of top priority would likely be the lakes immediate shoreline. When a lake's shoreline is developed, the increased impervious surface, removal of natural vegetation, installation of septic systems, and other human practices can severely increase nutrient loads to the lake while degrading important habitat. Limiting these anthropogenic (human derived) affects on the lake is important in maintaining the quality of the lake's water and habitat.

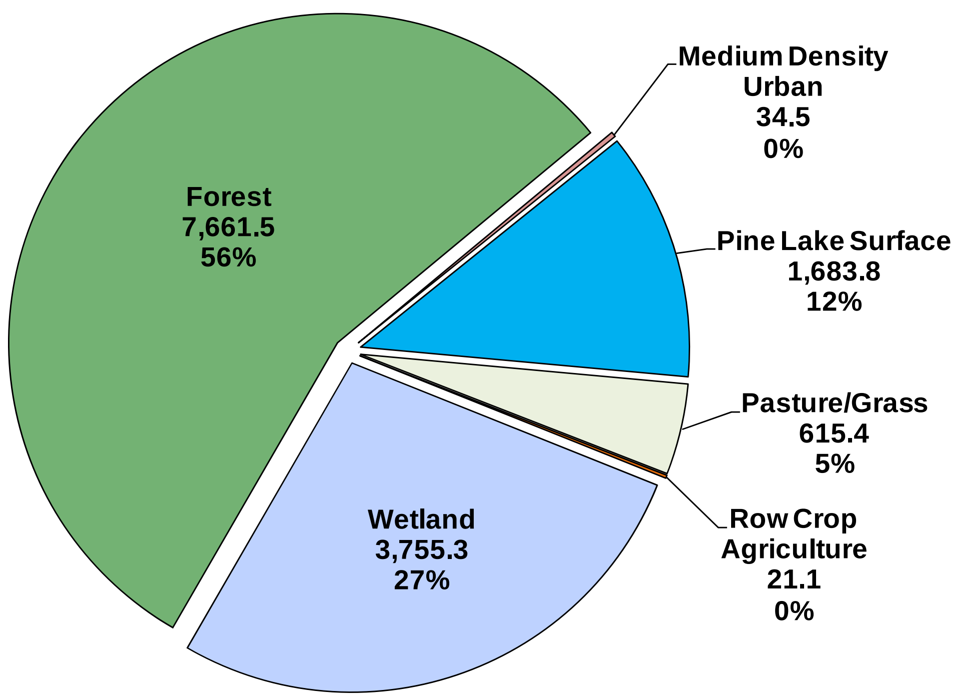

Figure 3.2-1. Pine Lake watershed land cover types in acres. Based upon Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) (WDNR, 1998).

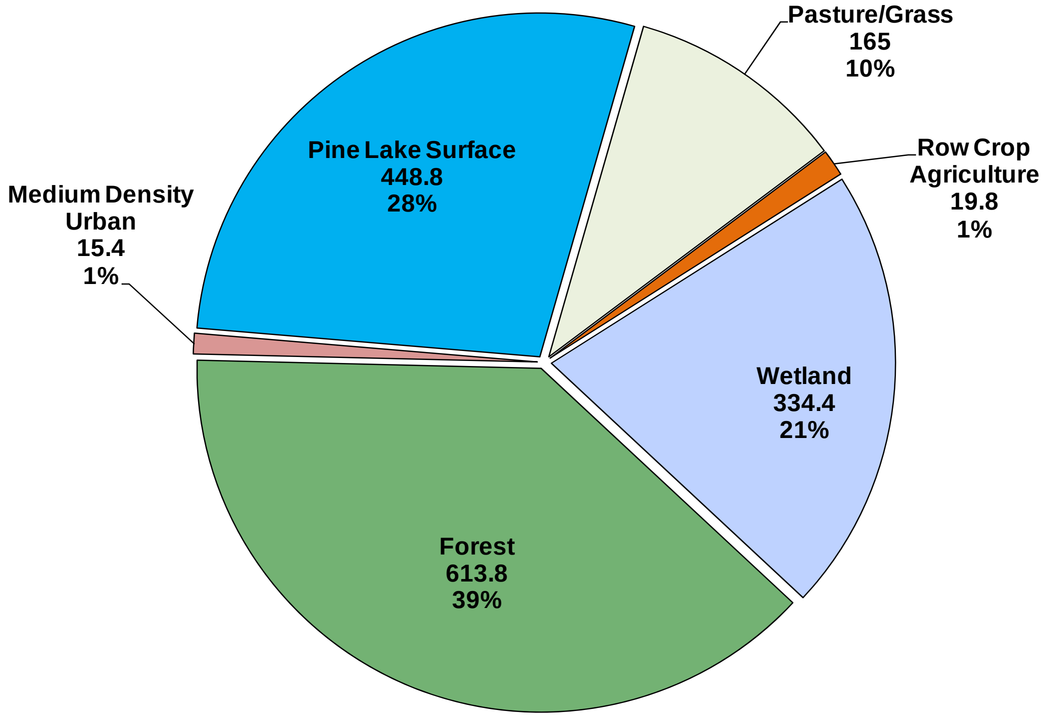

Figure 3.2-2. Pine Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

3.3 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.

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 shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

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 shoreline. 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 shoreline 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).

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 depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
    - An upland buffer zone measuring 35' x 100'.
    - An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
    - Site is assumed to need little invasive species removal prior to restoration.
    - Site has a moderate slope.
    - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
    - Plant spacing for the aquatic zone would be 3 feet.
    - Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
    - Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
    - There is no hard-armor (rip-rap or seawall) that would need to be removed.
    - The property owner would maintain the site for weed control and watering.

Advantages	***Disadvantages***
• Improves the aquatic ecosystem through species diversification and habitat enhancement. • Assists native plant populations to compete with exotic species. • Increases natural aesthetics sought by many lake users. • Decreases sediment and nutrient loads entering the lake from developed properties. • Reduces bottom sediment re-suspension and shoreline erosion. • Lower cost when compared to rip-rap and seawalls. • Restoration projects can be completed in phases to spread out costs. • Many educational and volunteer opportunities are available with each project.	• Property owners need to be educated on the benefits of native plant restoration before they are willing to participate. • Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in. • Monitoring and maintenance are required to assure that newly planted areas will thrive. • Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

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

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

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

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.

Costs

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

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

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

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 does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

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.

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.

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 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. Some herbicides are applied at a high dose with the anticipation that the exposure time will be short. Granular herbicides are usually applied at a lower dose, but the release of the herbicide from the clay carrier is slower and increases the exposure time.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothall (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothall (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, DMA IV®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water-milfoil without affecting many of our native plants, which are monocots. Drinking and irrigation restrictions may apply.

Triclopyr (Renovate®) Selective, systemic herbicide that is effective on broad leaf plants and, similar to 2,4 D, will not harm native monocots. Triclopyr is available in liquid or granular form, and can be combined with Endothal in small concentrations (<1.0 ppm) to effectively treat Eurasian water-milfoil. Triclopyr has been used in this way in Minnesota and Washington with some success.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species. This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*). Glyphosate is also marketed under the name Roundup®; this formulation is not permitted for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic organisms.

Imazapyr (Habitat®) Broad spectrum, system herbicide, slow-acting liquid herbicide used to control emergent species. This relatively new herbicide is largely used for controlling common reed (giant reed, *Phragmites*) where plant stalks are cut and the herbicide is directly applied to the exposed vascular tissue.

Cost

Herbicide application charges vary greatly between $400 and $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments.	• Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many herbicides are nonselective. • Most herbicides have a combination of use restrictions that must be followed after their application. • Many herbicides are slow-acting and may require multiple treatments throughout the growing season. • Overuse may lead to plant resistance to herbicides

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 waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. 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 Pine 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 species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific 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 life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain 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 Pine Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

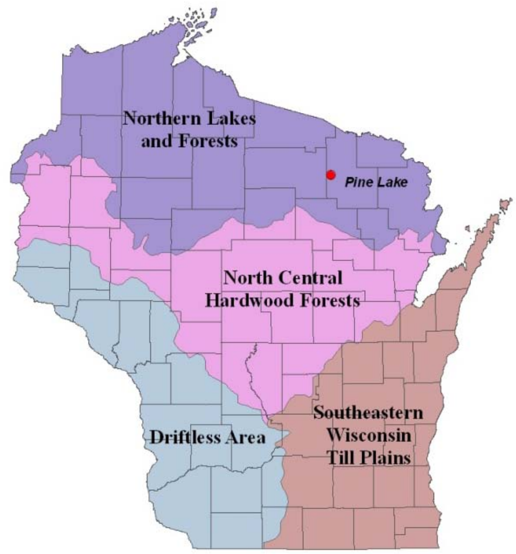

Figure 3.3-1. Location of Pine Lake within the ecoregions of Wisconsin. After Nichols 1999.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to a diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Pine Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.3-1).

Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. 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.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with surveys completed in the future. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

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 water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.3-2). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly –leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native

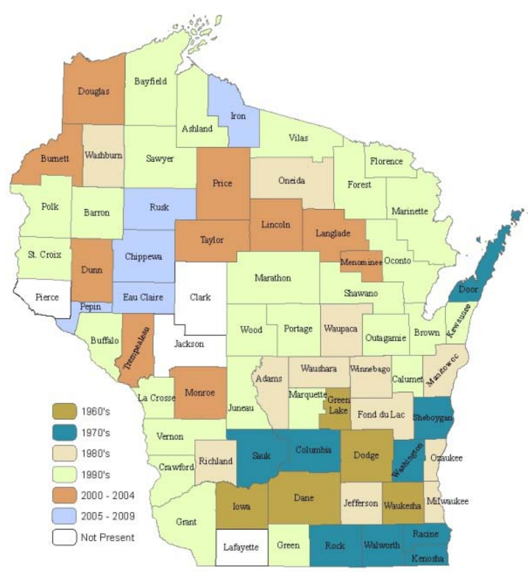

Figure 3.3-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2009 mapped by Onterra.

vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

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

As mentioned above, numerous plant surveys were completed as a part of this project. In June of 2009, a survey was completed on Pine Lake that focused upon curly-leaf pondweed. During this meander-based survey, a single strand of curly-leaf pondweed was found near the boat landing. During the point-intercept survey conducted by the WDNR (see below) curly-leaf pondweed was found on the rake 5 times during the survey and at all of these locations, the plant could not be seen from the water's surface. The point intercept survey was conducted on Pine Lake in early July of 2009 by the WDNR. Additional surveys were completed by Onterra on Pine Lake to create the aquatic plant community maps (Map 3) during mid-August 2009.

Median Value This is the value that roughly half of the data are smaller and half the data are larger. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

During the point-intercept and aquatic plant mapping surveys, 44 species of plants were located in Pine Lake (Table 3.3-1). Two are considered non-native species: Eurasian water milfoil and curly-leaf pondweed. Because of their invasive nature, Eurasian water milfoil and curly-leaf pondweed are discussed in depth in separate sections. For the aquatic plant analysis that follows, only the plants sampled with a rake during the point-intercept survey (33 species) are included; plants observed visually or noted during the community mapping survey are not included in this statistical analysis.

Coontail, naiad sp., and fern pondweed (Figure 3.3-3) are the most abundant plants within Pine Lake, together accounting for over 55% of the frequency of plants found within this lake. Interestingly, these three plants also accounted for the same total relative frequency during the 2006 study completed by Wisconsin Lake and Pond Solutions as well. Coontail lacks true root structures and its locations are often subject to water movement and their tendency to become entangled in plants, rocks, or debris. This plant does well in fertile systems such as Pine Lake, and can at times grow towards nuisance conditions. Naiad sp. are slender branching plants that are eaten by waterfowl and provides excellent shelter for aquatic insects and small fish. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes.

Because Pine Lake has a very high number of aquatic plant species within the lake, one may assume that the lake would also have a very high diversity. The relatively uneven distribution of these three species throughout the lake (relative frequency) has an influence on the diversity metric. Pine Lake exhibited a moderately high Simpson's diversity of 0.88 during 2009, which was very similar to diversity determined with the 2006 data of 0.87. Other common species that occur throughout much of the lake include common waterweed and wild celery (Figure 3.3-3). During the survey in 2009, Eurasian water milfoil was the 12th most abundant plant in the lake.

Table 3.3-1. Aquatic plant species located on Pine Lake during July 2009 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
Emergent	*Calla palustris**	Water arum	9
	*Dulichium arundinaceum**	Three-way sedge	9
	Eleocharis palustris	Creeping spikerush	6
	Isoetes sp	Quillwort sp	N/A
	Pontederia cordata	Pickerelweed	9
	*Sagittaria latifolia**	Common arrowhead	3
	Schoenoplectus acutus	Hardstem bulrush	5
	*Typha angustifolia**	Narrow-leaved cattail	1
	*Typha latifolia**	Broad-leaved cattail	1
	*Zizania paulstris**	Northern wild rice	8
FL	*Brasenia schreberi*	Watershield	7
	Nymphaea odorata	White water lily	6
	Nuphar variegata	Spatterdock	6
FL/E	*Sparganium emersum**	Short-stemmed bur-reed	8
	*Sparganium eurycarpum**	Common bur-reed	5
	Sparganium angustifolium	Narrow-leaf bur-reed	9
Submergent	*Chara sp.*	Muskgrasses	7
	Ceratophyllum demersum	Coontail	3
	Elatine minima	Waterwort	9
	Elodea canadensis	Common waterweed	3
	Heteranthera dubia	Water stargrass	6
	Myriophyllum sibiricum	Northern water milfoil	7
	Megalodonta beckii	Water marigold	8
	Myriophyllum spicatum	Eurasian water milfoil	Exotic
	Nitella sp.	Stoneworts	7
	Najas flexilis	Slender naiad	6
	Najas guadalupensis	Southern naiad	7
	Potamogeton crispus	Curly-leaf pondweed	Exotic
	Potamogeton strictifolius	Stiff pondweed	8
	Potamogeton pusillus	Small pondweed	7
	Potamogeton gramineus	Variable pondweed	7
	Potamogeton zosteriformis	Flat-stem pondweed	6
	Potamogeton richardsonii	Clasping-leaf pondweed	5
	Potamogeton praelongus	White-stem pondweed	8
	Potamogeton amplifolius	Large-leaf pondweed	7
	Potamogeton robbinsii	Fern pondweed	8
	Ranunculus aquatilis	White water-crowfoot	8
	Utricularia vulgaris	Common bladderwort	7
	Vallisneria americana	Wild celery	6
S/E	*Eleocharis acicularis*	Needle spikerush	5
	Juncus pelocarpus	Brown-fruited rush	8
FF	*Lemna minor*	Lesser duckweed	5
	Lemna trisulca	Forked duckweed	6
	Spirodela polyrhiza	Greater duckweed	5

FL = Floating Leaf
FL/E = Floating Leaf and Emergent
S/E = Submergent and Emergent
FF = Free Floating
* = Incidental

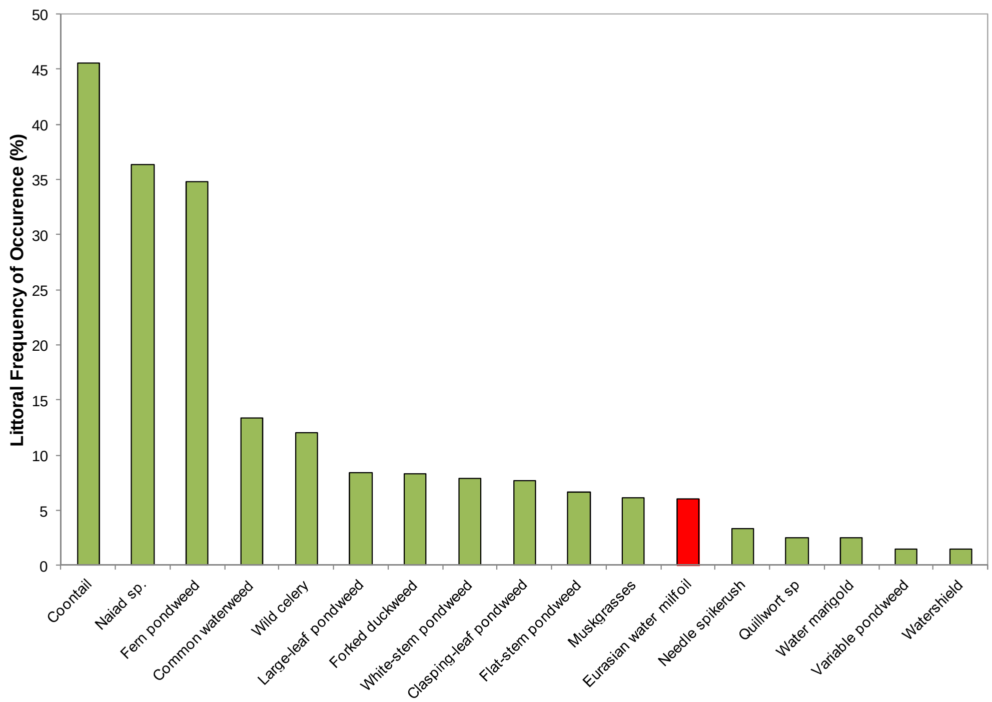

Figure 3.3-3 Pine Lake littoral aquatic plant frequency of occurrence. Created using data from July and August 2009 surveys. Exotic species indicated with red.

Data collected from the aquatic plant surveys indicate that the average conservatism value from Pine Lake is higher than the state median and just below the Northern Lakes Ecoregion median (Figure 3.3-4). This shows that the aquatic plants within Pine Lake are slightly more indicative of an undisturbed condition than those found in most lakes in the state; however, when compared to lakes within the ecoregion, it can be seen that Pine Lake is likely more disturbed than other lakes in the area. Combining the lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in an exceptionally high value of 37.0. Pine Lake's value (calculations shown below), is well above the median values of the state and ecoregion (Figure 3.3-5). Please note than in this calculation, the total number of native species used is the number generated from the WDNR point-intercept survey and does not include species found during Onterra's community mapping survey.

<u>FQI Calculation</u>

FQI = Average Coefficient of Conservatism (6.4) * √ Number of Native Species (33)

FQI = 36.6

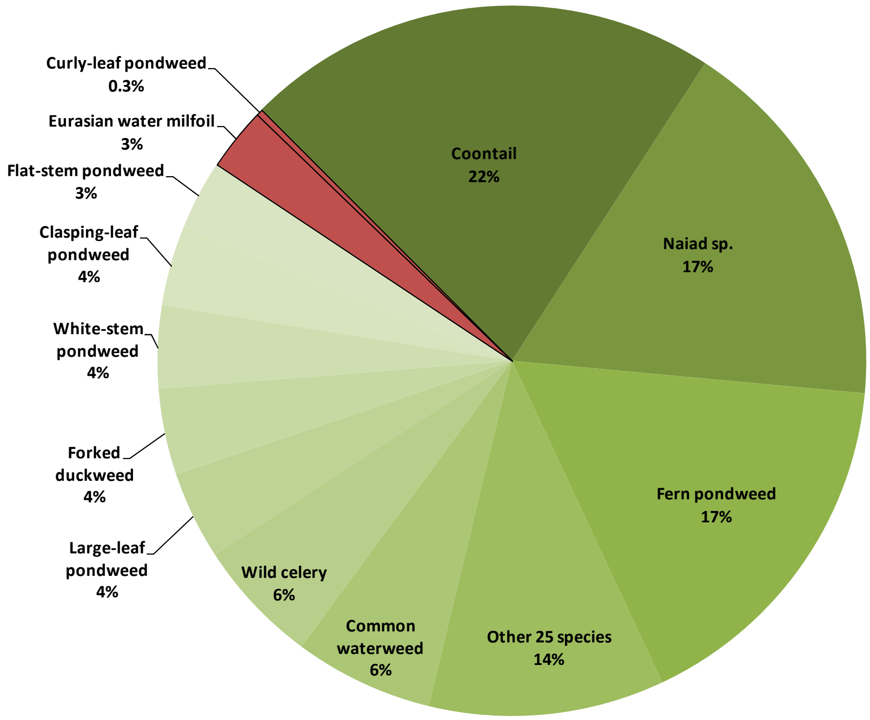

Figure 3.3-4. Pine Lake aquatic plant relative frequency of occurrence. Created using data from July and August 2009 surveys. Exotic species indicated with red.

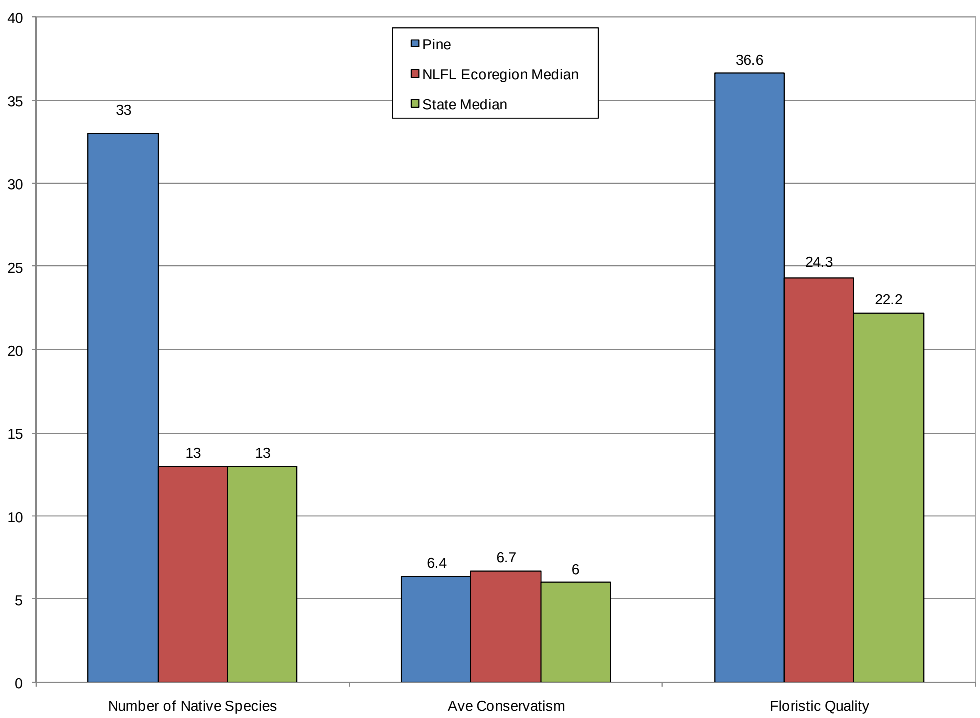

Figure 3.3-5. Pine Lake Floristic Quality Assessment. Created using data from a July 2009 WDNR survey. Analysis following Nichols (1999).

The plant community's quality is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in the lakes. The 2009 community map (Map 3) indicates that approximately 49.3 acres (3.0%) of the 1,670-acre Pine Lake contain these types of plant communities (Table 3.3-3). Eleven floating-leaf and emergent species were located on Pine Lake. These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can become quite sparse along the shores of receding water lines.

Table 3.3-2. Pine Lake plant community types and acreage from the 2009 community mapping survey.

Plant Community	Acres
Emergent	6.2
Mixed Floating-leaf and Emergent	43.1
Total	49.3

The community map represents a 'snapshot' of the important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Pine Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development. Many studies have documented the adverse effects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomasses and/or declines and higher turbidity were associated with motorboat traffic. With regards to lakeshore development, Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. The researchers 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 shorelines.

Emergent and floating-leaf communities, along with submergent plant species, may be altered due to another anthropogenic environmental alteration – water level control. Lakes in the Midwestern United States undergo a natural yearly water fluctuation. This fluctuation includes a pulse of water in the spring following snowmelt, and another pulse again in the fall with rains and cool weather (White et al. 2008). This natural fluctuation is beneficial to the aquatic plant community, as many of these species have adapted to the natural process.

Numerous studies have shown that water level regulation will result in aquatic plant communities that differ in composition and structure from those in an unregulated or unaltered lake. Wilcox and Meeker (1990) demonstrated that two Minnesota water level regulated lakes saw a reduced structural aquatic plant community diversity compared to their unregulated counterparts. Hill et all (1998) noticed that shoreline species were rarely found within dammed systems. Overall, lakes that experience a natural cycle of water level fluctuation have the highest aquatic plant diversity (Hill et al. 1998; Wagner & Falter 2002; Wilcox & Meeker 1991).

Naiad Issues in Pine Lake

In August 2010, great concern was expressed by property owners over plant biomass that had washed up on the southeast shore of the lake. On August 19, 2010, Tim Hoyman, Onterra, met with representatives from the PLPRD to tour the lake and investigate the issue.

Photo 3.3-1. Naiad fragments washed up on southeastern shore of Pine Lake during August 2010.

As a result of the visit, it was discovered that the plants washing up on shore were that of a naiad species (Photo 3.3-1). This plant is somewhat narrow-leaved and stemmed and is commonly dislodged during wind events. During the lake tour, it was evident that there were many floating mats of these plants scattered about the lake, especially in the northern half. Evidently, numerous mats had been pushed by the wind to the southeast side of the lake where they accumulated along the shore.

Many residents voiced that they believed that the mats were the result of mechanical harvesting that had been completed on the west shore earlier that summer. This, of course, was not the case as evidenced by the fact that the plants massed on the southeastern shore were comprised vastly of naiad. If the fragmentation was caused by the harvesting activities, they would be comprised of a variety of species.

As mentioned above, naiad sp. are one of the most common plants in Pine Lake. This was also found to be the case in 2006. Figure 3.3-6 displays the depth distribution at which naiad (and EWM) is growing within the lake. Figure 3.3-7 displays the spatial distribution and rake fullness results for the species during the 2006 and 2009 point-intercept surveys. These charts illustrate that this species is found throughout the lake at a variety of depths (though primarily between 5 and 13 feet). There appears to be a greater abundance of naiad within the lake during the 2006 survey; however, during both years the plant is found within the majority of the lake.

Reliable anecdotal information states that a similar occurrence happened in 2005, but likely not to the same extent. Also, 2002 harvesting records indicate that about 1- 1 ½ hours per day were spent picking up floating mats of vegetation within Pine Lake. Considering what happened during 2010 and the historical information, it is likely that mats will likely occur in the future.

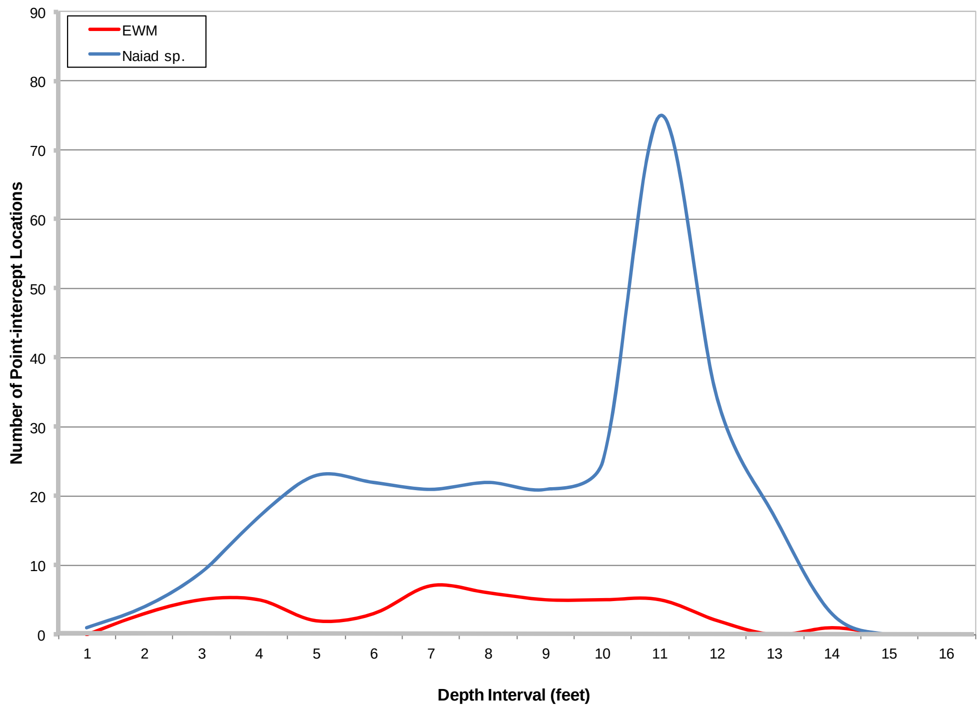

Figure 3.3-6 Pine Lake select aquatic plant depth distribution. Created using data from July 2009 surveys.

Following the WDNR point-intercept survey in 2009, a specimen of the naiad species was sent to Dr. Robert Freckman at the University of Wisconsin – Steven's Point Herbarium. This plant was morphologically identified as *Naias flexilis*, or slender naiad. Another naiad species, *Naias guadalupensis*, or southern naiad, is known to be found in Wisconsin lakes also. These two species are closely related and morphologically similar, so distinguishing between them is often difficult. In 2010, during Onterra's aforementioned visit to Pine Lake, a sample of the floating naiad species was collected and then sent to Donald Les in the Department of Ecology and Evolutionary Biology at the University of Connecticut for DNA analysis. The genetic testing confirmed that the specimen was *Naias guadalupensis*, or southern naiad. Specifically, it is a strain of southern naiad that has hybridized with another strain of the same species. This hybridization creates a plant that is listed as a subspecies. Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed acting aggressively and growing to nuisance levels (Les et al. 2010). This is the case in Pine Lake, as the southern naiad here is displaying aggressive growth. At this time, it is known that southern naiad exists in Pine Lake, and that possibly both slender naiad and southern naiad are present.

Non-native Aquatic Plants

Curly-leaf Pondweed

In 2004, curly-leaf pondweed was located during a point-intercept survey completed by Wisconsin Lake and Pond Solutions, primarily in the southern portion of the lake. However, in 2006, the exotic was not located as a part of surveys completed by the same group during the months of May and July.

Based upon the results of the studies completed in 2009 by Onterra and the WDNR, it is apparent that curly-leaf pondweed still exists within Pine Lake. As mentioned above, Onterra field crews located a single fragment floating near the boat landing and the WDNR surveyors only found the plant on their sampling rake five times while not seeing it from the surface.

In some Wisconsin lakes, especially those found in the southern portion of the state where nutrient loading is high, curly-leaf pondweed can become a serious nuisance within the lake by disrupting recreation, impacting water quality, and altering the aquatic plant community. Often, in northern Wisconsin lakes, like Pine Lake, curly-leaf pondweed does not reach nuisance levels and more or less acts as a native plant. Still, curly-leaf pondweed is an exotic plant and at times, it has become a problem in northern lakes; therefore, as described in the Implementation Plan, continued monitoring of this plant is warranted.

Eurasian Water Milfoil Hybrid

Historical accountings of Eurasian water milfoil in Pine Lake are spotty at best. These accountings are further confounded by the fact that in 2004, the species was confirmed as a hybrid between native northern water milfoil and the exotic species Eurasian water milfoil. In Wisconsin, Eurasian water milfoil hybrid is managed as an exotic because it has been found to act as an invasive species like its non-native parent. For the purpose of this report, all exotic milfoil findings will be referred to as Eurasian water milfoil hybrid.

Eurasian water milfoil hybrid was located in less than 6% of the littoral points in the WDNR 2009 survey. In other words, in the areas less than the maximum depth of plant growth (14 feet), Eurasian water milfoil was found in only 6 out of every 100 locations. Figure 3.3-8 displays the distribution of Eurasian water milfoil hybrid found during the 2006 and 2009 point-intercept surveys. It is apparent that slightly more Eurasian water milfoil hybrid was found during the 2006 survey than during the 2009; still, the spatial distribution of the species is very similar with the greatest frequencies occurring in the northern, western, and southern portions of the lake. This distribution is likely controlled by sediment type and water depth as the plant does not occur greatly in the center of the lake were the greatest depth exist or on the western shore, which is dominated by sandy and rock substrates. Areas of the lake where the exotic does occur include depths of less than approximately 12 feet and softer substrates (Figure 3.3-6).

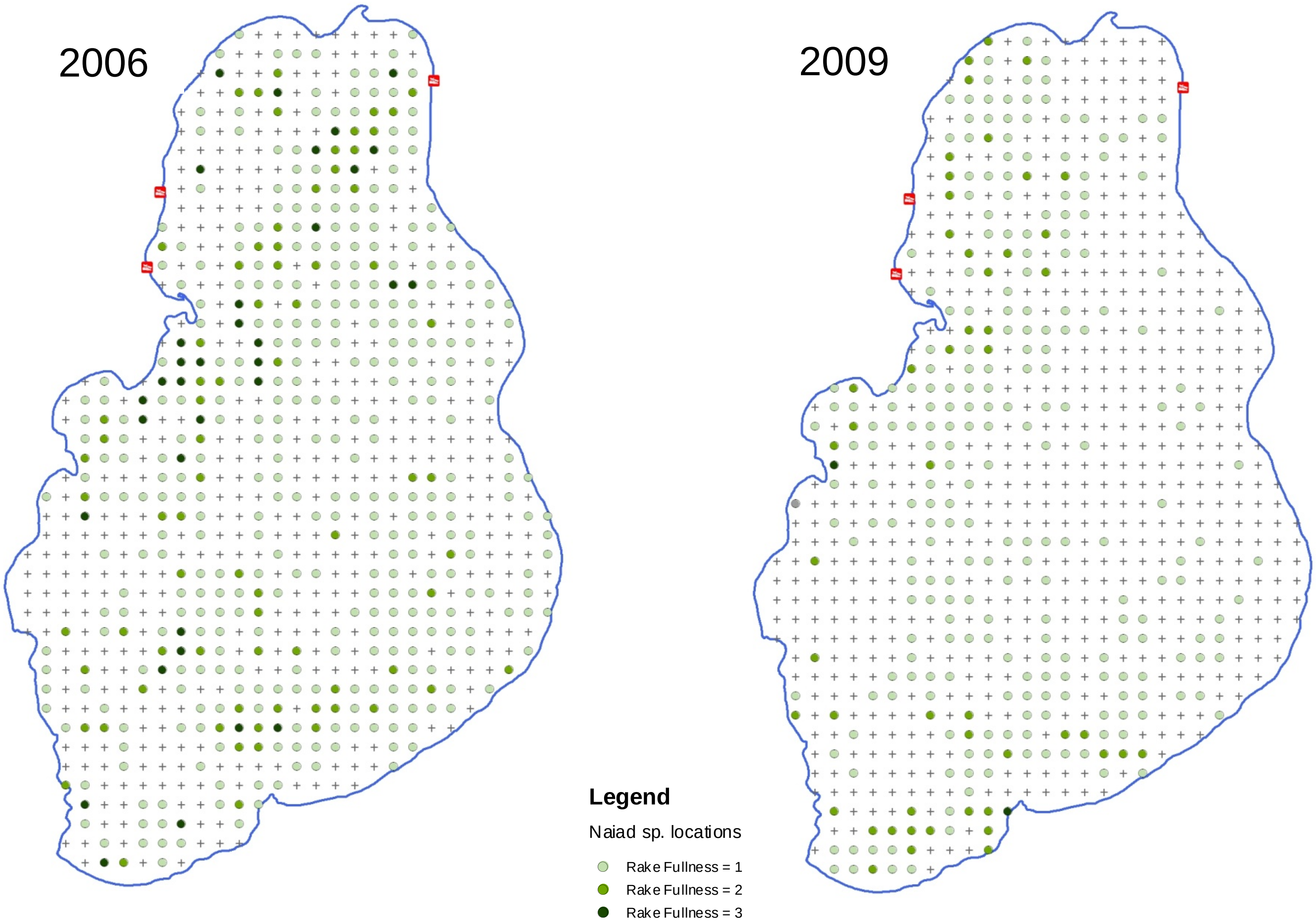

Figure 3.3-7. Pine Lake naiad sp. distribution. Created using data from 2006 and 2009 WDNR point-intercept surveys.

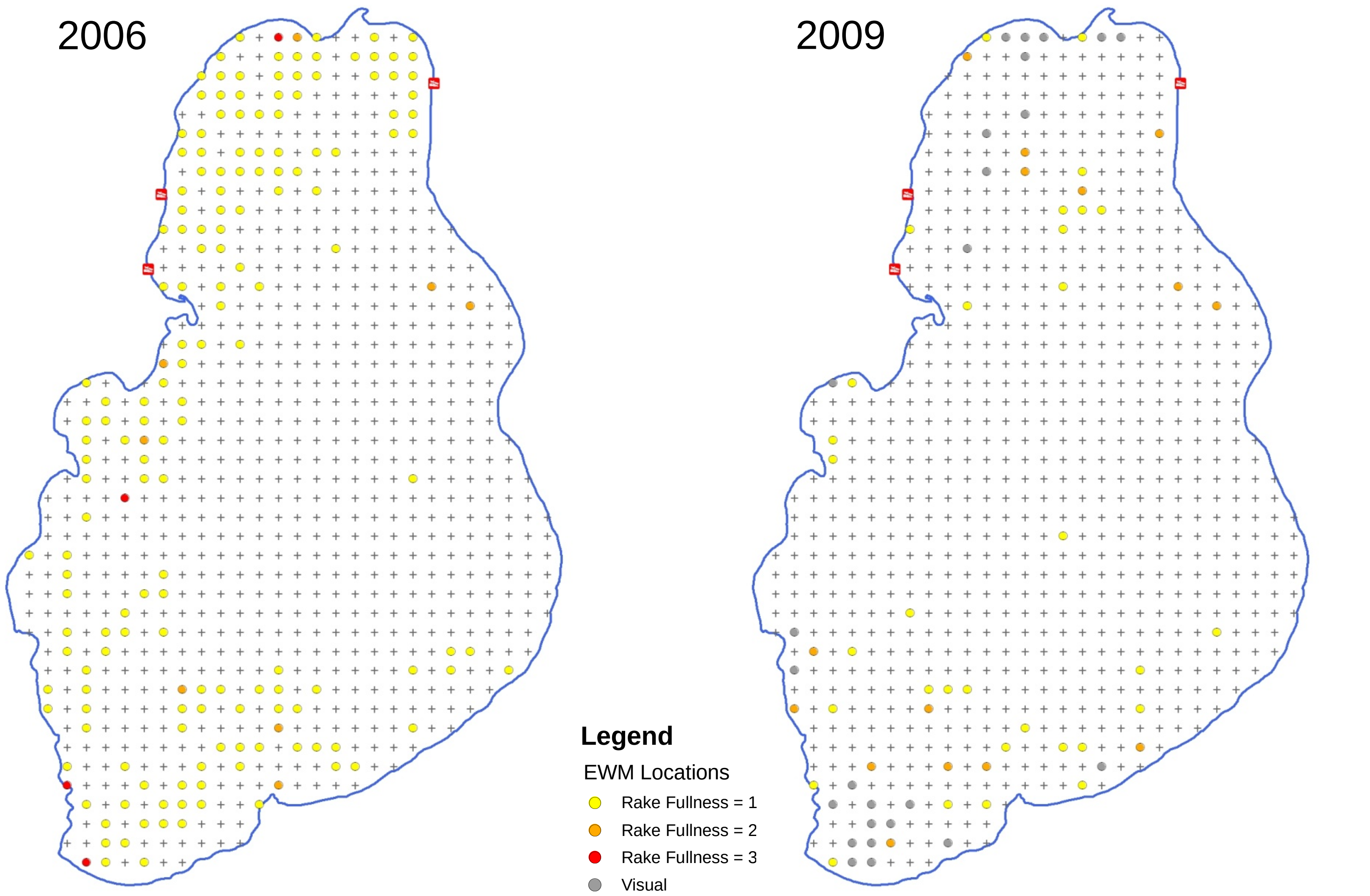

Figure 3.3-8. Pine Lake Eurasian water milfoil hybrid distribution. Created using data from 2006 and 2009 WDNR point-intercept surveys.

3.4 Pine Lake Fishery

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2010 & GLIFWC 2010).

Table 3.4-1. Gamefish present in the Pine Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculaatus*	7	May – June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other inverts
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
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, wave-washed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Pine Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on Pine Lake (Question #13). In fact, about 86% of survey respondents have fished on Pine Lake in the last 3 years (Question #8), and 75% have been fishing the lake for more than 10 years (Question #7). Approximately 86% of these same respondents believed that the quality of fishing on the lake was either fair to excellent (Question #9); and approximately 82% believe that the quality of fishing has remained the same or gotten worse since they have obtained their property (Question #12). Survey respondents also reported that bluegill/sunfish, crappie, and northern pike were their favorite species of fish to catch on Pine Lake (Question #11).

Table 3.4-1 (above) shows the popular game fish that are present in the system. Management actions that have taken place and will likely continue on Pine Lake according to this plan may include herbicide applications or mechanical harvesting to control Eurasian water milfoil or native plants which are displaying aggressive growth. In the future, herbicide applications should occur in May when the water temperatures are below 65°F. Species that spawn in late spring or early summer may be impacted as water temperatures and spawning locations often overlap, and vital nursery areas for emerged fry could become vulnerable. Yellow perch is a species that could potentially be affected by early season herbicide applications, as the treatments could eliminate nursery areas for the emerged fry of these species. Mechanical harvesting activities should begin after June 1st in areas with only native plant growth, which would allow the vast majority of fish species to complete their spawning season.

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 3.4-1). Pine 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. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an "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% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then 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". The safe harvest is a conservative estimate of the number of fish

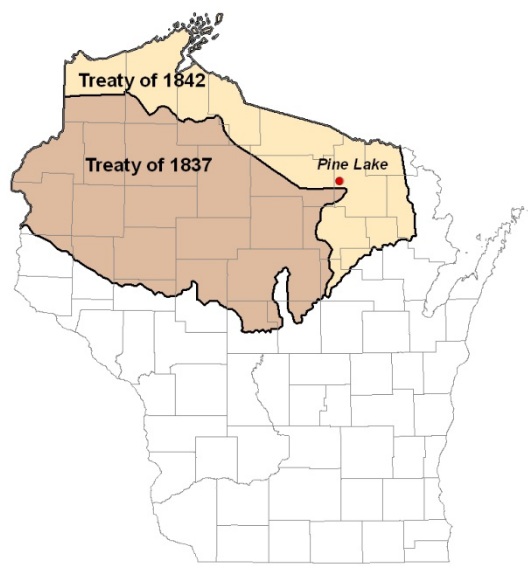

Figure 3.4-1. Location of Pine Lake within the Native American Ceded Territory (GLIFWC 2010A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, 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 quota 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 typically target muskellunge and walleye, during the open water season, and occasionally also harvest northern pike, and bass. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2010B). 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. An updated nightly quota 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 quota is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Besides a single northern pike taken in 1999, walleye have been the only species included in the open water spear fish harvest. Walleye open water spear harvest records are provided in Table 3.4-2. One common misconception noted from the stakeholder survey (Appendix B – Written Comments) is that the spear harvest targets the large spawning females. Table 3.4-2 and Figure 3.4-2 clearly show that the opposite is true with only 8.5% of the total walleye harvest (33 fish) since 1998 comprising of female fish on Pine Lake. 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 (GLIFWC 2010B). This regulation limits the harvest of the larger, spawning female walleye.

Because Pine Lake is located within ceded territory, special fisheries regulations may occur, specifically in terms of walleye. An adjusted walleye bag limit pamphlet is distributed each year by the WDNR which explains the more restrictive bag or length limits that may pertain to Pine Lake. In 2010, the daily bag limit remained at 3 for the lake.

Table 3.4-2. Spear harvest data of walleye for Pine Lake (GLIFWC annual reports for Pine Lake, Krueger 1998-2009).

Year	Tribal Quota	Tribal Harvest	%Quota	Mean Length* (in)	# Male	# Female	# Unknown
1998	138	0	0.0				
1999	130	55	42.3	18.4	51	3	1
2000	140	8	5.7	19.2	7	0	0
2001	141	0	0.0				
2002	144	40	27.8	15.3	38	0	2
2003	152	96	63.2	17.5	72	9	15
2004	118	13	11.0	18.4	9	3	1
2005	101	91	90.1	17.4	84	7	0
2006	105	49	46.7	18.7	44	3	2
2007	156	28	17.9	20.5	18	7	3
2008	158	0	0.0				
2009	155	9	5.8	18.5	8	1	0

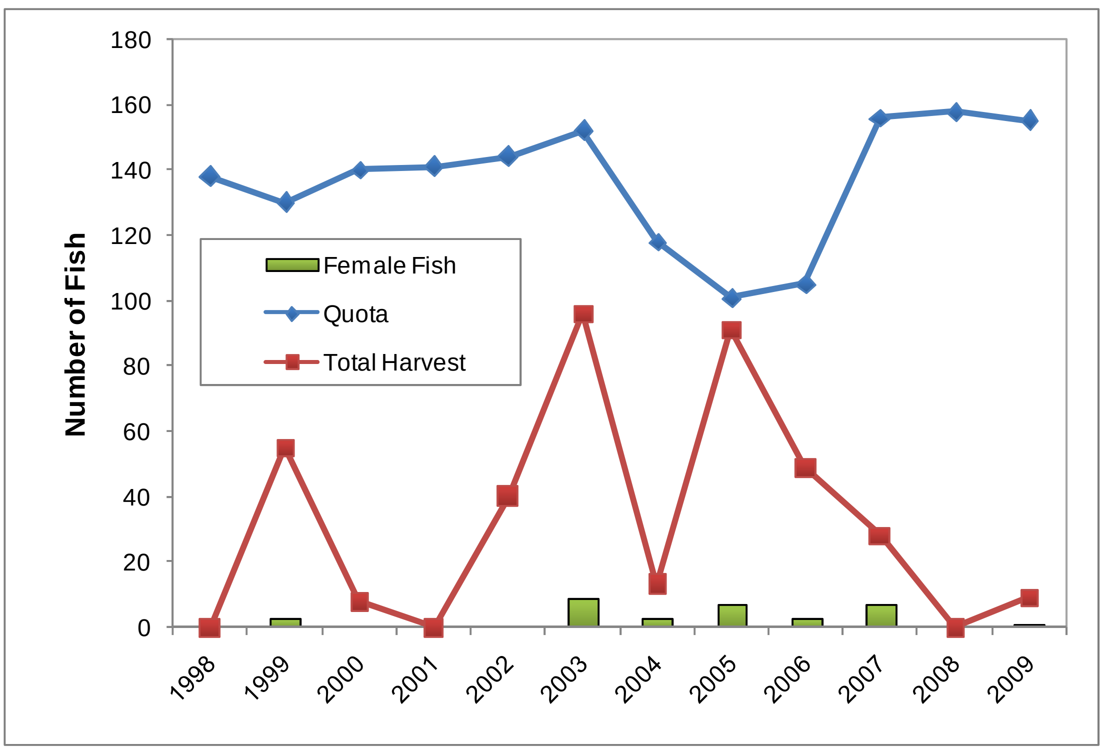

Figure 3.4-2. Walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 1998 from GLIFWC annual reports for Pine Lake (Krueger 1998-2009).

Pine Lake Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults.

Although walleye were the most encountered species found in a 2003 WDNR survey, this population is likely supported primarily through stocking as there is little evidence of natural reproduction (Pine Lake Fisheries Report, Appendix F). In this 2003 report, it was recommended that Pine Lake be stocked every other year at a rate of 50 small fingerlings per acre, and large fall fingerlings stocked when available at a rate of 20 per acre. Recent stocking efforts by the WDNR are summarized in Table 3.4-3.

Table 3.4-3. Walleye stocking data available from the WDNR from 1972 to 2010 (WDNR 2010).

Year	Age Class	# Stocked	Avg. Length (inches)
1972	Fingerling	15,300	5
1976	Fingerling	15,000	3
1980	Fingerling	78,705	2.5
1981	Fingerling	85,100	3
1982	Fingerling	78,780	3
1983	Fingerling	49,660	3
1984	Fingerling	77,500	2.5
1986	Fingerling	40,000	2
1988	Fingerling	44,389	3
1989	Fingerling	20,090	4
1991	Fingerling	40,110	2
1991	Fry	1,500,000	0
1992	Fingerling	20,367	3
1995	Fingerling	83,319	2.23
1998	Small Fingerling	167,000	1.5
2001	Small Fingerling	5,000	1.5
2001	Small Fingerling	2,000	1.5
2004	Small Fingerling	4,250	1.8
2005	Small Fingerling	83,500	1.5
2006	Large Fingerling	8,344	7.4
2008	Small Fingerling	63,844	1.7
2010	Small Fingerling	58,450	1.0

In the 2003 report, it was noted that walleye growth was well above average; however the density was well below average for stocked lakes. Northern pike were naturally reproducing, and doing so very well, while growing at average rates. Largemouth bass were naturally reproducing, and were growing at average rates but were however found at a low density. It was also noted that amongst the panfish, bluegills and to a lesser extent pumpkinseed and black crappie were found high in density but contained individuals that displayed poor growth rates. It was speculated that the panfish characteristics are related to the dense vegetation found in the lake, and possibly from high angling pressure of larger fish as well (Question #11 of the stakeholder survey indicates that bluegill/sunfish are the most commonly sought after species by lake residents). To combat the issue of numerous small panfish and few largemouth bass, it was recommended by the WDNR that the lake association increase its aquatic plant harvest and to maintain open lanes on the lake. Besides aiding in navigation, this would likely increase predation of bass upon panfish, and thus increase bass numbers and size while reducing the number of small panfish and thus improve their size structure and growth (Appendix F).

In February of 2011, the PLPRD contacted WDNR fish biologist Greg Matzke regarding stocking options for Pine Lake. Members of the district had questions regarding current walleye stocking activities, and also the potential to stock muskellunge in the lake. According to WDNR fisheries biologist Greg Matzke, the lake is stocked on a schedule of every other year. By doing this, competition is reduced between the fish classes, allowing them a better chance to survive. Pine Lake is scheduled to be stocked with walleye again in 2012. There is no fishable muskellunge population in Pine Lake - in the comprehensive 2003 fish survey conducted by the WDNR, only 2 muskellunge were caught. Because the fishery currently provides many options for anglers (stable largemouth bass, high density northern pike and abundant panfish), the WDNR does not see the need for muskellunge stocking at this time. However, Mr. Matzke would support privately funded stocking of muskellunge in the lake if the PLPRD wished to do so. In the event that the district decided to pursue this option, Mr. Matzke recommended that large fall fingerling muskellunge of the Upper Wisconsin River Strain be stocked by the end of October every other years, at a density of 1 to 2 fish per acre, or about 1,670 fish (personal communication between WDNR biologist Greg Matzke and Terry Kloehn, PLPRD, February 2011).

In his correspondence with Terry Kloehn, Greg Matzke recommended cutting lanes through dense vegetation to create ambush spots for predators. Like Bob Young stated in the 2003 fisheries survey report, these lanes would allow northern pike to feed more heavily on panfish while reducing the slow growth of the panfish population.

Pine Lake Substrate Type

According to the point-intercept survey conducted by the WDNR in July of 2009, 64% of the substrate sampled in the littoral zone on Pine Lake was muck, while 34% was classified as sand with the remaining 2% found to be rock (Map 4). Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Some species broadcast their eggs over woody habitat and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so they do not get buried in sediment and suffocate. Walleye is an example of a 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 in muck as well.

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 Pine Lake ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on curly-leaf pondweed and Eurasian water milfoil.
3) Collect sociological information from Pine 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 Pine Lake ecosystem, the folks that care about the lakes, and what needs to be completed to protect and enhance them.

The Pine Lake watershed exports almost 1,600 lbs of phosphorus to the lake on an annual basis. This is a moderate amount for a lake the size of Pine Lake and as indicated by the current and historical water quality, this annual phosphorus load is not harming the health of the lake in this respect. Surface water phosphorus concentrations and algal content, as well as Secchi disk clarity are as expected for a relatively shallow and productive lake such as Pine Lake.

As indicated throughout this report, Pine Lake is a productive system, meaning that nutrient content is sufficient to produce high levels of plant biomass. Shallow, productive lakes typically fall into one of two categories – clear state and turbid state lakes. Clear state lakes are characterized by having clear water, yet enough nutrients to produce abundant vegetation. Turbid state lakes may have the same amount of nutrients within them; however, it is algae that utilize these nutrients. As a result, the water becomes turbid and vegetation is relatively sparse. It is believed that these two states are "stable" in that the lake will persist in this way until a disturbance shifts the system from one state to the other.

Pine Lake may be described as a clear state lake. The Watershed Section describes that Pine Lake receives a moderately large amount of phosphorus from the surrounding land. As the results of years of chlorophyll-*a* monitoring indicates, this nutrient supports a modest amount of algae, which in turn allows for high water clarity for a lake with such a nutrient load. Instead of supporting highly abundant algae growth, which is the case for turbid state lakes, nutrients in Pine Lake support abundant aquatic macrophytes growth. The Fisheries Section discusses the diverse and productive gamefish community, which is the result of the large amount of habitat the aquatic macrophytes provide.

Clear state lakes provide a number of ecological benefits, such as good habitat for aquatic organisms like fish, clear water for swimming, and only the occasional nuisance algae bloom. Additionally, abundant native plant growth reduces the spread of exotic species such as Eurasian water milfoil and curly-leaf pondweed within the lake by competing against them for nutrients and light. Overall, the analysis described in the Aquatic Vegetation Section, indicates that while abundant plant biomass exists within Pine Lake, the plant community is of high quality, adding additional evidence to the general good health of the lake. It is the abundant plants that are responsible for keeping Pine Lake within a clear state; not only because they compete with algae for light and nutrients, but also because they provided critical cover for microscopic crustaceans called zooplankton. The zooplankton literally graze on algae keeping their numbers low. Without the aquatic vegetation, the zooplankton are easy prey for small fish species. When zooplankton numbers decrease, the algae population increases, lowering light and nutrients availability for vascular plant growth. As the plant population continues to crash, the algae population increases to the point that the lake "flips" from a clear state to a turbid state system.

Despite being classified as a clear state lake, algae blooms can occur on Pine Lake. In 2012, a Pine Lake resident provided WDNR staff with samples of algae that were clumping into balls and were washed in abundance to his lake front property. These "lake balls" were discovered to be a species of *Cladophora* called *Aegagropila linnaei*. This is a non-harmful algae species that may grow as large as 30 cm in diameter. It is considered rare, and its populations across the world are declining due to eutrophication. Conditions in early spring of 2012 (March was a very warm month) likely increased photosynthetic rates and oxygen bubbles within the structure of this algae, allowing more balls than usual to float off the bottom and accumulate on shore. While this species is harmless and 2012 likely produced exceptional conditions for so many "lake balls" to be found, PLPRD members should keep watchful eye over the lake for suspicious algae bloom occurrences, and notify WDNR staff if these occur.

In some areas of the lake, the biomass of aquatic plants can be overwhelming and reach nuisance conditions in some cases. Such is the case for Pine Lake. Within the stakeholder survey that was distributed in 2009, excessive aquatic plant growth was listed as the top factor negatively impacting the lake (Appendix B, Question #19) as well as the top concern listed by lake stakeholders (Question #20). Furthermore, 92% of survey respondents indicated that aquatic plant growth negatively impacts their enjoyment of the lake (Question #21) and 84% believe aquatic plant control is needed (Question #22).

Through discussions with the PLPRD, WDNR and Onterra and as a result of this planning project, several options to control aquatic plant growth were examined for their potential use on Pine Lake. Because of the scale of aquatic plant growth in Pine Lake, options such as dredging and chemical treatments would be incredibly expensive and harmful to native plant populations. Contracted harvesting, however, is a good solution because of the benefits it would provide at a relatively lower cost to the PLPRD. Harvested lanes will provide ease of navigation through areas of dense aquatic plant growth. Additionally, there is belief that the fish community would benefit from these lanes as well, by providing ambush areas for predatory fish such as northern pike. Pike would be able to feed more heavily on panfish, which should result in thinning out the stunted panfish population and increasing the size structure of predator fish.

Discussions between Onterra and the PLPRD Planning Committee have resulted in several management goals which aim to protect the health of Pine Lake in addition to increasing recreational opportunity for stakeholders. These goals include maintaining current water quality conditions in the lake, continuing invasive plant monitoring, and operating a harvesting program which would increase lake access and navigability. In the Implementation Plan that follows, these management goals are presented along with achievable actions and timelines that aim to guide the PLPRD towards completion of these goals.

5.0 IMPLEMENTATION PLAN

The intent of this project was to complete a *comprehensive* management plan for Pine Lake. As described in the proceeding sections, a great deal of study and analysis were completed involving many aspects of the Pine Lake ecosystem. This section stands as the actual "plan" portion of this document as it outlines the steps the Pine Lake Protection and Rehabilitation District will follow in order to manage Pine Lake, its watershed, and the district itself.

The implementation plan is broken into individual *Management Goals*. Each management goal has one or more management actions that if completed, will lead to the specific management goal in being met. Each management action contains a timeframe for which the action will be taken, a facilitator that will initiate or carry out the action, a description of the action, and if applicable, a list of prospective funding sources and specific actions steps.

Management Goal 1: Maintain Navigation in Open Water and Near-shore Areas on Pine Lake

Management Action: Use contracted mechanical harvesting to maintain reasonable navigation on Pine Lake and to open predator fish cruising lanes to reduce slow-growth panfish.

Timeframe: 4-year trial study beginning in 2011

Facilitator: Pine Lake P & R District Board of Directors

Description: The purpose of the harvesting is to allow navigability in certain areas of the lake that contain dense, nuisance levels of native aquatic plants. Map 5 shows the mechanical harvesting plan that was developed in conjunction with Onterra ecologists, WDNR staff, and district members. The map illustrates two types of harvesting lanes; shoreland navigation lanes, which are 20 feet wide, and common use/fish lanes, which are 30 feet wide. Despite the naming convention, both types of lanes will serve as navigational lanes and predator fish cruising lanes.

The district has conducted harvesting operations in the past, using both contracted services and through the operation of district-owned equipment. Over the course of that time, opinions regarding the success of the operations were mixed among district members. Still, as elaborated upon in the Summary and Conclusions section, the stakeholder survey results indicate that the vast majority of respondents have navigation issues involving excessive plants and believe that control is warranted. However as brought forth earlier, other alternatives to harvesting, such as dredging and herbicides, are not feasible for numerous reasons at the scale required to control plants on Pine Lake.

Understanding that harvesting is somewhat of a controversial action on Pine Lake; therefore, the district will move forward with contracted harvesting services on an experimental basis for the next four seasons (2011-2014). Following the completion of the fourth year of harvesting, the district would conduct a satisfaction survey to determine whether or not the program should be continued or altered in some fashion.

The contractor will follow the cutting plan displayed on Map 5. The following conditions would apply to the cutting:

1. Mechanical harvesting of lanes (or segments of lanes) should only occur on an as-needed basis, as determined by the PLPRD.
2. The harvesting map (Map 5) is a guide; therefore, the harvester operator should use it as such in determining the placement of lanes. Ultimately, the navigation lanes should be cut as close to the piers as possible, though cutting shall not occur shallower than 3 feet of water.
3. Cutting would occur no more than twice during each cutting season; likely prior to July 4th and if necessary, in mid to late August.
4. Two weeks prior to each cutting, district members will mark occurrences of Eurasian water milfoil hybrid consisting of colonies greater than 5 feet in diameter within the cutting lanes and immediately adjacent to it. A GPS unit would be pre-loaded by district members with the cutting pattern displayed and then used for this task. Those locations will be provided to the harvesting contractor and he will avoid those areas during cutting.
5. Using the GPS described above and a harvest map, district members will cruise the harvest areas and mark areas that do not need cutting during the next visit by the applicator. Again, this should be completed two or more weeks prior to scheduled harvesting. This map would be shared with the harvester contractor and the WDNR.
6. During the summer of 2014, a point-intercept survey would be completed to document any changes or lack of changes within the native and non-native plant communities within the lake.

An Aquatic Invasive Species Education, Prevention, and Planning Grant would fund approximately 75% of the costs of the point-intercept surveys, and data analysis/reporting. It is recommended that the PLPRD purchase a Garmin GPS Map 78 to use as their geospatial referencing device. Information regarding this unit may be viewed at www.garmin.com/us/.

Update: During the review process of draft 1 of this management plan, a harvesting permit was awarded to the PLPRD for 2013-2016. WDNR officials are happy to provide permitting for excessive plant growth within the lake, but would like to see efforts conducted that would reduce the nutrient load to the lake (which feeds the growth of the aquatic plants). So, before the permit is renewed in 2016, an initiative aimed at identifying impaired/developed shorelands will be required. This initiative would begin with a shoreland assessment survey aiming to identify and prioritize areas for restoration. This may be done in 2014 or 2015, and could be funded with a WDNR small-scale lake planning grant. The PLPRD should make contact with a qualified professional firm to conduct the studies prior to a February 1st grant deadline.

Action Steps:

1. District applies for a multiyear harvesting permit (3 year).
2. District contracts with reputable mechanical harvesting contractor.
3. District harvests in areas shown on Map 5 while following the plan listed above and restrictions indicated on WDNR permit.
4. Harvest summary report is provided to the WDNR annually after each harvesting season.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action: Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe: Continuation of current effort.
Facilitator: PLPRD volunteers
Description: Monitoring water quality is an import 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 as of why the trend is developing. Volunteers from the PLPRD have collected Secchi disk clarities and water chemistry samples during the past through the WDNR Citizen Lake Monitoring Program. A set of volunteers would be solicited from the PLPRD to continue collection of water quality samples on the Pine Lake. The volunteer monitoring of the water quality is a large commitment and new volunteers may be needed in the future as the volunteer's level of commitment changes. It is the responsibility of the Planning Committee to coordinate new volunteers as needed. Note: as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:
Please see description above

Management Action: Reduce phosphorus and sediment loads from shoreland watershed to Pine Lake.
Timeframe: Begin 2012
Facilitator: Pine Lake PRD Board of Directors or appointed committee/individual.
Description: As the watershed section discusses, the Pine Lake watershed is in good condition; however, watershed inputs still need to be focused upon, especially in terms of the lake's shoreland properties. These sources include faulty septic systems, shoreland areas that are maintained in an unnatural manner and impervious surfaces.

On April 14th, 2009, Governor Doyle signed the "Clean Lakes" bill (enacted as 2009 Wisconsin Act 9) which prohibits the use of lawn fertilizers containing phosphorus starting in April 2010. Phosphorus containing fertilizers were identified as a major contributor to decreasing water quality conditions in lakes, fueling plant growth. While this law also bans the display and sale of phosphorus containing fertilizers, educating lake stakeholders about the regulations and their purpose is important to ensure compliance.

To reduce these negative impacts, the PLPRD will initiate an educational initiative aimed at raising awareness among shoreland property owners concerning their impacts on the lake. This will include newsletter articles and guest speakers at association meetings. Topics of educational items may include benefits of good septic system maintenance, methods and benefits of shoreland restoration, including reduction in impervious surfaces, and the options available regarding conservation easements and land trusts.

Valuable resources for this type of conservation work include the WDNR, UW-Extension and Oneida County Land & Water Conservation Department. Several websites of interest include:

- Wisconsin Lakes website:
  www.wisconsinlakes.org/shorelands)
- Conservation easements or land trusts:
  (www.northwoodslandtrust.org)
- UW-Extension Shoreland Restoration:
  http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website:
  (http://dnr.wi.gov/topic/ShorelandZoning/)

Action Steps:

1. Recruit facilitator.
2. Facilitator gathers appropriate information from WDNR, UW-Extension, Forest County, and other sources.
3. Facilitator summarizes information for newsletter articles and recruits appropriate speakers for association meetings.

Management Action: Complete Shoreland Condition Assessment as a part of next management plan update

Timeframe: Next Management Plan Update

Facilitator: Board of Directors

Description: As the discussed above, unnatural shorelands can negatively impact the health of a lake, both by decreasing water quality conditions as well as removing valuable habitat for fish and other aquatic species that reside within the lake. Understanding the shoreland conditions around Pine Lake will serve as an educational tool for lake stakeholders as well as identify areas that would be suitable for restoration. Shoreland restorations would include both in-lake and shoreline habitat enhancements. In-lake enhancements would include the introduction of course woody debris, a fisheries habitat component lacking around the shores of Pine Lake. Shoreline enhancements would include leaving 30-foot no-mow zones or by planting native herbaceous, shrub, and tree species as appropriate for Forest County.

Projects that include shoreline condition assessment and restoration activities will be better qualified to receive state funding in the future. These activities could be completed as an amendment to this management plan and would be appropriate for funding through the WDNR small-scale Lake Planning Grant program.

Action Steps:

Please see description above

Management Goal 3: Prevent Further AIS Infestation within Pine Lake and the Infestation of Area Lakes with AIS Originating from Pine Lake

Management Action: Initiate Clean Boats Clean Waters watercraft inspections at Pine Lake public access locations

Category: Prevention & Education

Timeframe: Beginning Spring 2012

Facilitator: Planning Committee

Description: Pine 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 invasives from entering the lake through its public access point, but also to prevent the infestation of other waterways with invasives that originated in Pine Lake. The goal would be to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of its spread.

Often it is difficult for lake associations to recruit and maintain a volunteer base to oversee Clean Boats Clean Waters (CBCW) inspections throughout the summer months. Recruitment outside of the PLPRD may be necessary in order to have sufficient coverage of the Pine Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW.

Photo 5.0-1. AIS related roadside billboard in northern Wisconsin.

Recently, two efforts have been in motion to work towards educating the public about AIS. Paul Gagnon of Lumar Billboards and Chris Hamerla, Lumberjack AIS Coordinator, teamed up to coordinate the construction of 6 AIS related roadside billboards in the northwoods of Wisconsin. These billboards (Photo 5.0-1) were paid for in part through a grant, and aim to spread awareness about the threat AIS pose, as well as to warn motorists that cleaning their boats of lake water, fish and vegetation is now required by Wisconsin Law. (NR 40). These two individuals have begun working with Crandon High School teacher Cindy Ecklund in an effort to enlist high school students for Forest County CBCW activities and also educate them on AIS.

Members of the PLPRD, as well as other volunteers, will need to be trained on Clean Boats Clean Waters (CBCW) protocols in order to participate in public boat landing inspections. Chris Hamerla, Lumberjack AIS Coordinator (715.369.9886) is a great source of information for these training sessions. It is recommended that PLPRD members willing to assist in CBCW monitoring coordinate a day in which Mr. Hamerla can train as many people as possible.Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought in the future to ensure monitoring occurs at the public boat landing.

Action Steps:

1. Members of association periodically attend Clean Boats Clean Waters training session through the Lumberjack AIS Coordinator (Chris Hamerla – 715.369.9886) to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.
3. Begin inspections during high-risk weekends
4. Report results to WDNR and PLPRD, and enter into SWIMS database.
5. Promote enlistment and training of new of volunteers to keep program fresh.

Management Action: Coordinate monitoring efforts for Aquatic Invasive Species
Timeframe: Initiate in 2012
Facilitator: PLPRD & Forest County Aquatic Invasive Species Coordinator
Description: In lakes without invasive species, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. Even in lakes where these plants occur, monitoring for new colonies is essential to successful control. Such is the case for Pine Lake. Curly-leaf pondweed that was first located in Pine Lake in 2004, but then was not detected in 2006 surveys. During a mid-June 2009 Onterra survey, the only occurrence of this invasive plant was in the form of a small plant leaf discovered floating near the north public access. A July 2009 WDNR point-intercept survey found the plant at 5 sampling locations, however these plants were not visible from the water's surface. While the occurrence of curly-leaf pondweed remains very low at this point in time, and the anticipated threat of this AIS is also not terribly concerning, the PLPRD needs to be proactive about monitoring this AIS should it begin to cause issues on the lake.

Volunteers from the PLPRD would monitor curly-leaf pondweed within Pine Lake after receiving training through the UW Extension, or Forest County AIS Coordinator as appropriate. Initial training would include identification of curly-leaf pondweed and native look-a-likes and expand to proper use of GPS for recording aquatic plant occurrences, note taking, and transfer of spatial data. If this form of training is not available through the organizations listed above, the PLPRD may seek professional training on these tasks. Should curly-leaf pondweed be detected by volunteers, GPS coordinates and information will be transferred to the Forest County AIS Coordinator and the PLPRD's professional consultant and a decision made on the appropriate course of action from there.

The occurrence of Eurasian water milfoil hybrid in Pine Lake requires a different strategic approach. In 2006, the Eurasian water milfoil hybrid was located throughout most of the northern, western and southern littoral zone of Pine Lake. Its abundance has since decreased, as indicated by a 2009 point intercept survey. It is unknown how the plant will react in the future, given its uncharacteristic reduction in abundance from 2006-2009. Continued monitoring of this AIS by professional ecologists is recommended to assess the plant's abundance dynamics. Surveys would be completed every 3 years, beginning in 2014, and include both point-intercept surveys using the WDNR's standard protocol and EWM density mapping. If the Eurasian water milfoil hybrid displays an increase in abundance and density, or otherwise begins causing nuisance conditions, control options would be investigated.

Action Steps:

1. Engage all stakeholders in the process.
2. Retain consultant to map aquatic invasive species occurrences.
3. Determine control strategy based upon professional findings and consultation with WDNR.
4. Association, with help from an herbicide applicator if applicable, obtains the proper permits to implement management action.
    a. WDNR Plant Management and Protection Program: www.dnr.state.wi.us/lakes/plants
    b. The UW Extension Lake List is a great resource for locating an herbicide applicator: www.uwsp.edu/cnr/uwexlakes/lakelist/businessSearch.asp
5. Association updates management plan to reflect changes in control strategy

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Pine 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 PLPRD members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, winter, and fall. Although PLPRD 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.

Watershed Analysis

The watershed analysis began with an accurate delineation of Pine 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 Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Pine Lake during June 2009 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Pine 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 "Appendix D" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin, (April, 2007) was used by WDNR Science Services to complete this study in July of 2009. A point spacing of 90 meters was used resulting in approximately 828 points.

Community Mapping

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

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