DRAFT

Pigeon Lake

Waupaca County, Wisconsin

Comprehensive Management Plan

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Official First Draft for Agency Review

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Acknowledgements

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

Pigeon Lake Planning Committee

Jon Pahl	Emily Grosskreutz	Myron Radtke
Trish Dawson	Caz Muske	

Wisconsin Dept. of Natural Resources

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1.0 INTRODUCTION

According to the 1964 recording sonar WDNR Lake Survey Map, Pigeon Lake is 162.5 acres. The WDNR website lists the lake as 173 acres. At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2022. Based on heads-up digitizing of the water level from that photo, the lake was determined to be 174.5 acres. Pigeon Lake, Waupaca County, is a flowage with a maximum depth of 10 feet and a mean depth of 4 feet (Figure 1.0-1). This eutrophic lake has a very large watershed (68,210 acres) when compared to the size of the lake. Pigeon Lake contains 26 native plant species, of which coontail is the most common plant. Six exotic plant species are known to exist in Pigeon Lake.

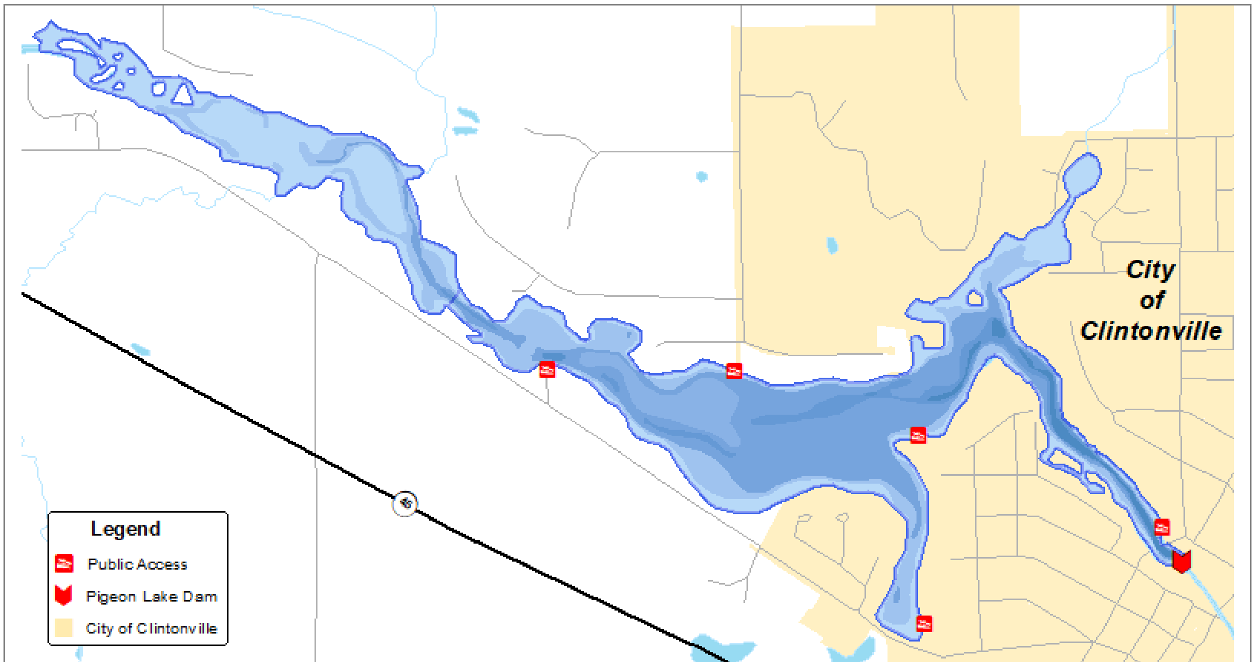


Figure 1.0-1 Pigeon Lake, Waupaca County.

Pigeon Lake is managed by the Pigeon Lake Protection & Rehabilitation District (PLPRD) which was formed in 1976 by citizens to maintain, protect, and improve Pigeon Lake as a recreational and environmentally beautiful inland waterway. The PLPRD has previously received grants from the WDNR to partially fund studies related to water quality, shoreline restoration, and to complete a lake management plan in 2015.

With Onterra's assistance, the PLPRD successfully applied for a WDNR grant in November of 2021 to update their comprehensive management plan. This project serves to update the previous comprehensive management plan by gathering and analyzing historical and current ecological data, identifying threats, determine the goals and values of stakeholders, present feasible management actions, and increase the lake group's capacity to implement the management plan. Fieldwork for this effort was conducted during the summer of 2022, with planning discussions and public outreach occurring during the winter and spring of 2023.

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 general public meetings.

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

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results These meetings were open to anyone interested and were generally held during the summer, on a Saturday, to achieve maximum participation.

Kick-off Meeting

On July 13, 2022, a project kick-off meeting was held at the Clintonville Community Center and streamed on the City of Clintonville Facebook Page to introduce the project to the general public. The meeting was announced through a mailing and personal contact by Pigeon Lake Protection & Rehabilitation District board members. The approximately 30 attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Tims'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.

Project Wrap-up Meeting

To be completed.

Committee Level Meetings

Planning committee meetings, similar to general public meetings, were used to gather comments, create management goals and actions and to deliver study results. These two meetings were open only to the planning committee and were held during the week. The first, following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the first meeting was to fortify a solid understanding of their lake among the committee members. The second planning committee meeting was held a few weeks after the first and concentrated on the development of management goals and actions that make up the framework of the implementation plan.

Planning Committee Meeting I

On March 28, 2023, Tim Hoyman of Onterra met with five members of the Pigeon Lake Planning Committee for over three 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. Many concerns were raised by the committee, including nuisance levels of aquatic plants, impacts of carp, and lack of volunteer/citizen involvement.

Planning Committee Meeting II

On July 17, 2023, Tim met with five members of the Planning Committee to discuss the stakeholder survey results and begin developing management goals and actions for the Pigeon Lake management plan. The discussion lasted two hours and resulted in a solid outline of goals and actions that were developed into the Implementation Plan (Section 5.0).

Management Plan Review and Adoption Process

A full draft of the Implementation Plan was provided to the Planning Committee for review on August 30, 2023. Comments were received from the Planning Committee through September and integrated within an updated draft that was sent out on October 21, 2023. The second draft of the implementation plan was approved by the Pigeon Lake Protection and Rehabilitation Board of Commissioners on November 15, 2023.

The Official First Draft (OFD) of the Pigeon Lake Comprehensive Management Plan was provided to the WDNR on January 26, 2023 for their review. The OFD was also placed on the PLPRD website for public comment on DATE. The plan's availability was announced through EXPLAIN.

3.0 RESULTS & DISCUSSION

Stakeholder Survey

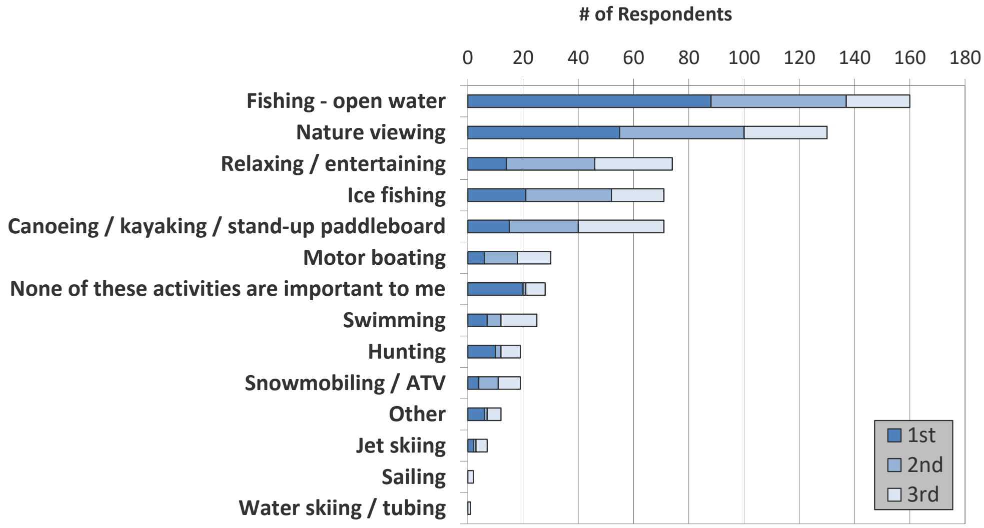
As a part of this project, a stakeholder survey was distributed to Pigeon Lake Protection & Rehabilitation District members and riparian property owners around Pigeon Lake. The survey was designed by Onterra staff and the Pigeon Lake Protection & Rehabilitation District planning committee and reviewed by a WDNR social scientist. During October and November of 2022, the eight-page, 32-question survey was posted online through Survey Monkey for survey-takers to answer electronically. If requested, a hard copy was sent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis. Twelve percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the stakeholder survey, much was learned about the people who use and care for Pigeon Lake. Less than one percent of respondents indicated that they live on the lake during the summer months only, when less than three percent visit on weekends through the year, 85% are year-round residents, and the remaining (about 11%) was indicated as "other" or resort property. According to the survey results, 24% of respondents have owned their property for over 11 years, and 44% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use either a pontoon boat, larger motor boat, canoe/kayak, or a combination of these three vessels on Pigeon Lake (Question 7). With canoe, kayak, and stand-up paddleboard being the most popular option of 27%, behind not using any watercraft on Pigeon Lake (47%). On a relatively small lake such as Pigeon Lake, the importance of responsible boating activities is increased. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 2, several of the top recreational activities on the lake involve boat use, however, it was of low concern on a list of stakeholder's top concerns regarding the lake (Question 17).

A concern of stakeholders noted throughout the stakeholder survey (see Question 17 and survey comments – Appendix B) was water quality degradation within Pigeon Lake. This topic is touched upon in the Summary & Conclusions section as well as within the Implementation Plan.

Question 2: Please rank up to three activities that are important reasons for owning your property on or near Pigeon Lake, with 1 being the most important



Question 7: What types of watercrafts do you currently use on Pigeon Lake?

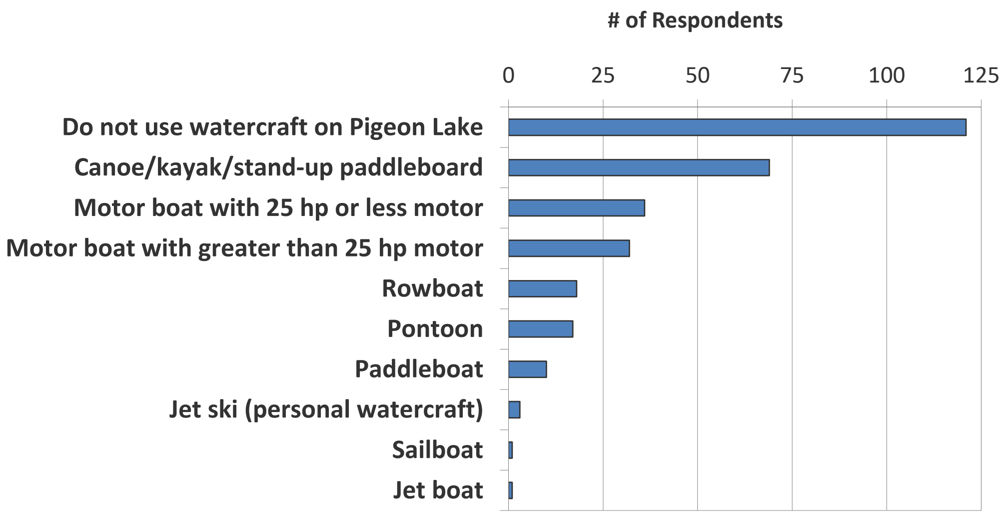


Figure 2.0-1. Select survey responses from the Pigeon Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: From the list below, please rank your top three concerns regarding Pigeon Lake, with 1 being your greatest concern.

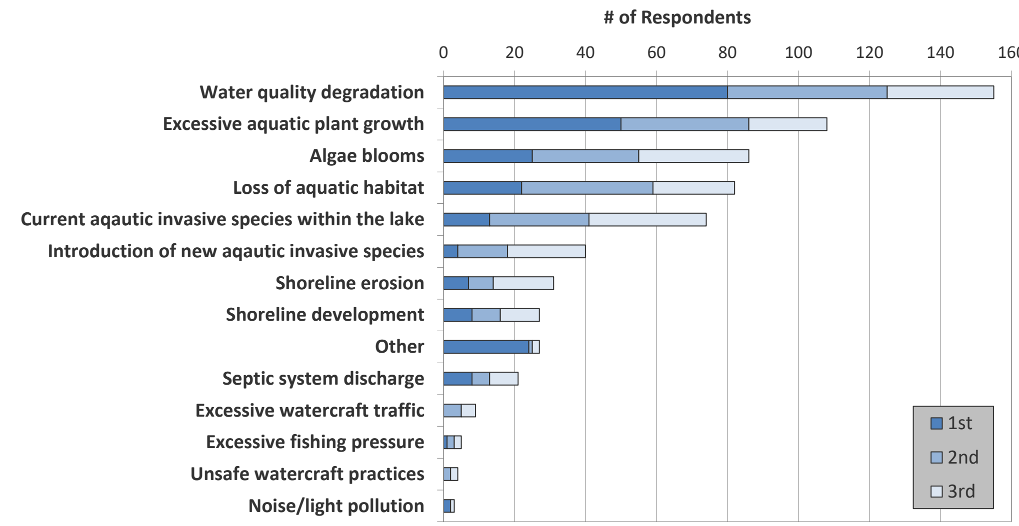


Figure 2.0-2. Select survey responses from the Pigeon Lake Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

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

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

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

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 Pigeon 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 quadrants (a Secchi disk) into the water and recording the depth just before it disappears from sight.

> 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.

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, Nelson, & Everett, 1994) (Dinius, 2007) (Smith, Cragg, & Croker, 1991).

Trophic State

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

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 clearer understanding of the lake's trophic state while facilitating clearer long-term tracking. (Carlson, 1977) presented a trophic state index that gained great acceptance among lake managers.

Limiting Nutrient

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

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

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

Temperature and Dissolved Oxygen Profiles

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

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

Internal Nutrient Loading*

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2020 Consolidated Assessment and Listing Methodology* (WDNR, 2019) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Pigeon Lake will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

> **Seepage Lakes** have no surface water inflow or outflow in the form of rivers and/or streams.
>
> **Drainage Lakes** have surface water inflow and/or outflow in the form of rivers and/or streams.
>
> > Headwater drainage lakes have a watershed of less than 4 square miles.
> >
> > Lowland drainage lakes have a watershed of greater than 4 square miles.

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

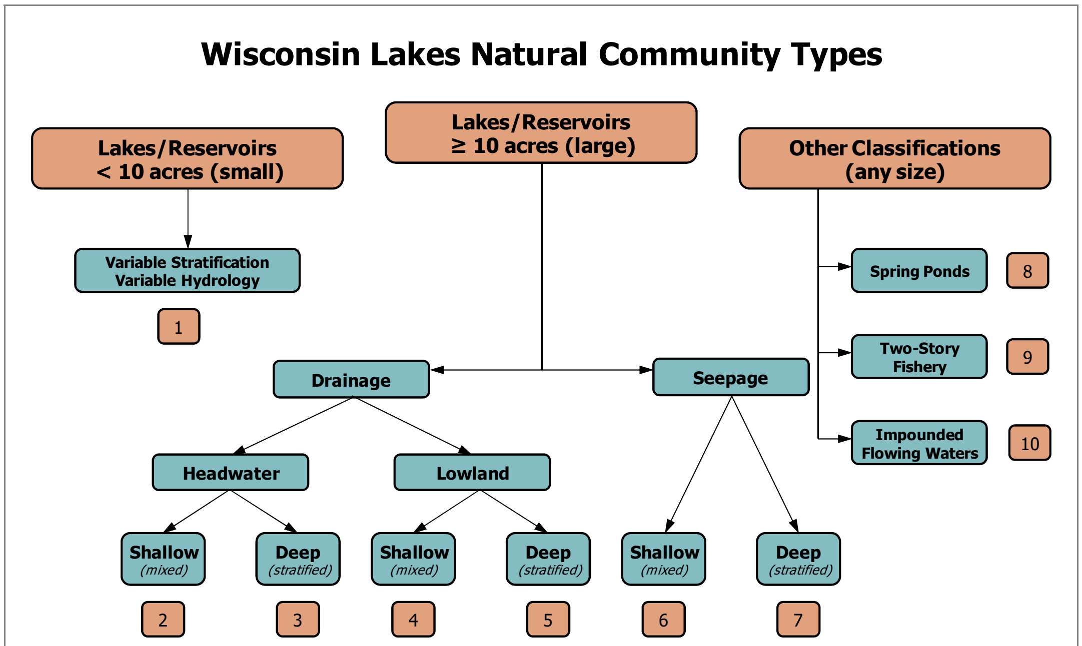


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

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

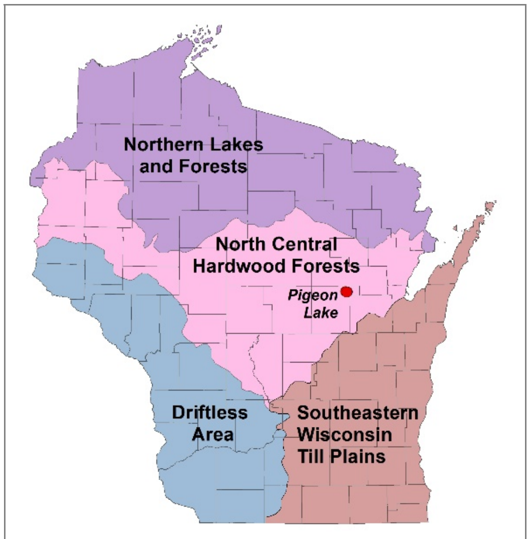


Figure 3.1-2. Location of Pigeon Lake within the ecoregions of Wisconsin. After Nichols 1999.

The Wisconsin 2020 Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

These data along with data corresponding to statewide natural lake median values, historic, current, and average data from Pigeon Lake are displayed in Figures 3.1-3 - 3.1-6. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Pigeon Lake Water Quality Analysis

Pigeon Lake Water Quality Analysis

Surface water samples were collected from the deepest location in the lake (Map 1, Station ID 693176) by Onterra ecologists during spring, June, July, August, September, and October, 2022, and February 2023. All samples were collected with a Van dorn bottle and all analysis were completed by the WI State Laboratory of Hygiene in Madison. Results of the analysis were entered in the WDNR Surface Water Integrated Management System (SWIMS).

Pigeon Lake Long-term Trends

As mentioned above, total phosphorus, chlorophyll-*a*, and Secchi disk transparency are the primary water quality parameters for assessing lake management needs. Unfortunately, very little data has been collected from Pigeon Lake over the years. Total phosphorus data are available from 2001, 2002, and 2022. Chlorophyll-*a* data are available from 2001, 2002, 2004, and 2022, while water clarity values are available sporadically from the 1990s, 2001, 2002, and 2022. Two of the years during which Secchi disk transparencies were collected, 1996 and 2002, only a single reading was collected. However, during 1994, twenty-three individual readings were collected. Water quality results from 2014, mentioned in the 2015 lake management plan, could not be located.

Total phosphorus concentrations in Pigeon Lake (Figure 3.1-3) range from as low as 32 µg/L to as high as 103 and 112 µg/L. Average growing season and summer month concentrations fall within the *Poor* category and are considerably higher than median values from other Shallow Lowland Drainage Lakes and all lake types within the North Central Hardwood Forest ecoregion. While it may appear that the phosphorus concentrations have been increasing since the early 2000s, is likely not the case. Actually, the phosphorus concentrations likely fluctuate greatly depending on precipitation levels within the Pigeon Lake watershed. All that can be said about the available data is that the summer month concentrations are slightly higher in 2022 than they were in 2001 and 2002, but no conclusions can be drawn regarding a trend because of the large data gap that occurs between 2002 and 2022.

Chlorophyll-*a* values in Pigeon Lake (Figure 3.1-4) vary greatly from year-to-year and within some years. Only three values were collected during each year in 2001, 2002, and 2004, yet concentrations within each of those years increased and decreased greatly between samplings. For instance, in 2001, a mid-June sample resulted in a concentration of 42.00 µg/L, while a late August sample concentration was 8.00 µg/L. In 2004, a July concentration of 12.30 µg/L was recorded, followed by highest concentration in the dataset of 104 µg/L, in mid-August. By late-September 2004, the chlorophyll-*a* concentration was down to 4.63. In 2022, six samples were collected throughout the growing season and ranged from 3.38 µg/L in mid-June to 90 µg/L in late-September.

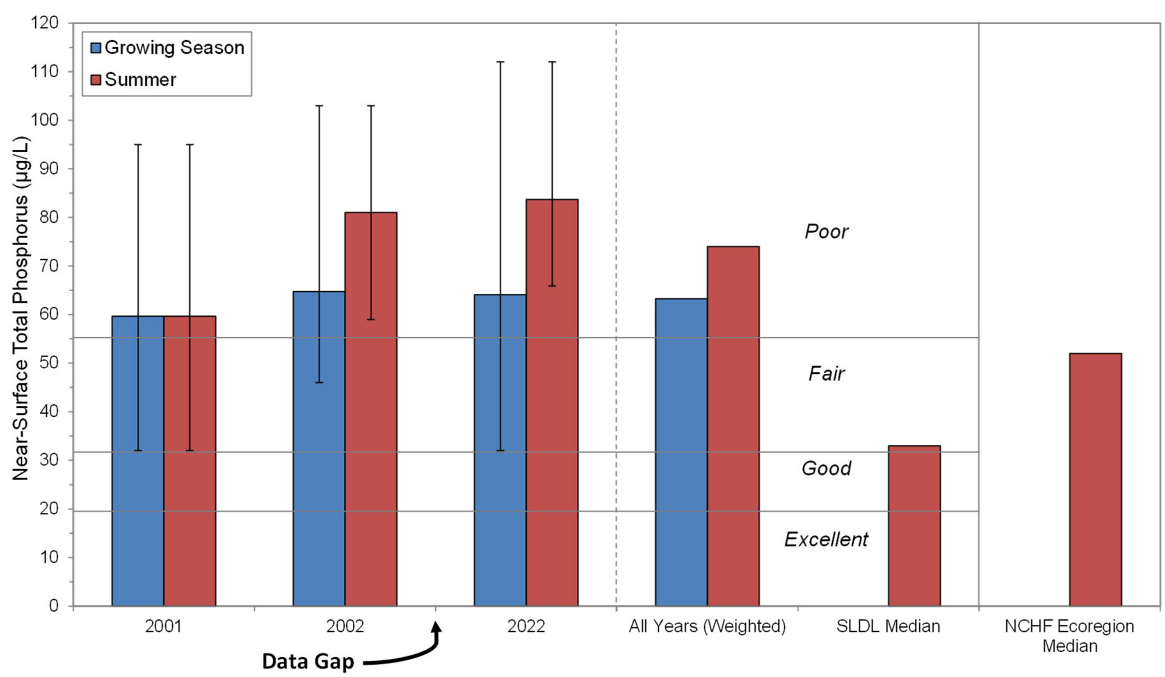


Figure 3.1-3. Pigeon Lake, statewide class 4 lakes, and regional total phosphorus concentrations. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

As discussed below, phosphorus availability is a significant controller in the abundance of algae that can be produced in Pigeon Lake. However, the lake's flushing rate plays a very important role as well. Watershed modeling indicates that Pigeon Lake exchanges its water about every 2 ½ days, which limits the amount of time algae have to utilize the available phosphorus and build biomass within the lake. Tributary inputs control the flushing rate and can vary within the growing season. During times of high tributary input, algae are flushed out of the lake before biomass can build; however, during low inputs, when flushing rate is lower and the residence time is higher (see Watershed Section for more information), the algal population can build and higher chlorophyll-*a* concentrations result.

Pigeon Lake chlorophyll-*a* concentrations range from the *Excellent* to *Poor* category, with growing season and summer month means typically falling in the *Good* to *Fair* category. The all years weighted means fall within the *Fair* category are much higher than the Shallow Lowland Drainage Lakes and ecoregion median values.

Secchi disk transparency data are available sporadically back to 1990 (Figure 3.1-5) and like phosphorus and chlorophyll-*a*, fluctuate greatly primarily between *Fair* and *Poor*, but some readings have reached the *Good* and lower *Excellent* category. The weighted average is in the high *Fair* range and in the lower 50th percentile when compared to other shallow lowland drainage lakes in the state and all types of lakes in the North Central Hardwood Forest ecoregion.

It is unfortunate that so little water quality data exist for Pigeon Lake because it makes it impossible to determine long-term trends and make comparisons before and after the 2017-18 drawdown.

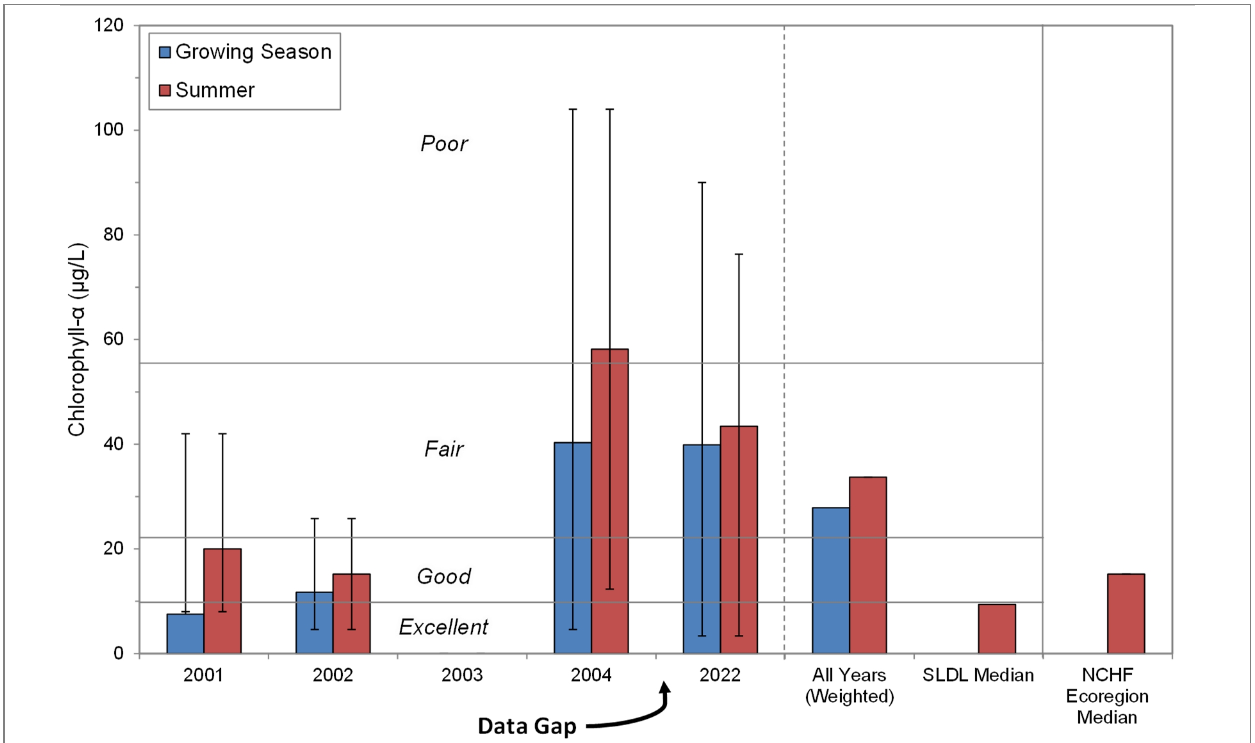


Figure 3.1-4. Pigeon Lake, statewide class 4 lakes, and regional chlorophyll-a concentrations. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

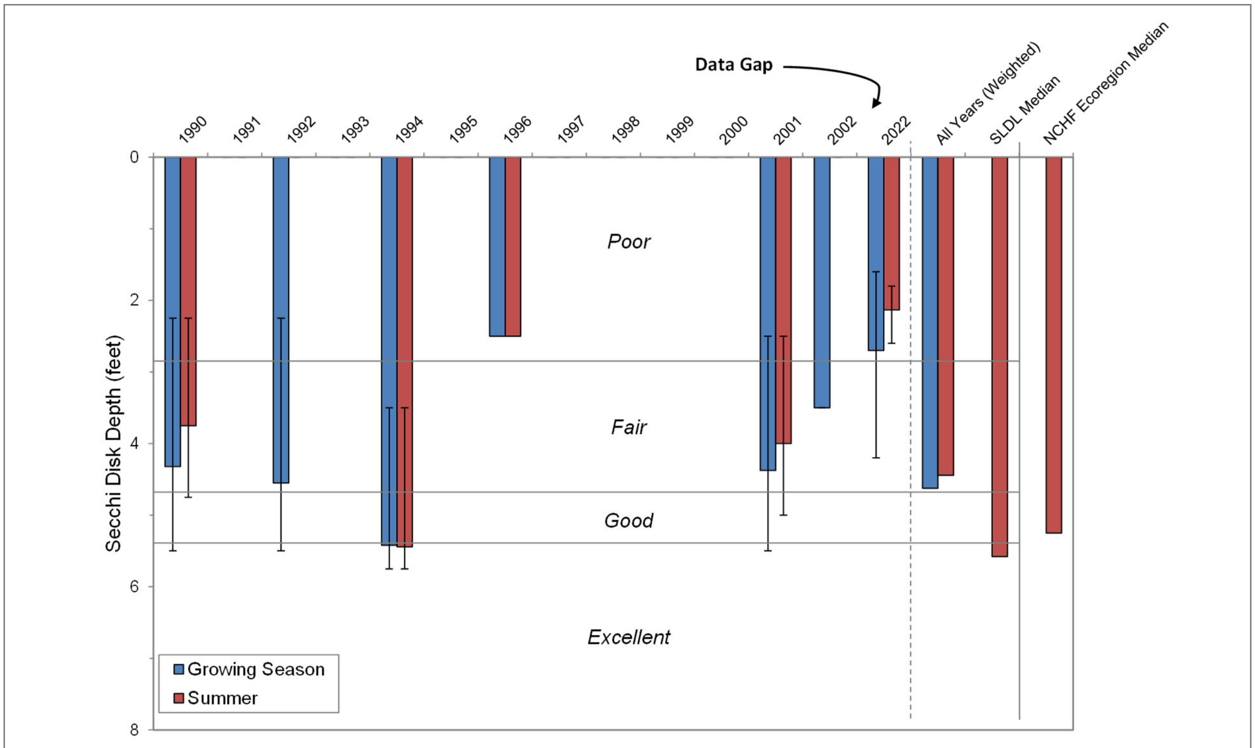


Figure 3.1-5. Pigeon Lake statewide class 4 lakes, and regional Secchi disk clarity values. Median values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Pigeon Lake

Using midsummer nitrogen and phosphorus concentrations from Pigeon Lake, a nitrogen to phosphorus ratio of 15:1 was calculated. This finding indicates that Pigeon Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that phosphorus controls algae growth and to some extent, vascular plant growth within the lake.

Pigeon Lake Trophic State

Figure 3.1-6 contain the TSI values for Pigeon Lake. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values. The Pigeon Lake values primarily remain in the mid eutrophic category. 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* TSI values, it can be concluded that Pigeon Lake is in strongly eutrophic system.

The proximity of the three symbols within a year is an indicator of the how strong the relationship is between the three parameters. As described above, high flows increase the flushing rate of the lake and reduce the relationship between phosphorus and chlorophyll-*a*. The 2022 relationship between the three trophic parameters is very strong, which corresponds to the fact that the April-June precipitation levels measured at the Midwest Climate Center station in Clintonville was lowest has been in over 12 years at 9.37 inches. The average since 2010 is 11.6 inches during those months. Again, more data would lead to a better understanding of the relationship between precipitation, flows, flushing rate, and growing season water quality. Maybe even to the point that summer water quality could be predicted based upon spring runoff.

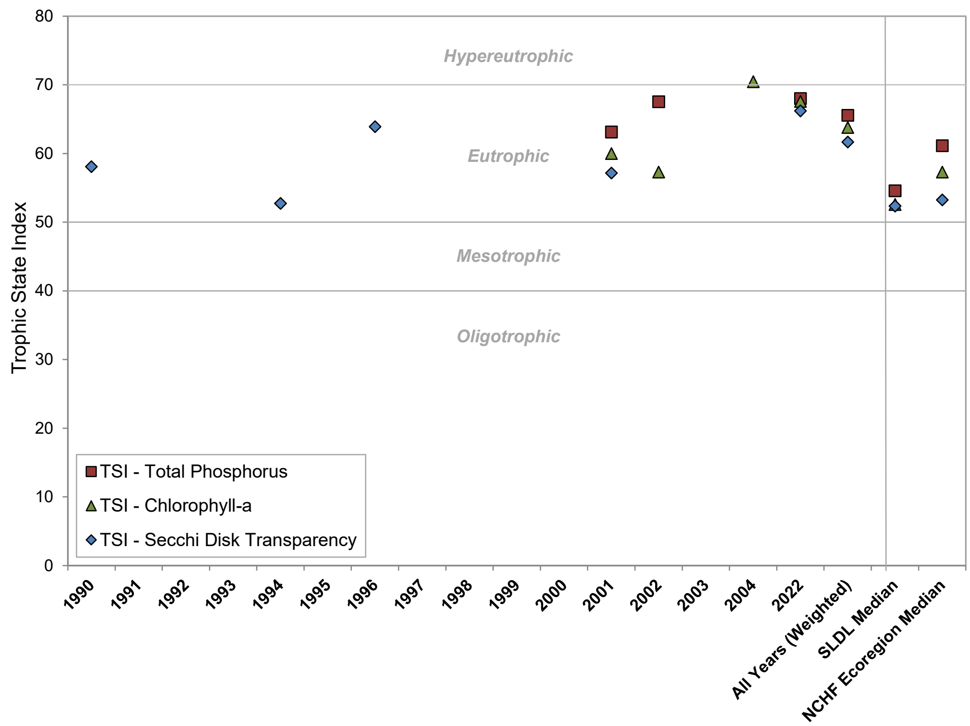


Figure 3.1-6. Pigeon Lake, statewide class 4 lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Pigeon Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Pigeon Lake by Onterra staff. Profiles depicting these data are displayed in Figure 3.1-7. During the extent of the spring, summer, and fall, Pigeon Lake remained mixed and very well oxygenated. This is typical of a flowing system. Even under the ice in mid-February, plenty of oxygen was available throughout the water column.

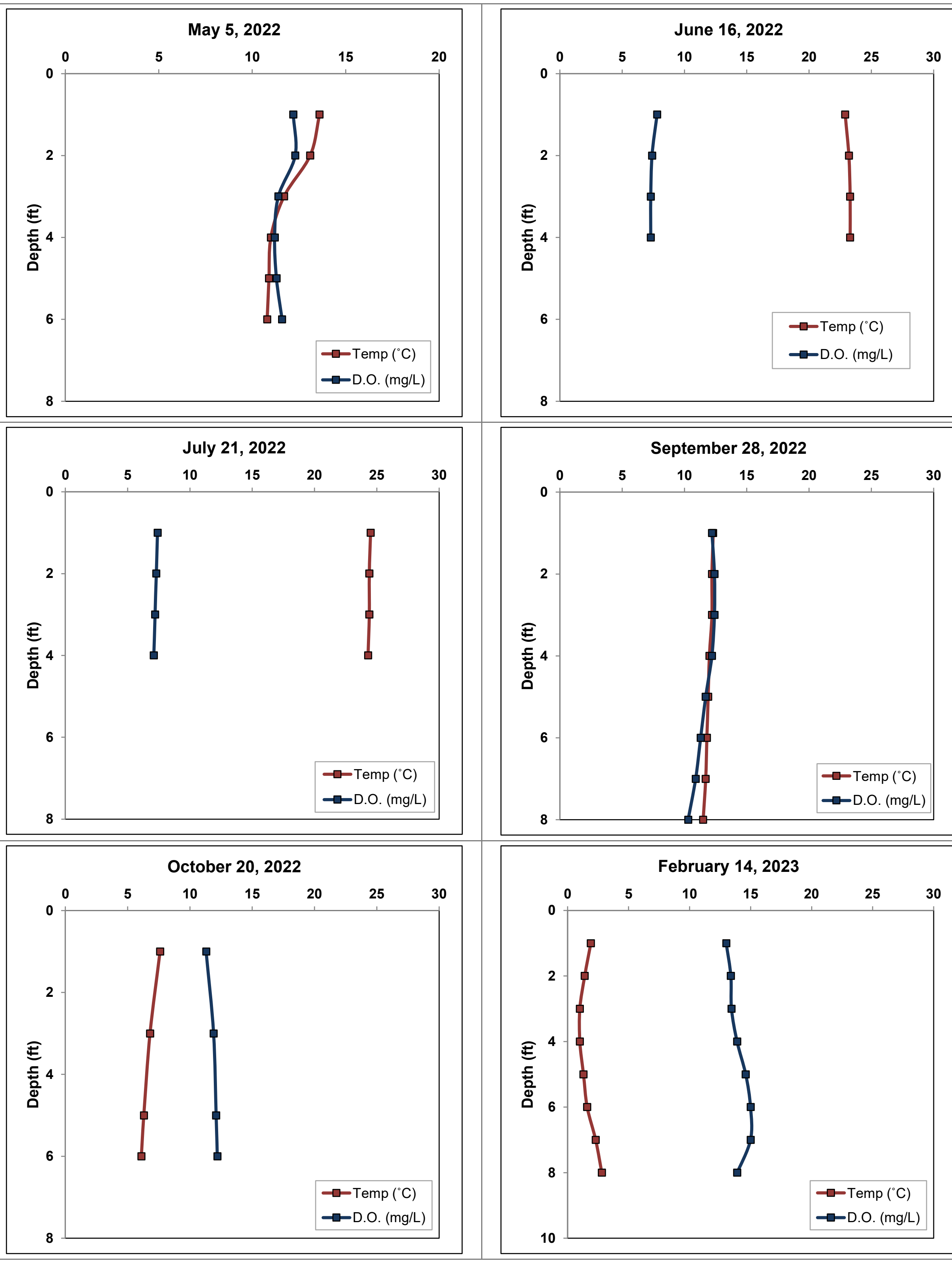


Figure 3.1-7. Pigeon Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Pigeon Lake

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

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic, meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw & Nimphius, 1985). The pH of the water in Pigeon Lake was found to be slightly alkaline with a value of 8.3 and falls within the normal range for Wisconsin Lakes (Figure 3.1-8).

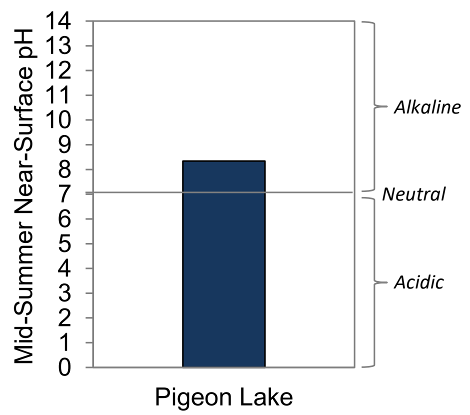


Figure 3.1-8. Pigeon Lake mid-summer near-surface pH value.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($(CaMgCO_3)_2$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Pigeon Lake was measured at 203 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain (Figure 3.1-9).

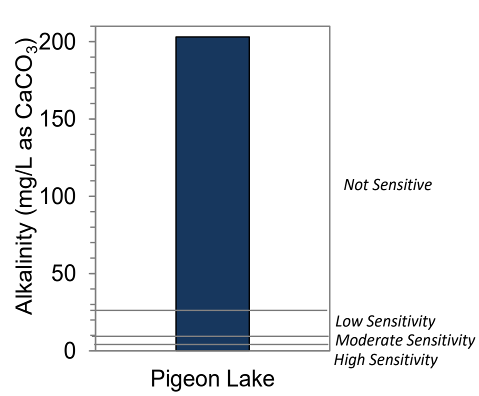


Figure 3.1-9. Pigeon Lake average growing season total alkalinity and sensitivity to acid rain. Samples collected from near-surface.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Pigeon Lake's pH of 8.3 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Pigeon Lake was found to be 47.3 mg/L, falling well within the optimal range for zebra mussels (Figure 3.1-10).

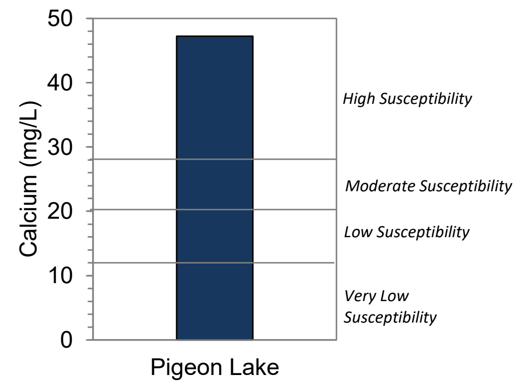


Figure 3.1-10. Pigeon Lake spring calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

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

A measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured at 60 SU (standard units) in April and 30 SU in July of 2022, indicating the lake's water was *tea colored* in 2022 (Figure 3.1-11).

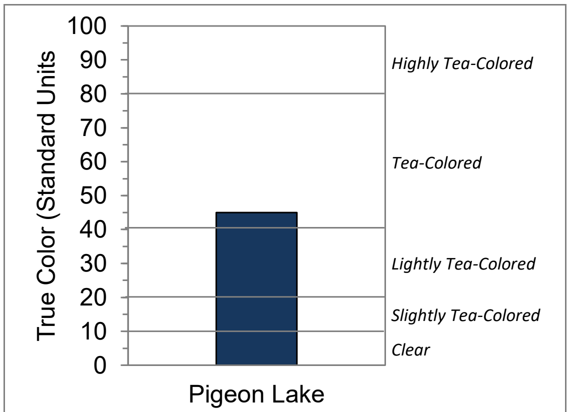
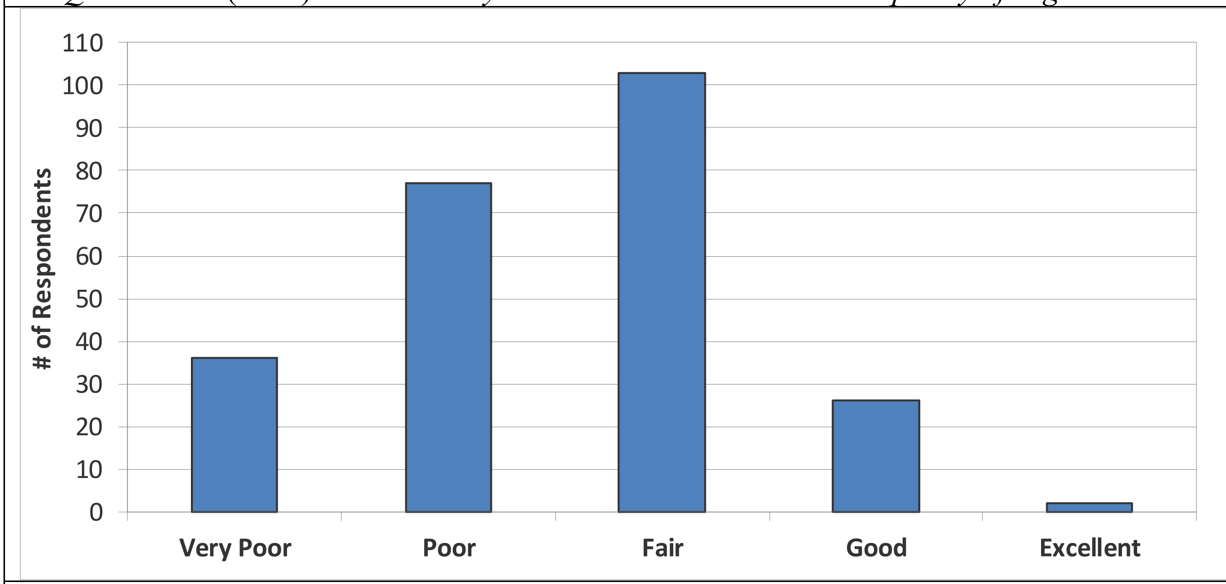


Figure 3.1-11. Pigeon Lake 2022 near-surface true color value.

Stakeholder Survey Responses to Pigeon Lake Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.1-12 displays the responses of members of Pigeon Lake stakeholders to questions regarding water quality and how it has changed over their years visiting Pigeon Lake.

Question 15 (2022)*: How would you describe the current water quality of Pigeon Lake?*



Question 16 (2022): How has the water quality changed in Pigeon Lake since you first visited the lake?

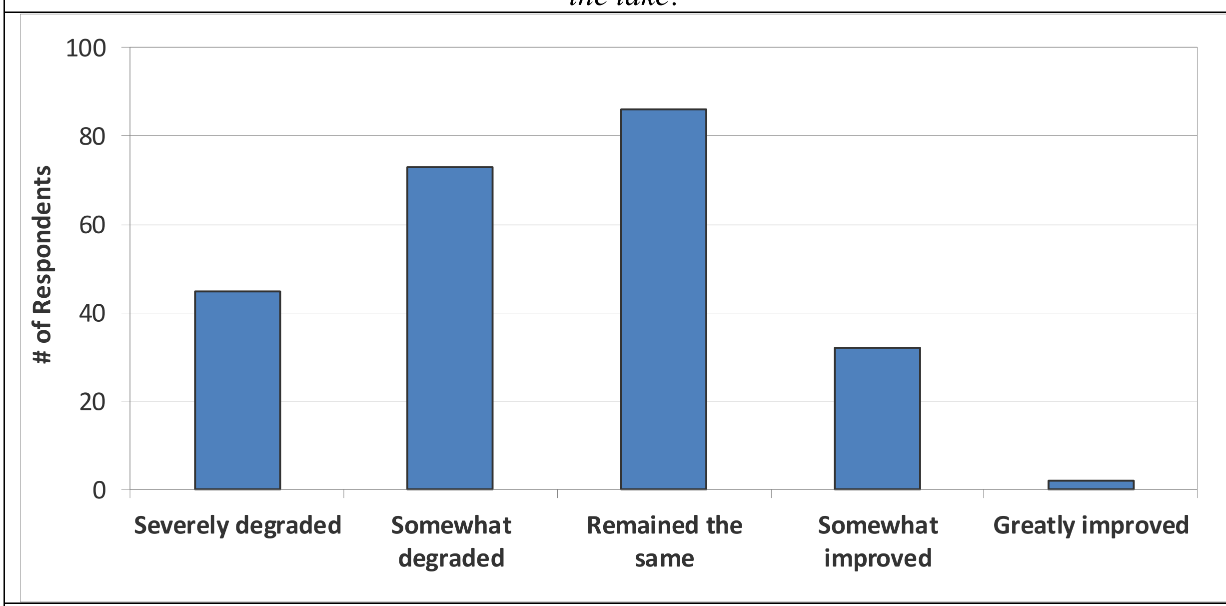


Figure 3.1-12. Select survey responses from the Pigeon Lake Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Pigeon Lake Watershed Assessment – TMDL Model

Section 303(d) of the Clean Water Act (CWA) requires states to determine which waterbodies are impaired and orchestrate a plan to reach the goal of restoring all identified impaired waters to meet applicable water quality standards (WDNR 2020). One of the tools WDNR biologists use to achieve this goal is to develop a total maximum daily load (TMDL) for an impaired waterbody. The primary objective of an approved TMDL is to establish pollutant load allocations to point and nonpoint sources in order to achieve pollutant load reductions needed to meet water quality goals (WDNR 2020). Meeting these water quality goals in turn should theoretically improve water quality and eventually lead to the delisting of the impaired waterbody from the impaired waters and restoration waters list.

The Wolf River TMDL watershed is approximately 2,387,200 acres (3,730 square miles), includes portions of eleven counties, and covers approximately 10% of the state of Wisconsin. The watershed originates in Pine Lake and discharges into Lake Poygan of the Lake Winnebago System. The Wolf River watershed is subdivided into twenty sub-watersheds (Figure 3.2-1). The U.S. EPA approved the Wisconsin River TMDL on February 27, 2020. This report can be accessed here: https://dnr.wisconsin.gov/topic/TMDLs/FoxWolf/index.html

Within the Wolf River watershed is the subbasin Pigeon Watershed (WR10 in Figure 3.2-2). This watershed lies in Waupaca and Shawano counties and covers over 74,000 acres, or 116 square miles. The watershed drains 146 miles of named and unnamed streams until its confluence with the Embarrass River. This watershed includes almost 30 miles of the North Branch, South Branch, and Mainstem of Pigeon River which supports fair to good quality of fish and aquatic life.

Code	Name	Acres
WR20	Upper Wolf River and Post Lake	131,503
WR19	Lily River	132,673
WR18	Wolf River - Langlade and Evergreen River	115,035
WR17	West Branch Wolf River	161,114
WR16	Red River	132,556
WR15	Shawano Lake	45,544
WR14	Middle Wolf River	85,619
WR13	Shioc River	121,447
WR12	Wolf River - New London and Bear Creek	91,191
WR11	Middle and South Branches Embarrass River	160,004
WR10	Pigeon River	74,444
WR09	North Branch and Mainstem Embarrass River	200,074
WR08	South Branch Little Wolf River	102,586
WR07	Upper Little Wolf River	116,512
WR06	Lower Little Wolf River	98,307
WR05	Waupaca River	186,096
WR04	Lower Wolf River	76,768
WR03	Walla Walla and Alder Creeks	71,739
WR02	Pine and Willow Rivers	193,329
WR01	Arrowhead River and Daggets Creek	91,463

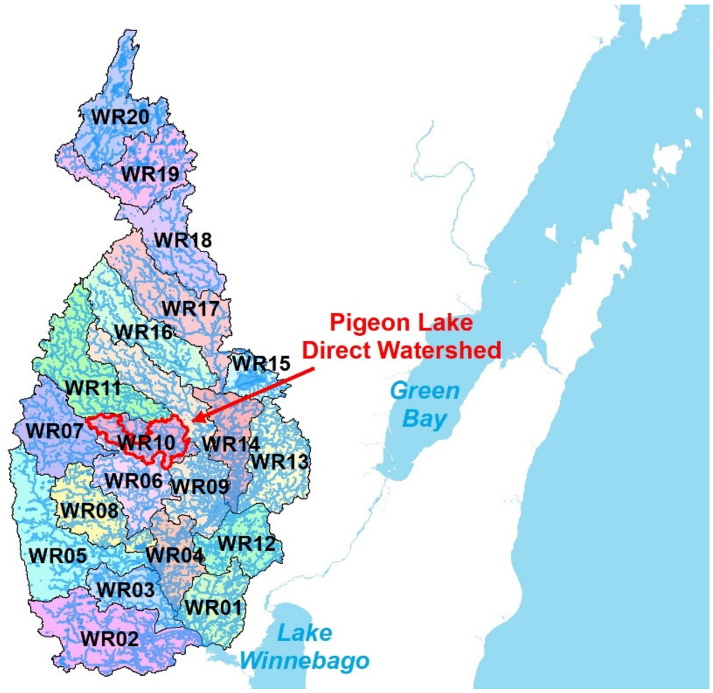


Figure 3.2-1. Pigeon Lake watershed in relation to Wolf River Watershed.

Pigeon Lake Watershed Assessment – WiLMS Model

Pigeon Lake's entire watershed encompasses an area of approximately 68,210 acres (106.6 sq.mi.) (Figure 3.2-2). The Pigeon watershed includes the Marion Millpond watershed with an acreage of 12,400. Subtracting the Marion Millpond subwatershed acreage from Pigeon Lake's total watershed area calculates to 55,810 acres, which is the area of Pigeon Lake's direct watershed.

Different types of landcover export varying amounts of phosphorus as water runs off the land and makes its way to a lake. Row crop agriculture and high-density development export the highest levels of phosphorus per acre, while forested areas and wetlands export the least. Figures 3.2-2 and 3.2-3 show the partitioning of landcover types within Pigeon Lake's direct watershed. Forest, pasture/grass, wetlands, and the surface area of Silver Lake itself, which are all considered relatively low contributors of phosphorus make up about 47% of the total watershed area. Landcover types such as urbanized areas and agricultural row crops occupy just over a third of the watershed area.

The Marion Millpond subwatershed occupies about 18% of the Pigeon Lake watershed. When modeling a watershed that has lakes in a series (one lake draining into another), the upper lake, the Marion Millpond in this case, is treated somewhat like a point-source to the downstream lake. Specifically, the upper lake's inflow and outflow are modeled along with the lake's annual mean phosphorus concentration to determine the hydraulic input and phosphorus load to the downstream lake. This methodology captures the upstream lake's impact on the water flowing into it before passing it through to the downstream lake.

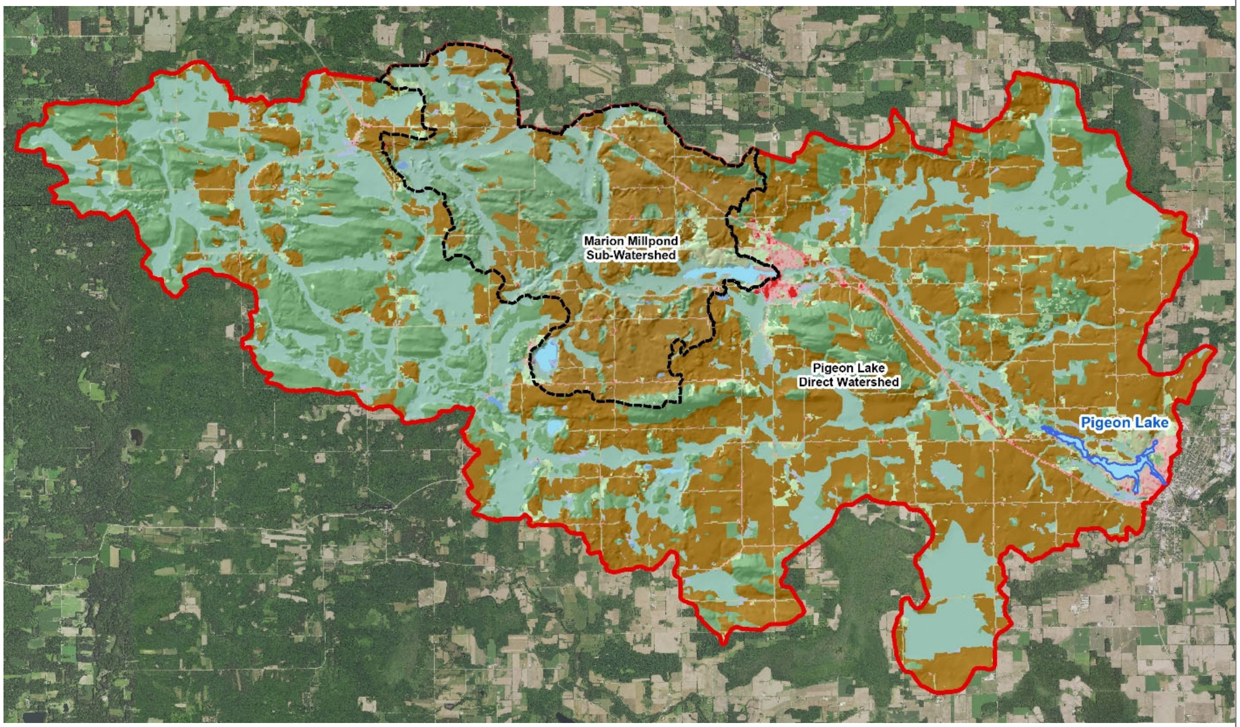


Figure 3.2-2. Pigeon Lake watershed and landcover categories. Based upon 2019 National Land Cover Database.

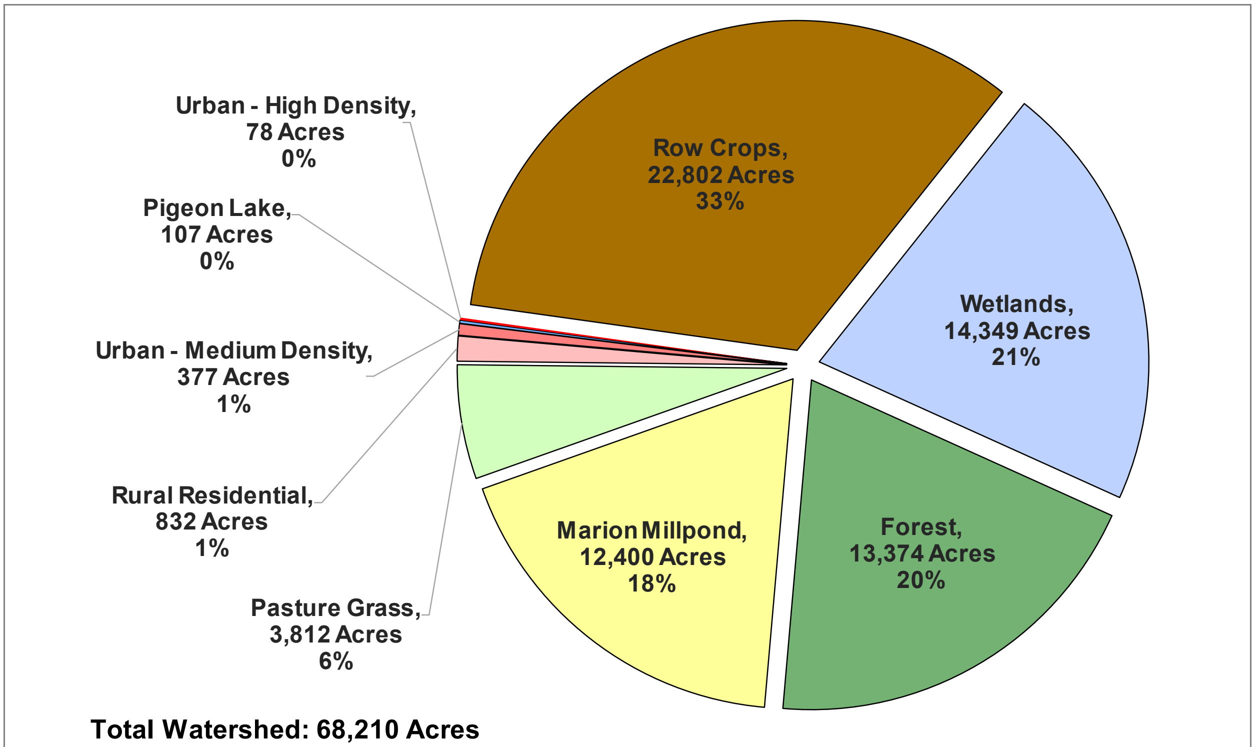


Figure 3.2-3. Pigeon Lake watershed landcover categories Based upon 2019 National Land Cover Database.

Figure 3.2-4 displays the annual estimated load of phosphorus to Pigeon Lake from each of the categories discussed above. As mentioned above, the row crop agriculture and urbanized areas make up about a third of the watershed acreage, but they account for over 80% of Pigeon Lake's annual phosphorus load. The less impactful landcover types, like forests, wetlands, pasture/grass, and the surface of Pigeon Lake, account for approximately 13%, while the Marion Millpond subwatershed contributes 6%.

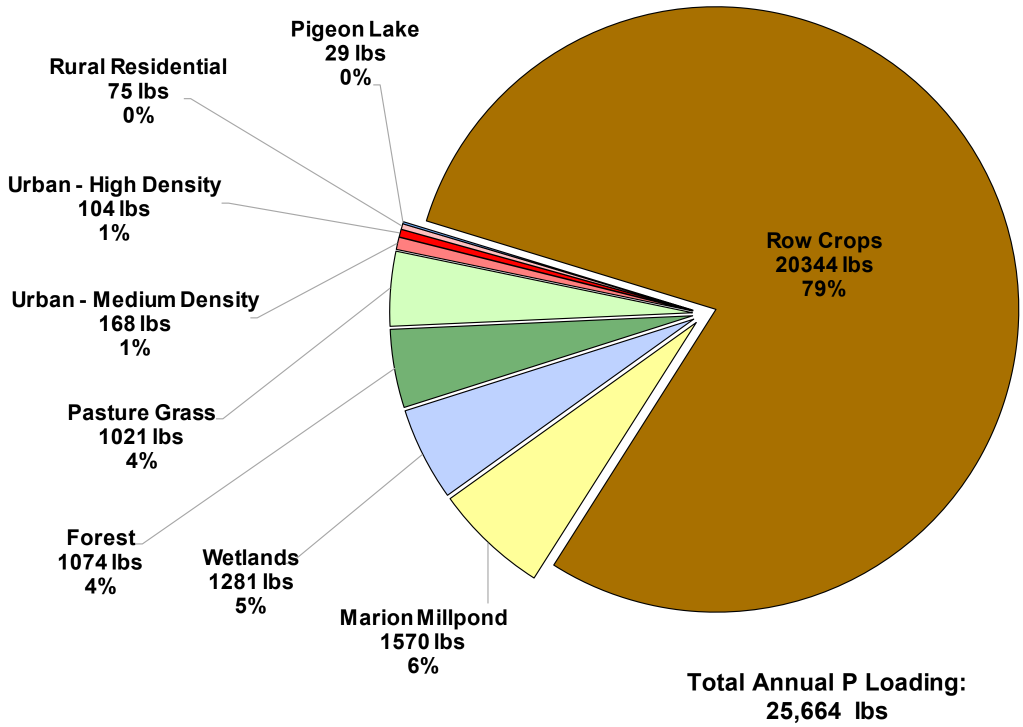


Figure 3.2-4. Pigeon Lake watershed and landcover categories. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

WiLMS is a screening-level model and its accuracy wains with very large watersheds like that of Pigeon Lake. Utilizing an annual phosphorus load of 25,664 lbs, the model predicted an average growing season phosphorus concentration of 64-119 µg/L. Considering the limited amount of historical phosphorus data, the wide fluctuations of the available data, and the fact that the growing season and summer month measured averages are 63 and 74 µg/L, respectively, the predicted value indicates the model is reasonably reflecting phosphorus loading to Pigeon Lake.

Once the model is set up, it can be used to predict how the annual phosphorus load and resulting in-lake phosphorus concentrations may change with changes to watershed landcover types. For demonstrational purposes, three scenarios are shown in Table 3.2-1 below.

The scenarios include replacing acreage of the highest phosphorus exporting landcover, row crops, with the lowest phosphorus exporting landcover, forested areas. Simply converting row crops to forests.

The development of scenario models demonstrates the large amount of change that would have to occur in Pigeon Lake's watershed to see a significant amount of change in the lake's phosphorus levels. Unrealistic changes, like converting 100% or 50% of row crop acreage to forests would lead to noticeable changes in the lake's phosphorus concentrations and algae blooms would likely be less frequent. However, converting 500 acres, or 2% of the current acreage, from row crops to forests, a more reasonable plan, would produce a negligible change in the lake's phosphorus levels.

Table 3.2-1. Modeling scenarios for landcover changes in the Pigeon Lake watershed. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Scenario	Phosphorous load from Row Crops (lbs/year)	Phosphorous load from Forested Areas (lbs/year)	Predicted Total Phosphorous (µg/L)
Current	20344	1074	64 - 119
50 % Row Crops to Forested Areas	10172	1989	42 - 81
100% Row Crops to Forested Areas	0	2906	19 - 38
500 ac. (2%) Row Crops to Forested Areas	19897	6406	63-117

While unfortunate, this is typical for man-made lakes with very large watersheds. The watershed to lake area ratio for Pigeon Lake is 378:1. This means that for every surface acre of lake, there are 378 acres of land draining to it. In this case, the sheer size of the watershed basically overrides the influence of landcover type in determining phosphorus loads to the lake. So, even if the watershed is dominated by forests and has no row crop acreage, the lake would still be eutrophic (highly productive). Fortunately, as described in Section 3.1 Lake Water Quality, the incredible flushing rate, which is brought on by that very large watershed, reduces the occurrence of nuisance algae blooms in the lake.

3.3 Shoreland Condition

Lake Shoreland Zone and its Importance

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

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

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed, but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means (Photograph 3.3-1). Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which is important for aquatic macroinvertebrates (Sass, 2009). While it impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

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

National Lakes Assessment

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

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

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings, E., Hatzenbeler, Edwards, & Bozek, 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings, E., Hatzenbeler, Edwards, & Bozek, 2003) (Radomski & Goeman, 2001) (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 & Schindler, 2004).

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

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state (Photograph 3.3-2). An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function.

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

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.3-1).

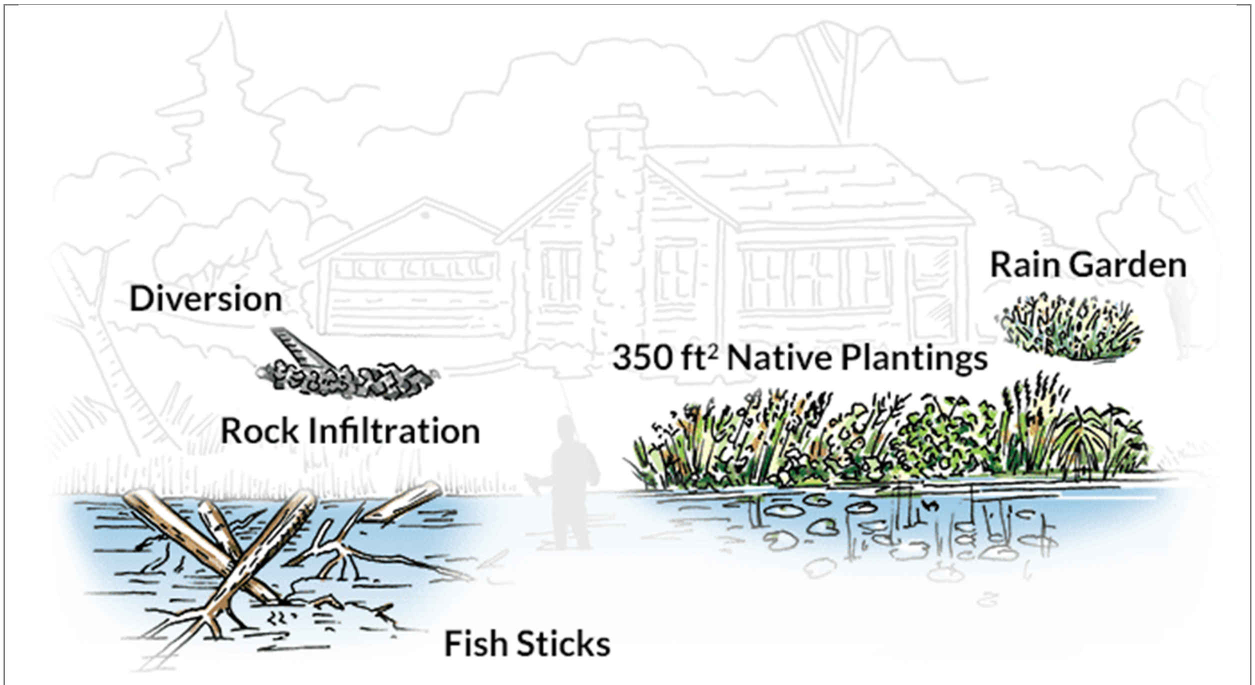


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here:

https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

Pigeon Lake Shoreland Zone Condition

Shoreland Development

The entire shoreline of Pigeon Lake was surveyed on June 6th, 8th, and 19th of 2022. A draft WDNR Lake Shoreland & Shallows Habitat Monitoring Field Protocol (WDNR, Lake Shoreland & Shallows Habitat Monitoring Field Protocol, 2020) was utilized to evaluate the shoreland zone on a parcel-by-parcel basis beginning at the estimated high-water level mark and extending inland 35 feet. The immediate shoreline was surveyed and classified based upon its potential to negatively impact the system due to development and other human impacts. Within the shoreland zone the natural vegetation (canopy cover, shrub/herbaceous) was given an estimate of the percentage of the plot which is dominated by each category (Photo 3.3-3). Human disturbances (impervious surface, manicured lawn, agriculture, number of buildings, boats on shore, piers, boat lifts, sea wall length and other similar categories) were also recorded by number of occurrence or percentage during the survey.

Photograph 3.3-3. Example of canopy, shrub and herbaceous layers.

For this management plan, the percent canopy cover, percent shrub/herbaceous, percent manicured lawn and percent impervious surfaces are primarily focused upon to assess the shoreline for development and determine a need for restoration. In general, developed shorelands impact a lake ecosystem in a negative manner, while definite benefits occur from shorelands that are left in their natural state or a near-natural state.

Canopy cover was defined as an area which is shaded by trees that are at least 16 feet tall (Photograph 3.3-2). The majority (68%) of Pigeon Lake's shoreline has more than 61% canopy cover (Figure 3.3-2).

Shrub and herbaceous layers consist of small trees that are less than 16 feet tall and smaller plants without woody stems (Photograph 3.3-2). The shoreland assessment survey indicates that 4.29 miles, or 58% Pigeon Lake's parcels contained between 81-100% shrub and herbaceous layers (Figure 3.3-2, Map 3). Another 2.05 miles (28%) only had between 0 and 20% shrub and herbaceous layer present on the parcel.

A manicured lawn is defined as grass that is mowed short and is direct evidence of urbanization. Having a manicured lawn poses a risk as runoff will carry pollutants, such as lawn fertilizers, into the lake. Approximately 49% of the shoreline around Pigeon Lake had no manicured lawn within the shoreland zone and another 23% of the shoreline had between 1-25% land containing manicured lawn (Figure 3.3-3, Map 4). Approximately 19% of the shoreline contained manicured lawn on 76% or greater of the shoreland zone.

Impervious surface is an area that releases all or a majority of the precipitation that falls onto it (e.g., rooftops, concrete, stairs, boulders and boats flipped over on shore). Approximately 84% of the shoreline had parcels with less than 24% of impervious surface within the shoreland zone (Figure 3.3-3, Map 5).

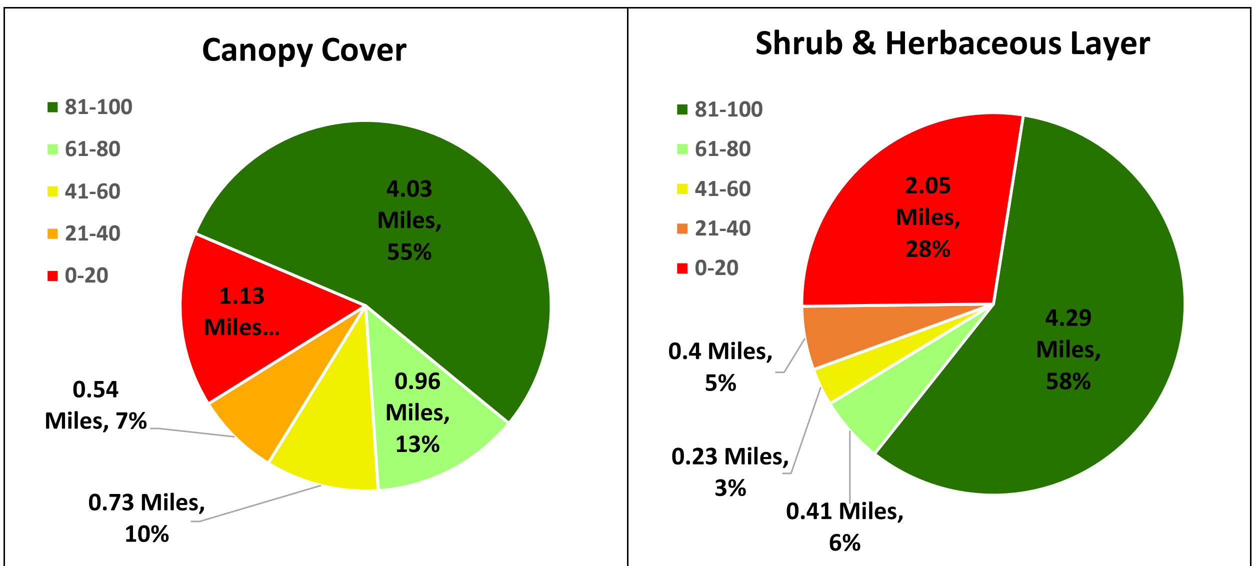


Figure 3.3-2. Pigeon Lake 2022 shoreland parcel cover types. Data from Onterra 2022 Survey.

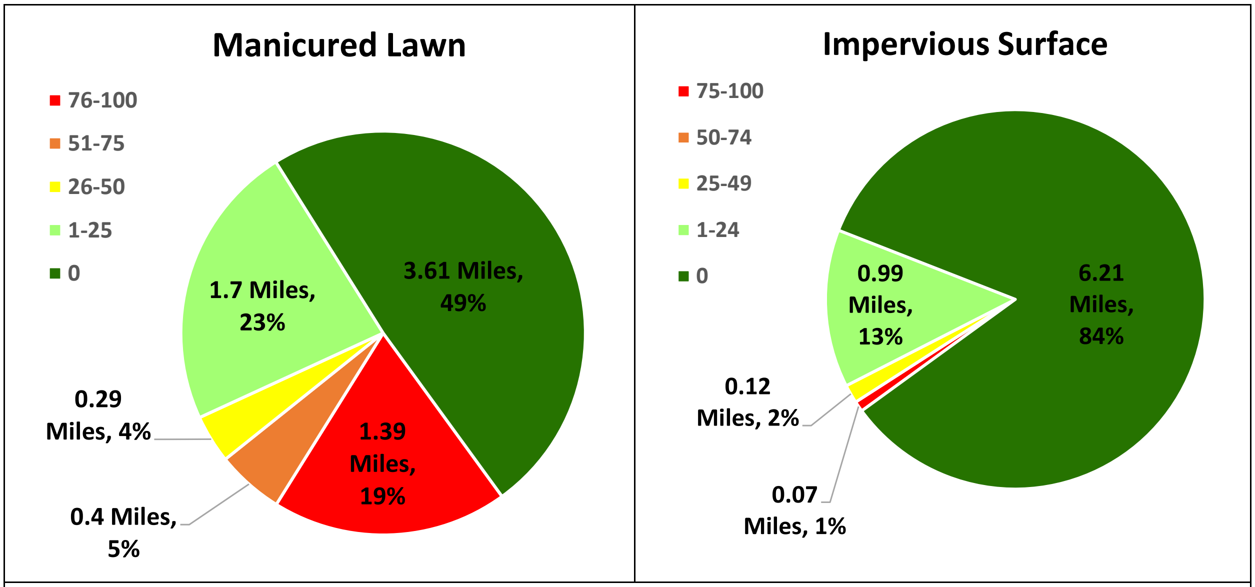


Figure 3.3-3. Pigeon Lake 2022 shoreland parcel cover types (continued). Data from Onterra 2022 Survey.

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

Coarse Woody Habitat

As part of the shoreland condition assessment, Pigeon Lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified and classified in three size categories (2-8 inches in diameter, 8+ inches in diameter, or clusters of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey, Bozek, Jennings, & Cook, 2005).

During this survey, 140 total pieces of coarse woody habitat were observed along nearly 7.5 miles of shoreline (Map 6), which gives Pigeon Lake a coarse woody habitat to shoreline mile ratio of 20:1 (Figure 3.4-4). The majority of these pieces cross the high-water level (HWL), meaning they come out from shore into the water. Any logs running parallel to shore would also count if the touch the HWL.

There has been 63 completed coarse woody habitat surveys utilizing the WDNR protocol throughout Wisconsin since 2017. The number of coarse woody habitat pieces per shoreline mile on Pigeon Lake falls at the 31st percentile for these lakes (Figure 3.3-4). To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen, Herwig, Schindler, & Carpenter, 1996). Please note the methodologies between the surveys done on Pigeon Lake and those cited in this literature comparison are different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

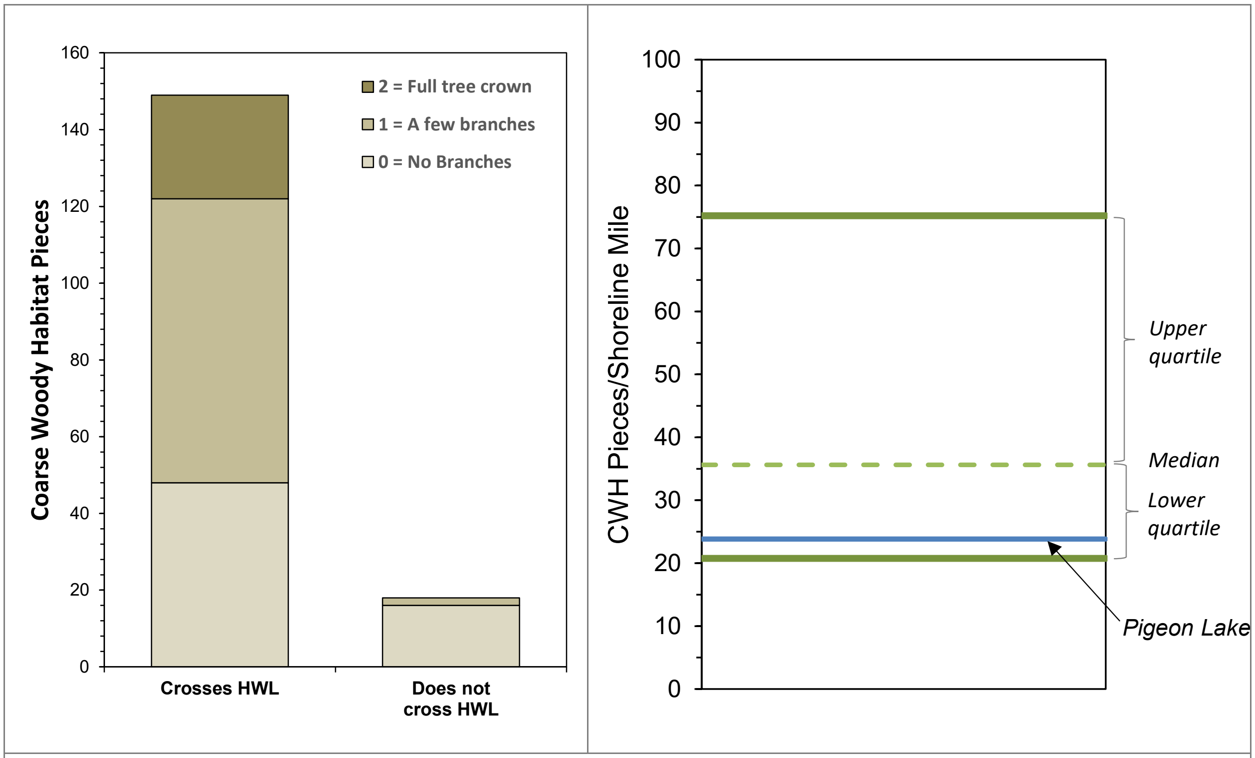


Figure 3.3-4. Pigeon Lake coarse woody habitat survey results. Based upon a Summer 2022 survey. Locations of the Pigeon Lake coarse woody habitat can be found on Map 6.

3.4 Aquatic Plants

Introduction

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

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

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) (Photograph 3.4-1). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

Manual Removal (Hand-Harvesting & DASH)

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody (Photograph 3.4-2). Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however, Wisconsin law states that all plant fragments must be removed.

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

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

Photograph 3.4-3. Mechanical harvester.

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet (Photograph 3.4-3). Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Cost

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

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

Herbicide Treatment

Photograph 3.4-4. An example of liquid herbicide application. Photo credit: Amy Kay, Clarke.

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers (Photograph 3.4-4). Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 60°F can be less impactful to many native plants, which have not emerged yet at this time of year. Emergent species are targeted with foliar applications at strategic times of the year when the target plant is more likely to absorb the herbicide.

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

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

Aquatic herbicides can be classified in many ways. Organization of this section follows Netherland (2009) in which mode of action (i.e., how the herbicide works) and application techniques (i.e., foliar or submersed treatment) group the aquatic herbicides. The table (Table 3.4-1) below provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from (Netherland, 2009).

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

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

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

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment;

invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g., mammals, insects)	therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

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

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from predetermined areas. In the case of the whole-lake point-intercept survey completed on Pigeon Lake, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

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

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

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

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Pigeon Lake is compared to data collected by Onterra and the WDNR Science Services on lakes within the Central Hardwood Forests (NCHF) ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

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

Exotic Plants

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

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

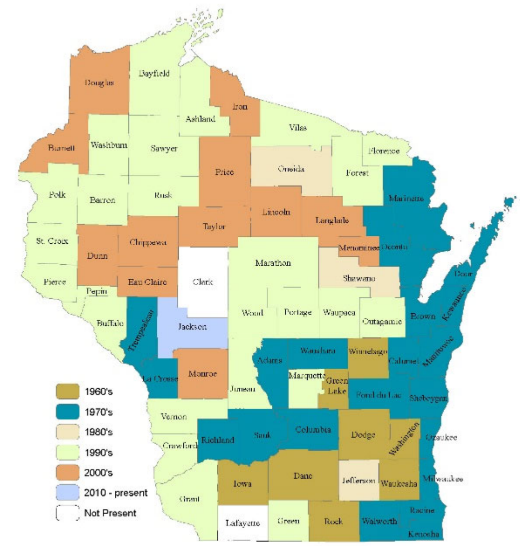


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2022 mapped by Onterra.

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

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian watermilfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer. Aquatic invasive species mapping methodology is discussed in Section 6.0, Methods.

Pigeon Lake Aquatic Plant Survey Results

The whole-lake point-intercept and community mapping surveys were conducted on Pigeon Lake on July 21, 2022 and July 22, 2022, respectively. The point-intercept survey utilized standard WDNR protocols (Hauxwell et al. 2010) at resolution of 36-meters, yielding 551 sampling points. During both 2022 surveys, a total of 31 aquatic plant species were located (Table 3.4-2). Seven are considered to be non-native, invasive species: Eurasian watermilfoil, curly-leaf pondweed, narrow-leaved cattail, flowering rush, pale-yellow iris, reed canary grass, and purple loosestrife. All of these non-native plant species are discussed in the subsequent *Non-Native Aquatic Plants in Pigeon Lake* section. A point-intercept survey was also completed in 2014 by Stantec which is used as a comparison to pre-drawdown conditions. From both point-intercept surveys and one community mapping survey, the total number of aquatic plant species located in Pigeon Lake is 33.

During the 2022 point-intercept survey, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 96% of the point-intercept locations contained soft organic sediments, 3% contained rock, and 1% contained sand (Figure 3.4-2). The soft organic sediment within littoral areas of Pigeon Lake is very conducive for supporting lush aquatic plant growth.

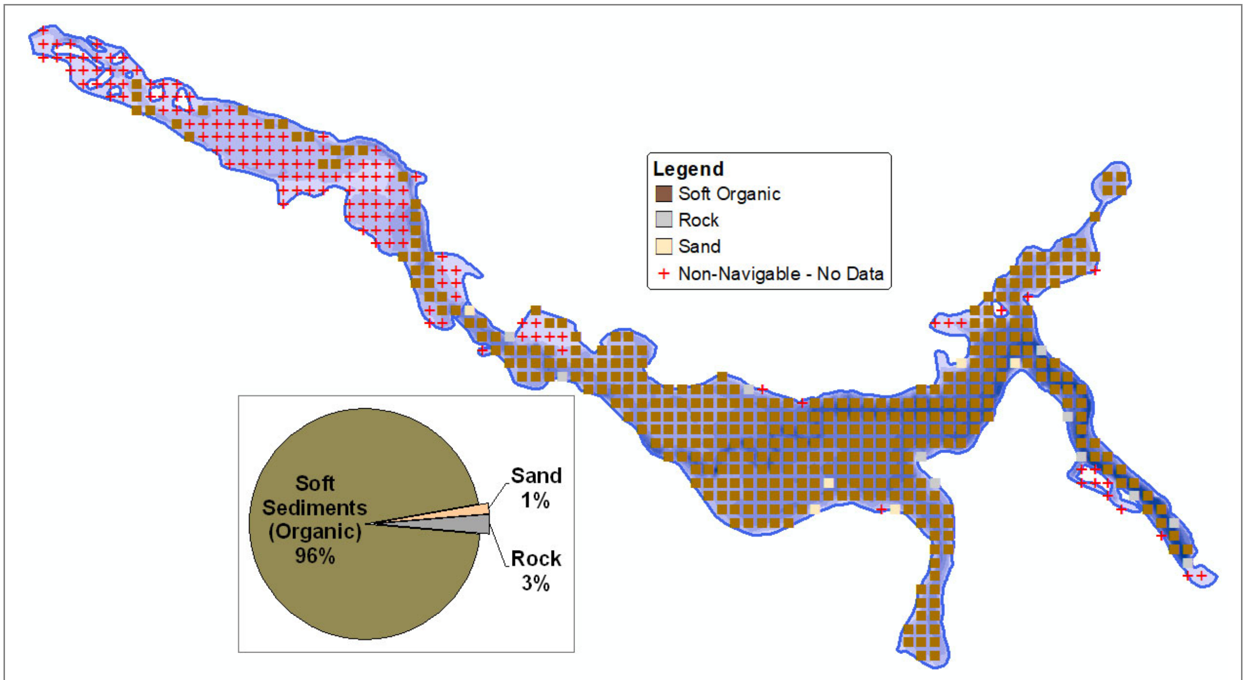


Figure 3.4-2. Pigeon Lake proportion of substrate types within littoral areas. Created using data from 2022 aquatic plant point-intercept survey.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The lack of various sediments and areas of harder substrates in Pigeon Lake produce a monoculture habitat for aquatic plants, and generally leads to a lower number of aquatic plant species within the lake.

Table 3.4-2. Aquatic plant species located on Pigeon Lake during the 2014 and 2022 surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2014	2022
Emergent	*Acorus americanus*	Sweetflag	Native	7		I
	Butomus umbellatus	Flowering rush	Non-Native - Invasive	N/A		X
	Carex comosa	Bristly sedge	Native	5		I
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A		I
	Iris versicolor	Northern blue flag	Native	5		I
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A		I
	Phalaris arundinacea	Reed canary grass	Non-Native - Invasive	N/A		I
	Pontederia cordata	Pickerelweed	Native	9		I
	Sagittaria latifolia	Common arrowhead	Native	3		I
	Schoenoplectus acutus	Hardstem bulrush	Native	5		I
	Sparganium eurycarpum	Common bur-reed	Native	5		I
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A		I
	Typha latifolia	Broad-leaved cattail	Native	1		I
FL	*Nuphar variegata*	Spatterdock	Native	6	X	X
	Nymphaea odorata	White water lily	Native	6	X	X
FL/E	*Sparganium sp.*	Bur-reed sp.	Native	N/A	X	
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X
	Chara spp.	Muskgrasses	Native	7	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X
	Heteranthera dubia	Water stargrass	Native	6	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X
	Najas flexilis	Slender naiad	Native	6	X	
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X	X
	Potamogeton friesii	Fries' pondweed	Native	8		X
	Potamogeton praelongus	White-stem pondweed	Native	8	X	
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8	X	X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X
	Vallisneria americana	Wild celery	Native	6	X	X
FF	*Lemna minor*	Lesser duckweed	Native	5	X	X
	Lemna trisulca	Forked duckweed	Native	6	X	
	Spirodela polyrhiza	Greater duckweed	Native	5	X	
	Wolffia spp.	Watermeal spp.	Native	N/A	X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL = Floating-leaf; F/L = Floating-leaf & Emergent; S/E = Submergent and/or Emergent; FF = Free-floating

In 2022, Onterra ecologists completed an acoustic survey on Pigeon Lake. The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in green/blue (Map 7). The acoustic survey shows aquatic plant abundance within the littoral zone in 2022 was low.

In 2022, approximately 26% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (7 feet), also called the littoral zone, contained aquatic vegetation in 2022 (Figure 3.5-3). Aquatic plant rake fullness data collected in 2022 indicates that 24% of the 366 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, <1% had a TRF rating of 2, and 1% had a TRF rating of 3 indicating overall aquatic plant biomass in Pigeon Lake is very low (Map 8). In 2014, 402 (96%) of the 419 littoral sampling locations (≤ 9 feet) contained aquatic vegetation, and although TRF ratings were not recorded, the littoral frequency of occurrence was much higher when compared to 2022.

During the 2014 and 2022 point-intercept surveys, the maximum depth of aquatic plant growth varied from 9 feet to 7 feet, respectively. This means there was a smaller littoral zone or area for plants to obtain adequate sunlight to grow in 2022. As described in the Water Quality Section 3.1, the average growing season Secchi disk transparency was 2.7 feet in 2022. The photic zone, or depth at which sufficient light penetrates to support plant growth, is typically 2.5 to 3 times the Secchi disk depth. Therefore, the photic zone during 2022 was roughly between 6.75 and 8.1 feet. Unfortunately, no other recent Secchi disk data exists for comparisons of the same calculations leading up to 2022. It is likely that the distinct reduction in plant biomass in Pigeon Lake found during 2022 is a result of the 2017-18 drawdown and low water clarity presently found in the lake.

Following completion of the 2017-18 drawdown, there was the potential for added depth to be gained through channelization and compaction. Since no water level gauge is located on or near the dam, precipitation from a Clintonville weather station was analyzed to determine if high, low, or normal water levels would have been expected during the 2014 and 2022 point-intercept surveys. Precipitation data suggests, water levels during 2014 would have been about average with the amount of precipitation to the area and 2022 would be expected to be lower due to below average rainfall in 2021 and 2022. With precipitation data in consideration, a review of depths from the data collected during the two whole-lake point intercept surveys, indicates almost 2 feet on average of depth was gained throughout the flowage after the drawdown occurred (Map 9). Upon review of precipitation and depth data, it appears both channelization and compaction occurred throughout much of Pigeon Lake proper following the 2017-18 drawdown.

Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Of the 28 aquatic plant species located in Pigeon Lake in 2022, 16 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 3.4-3). The remaining 12 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 16 species directly sampled with the rake during the point-intercept survey, coontail, Eurasian watermilfoil, lesser duckweed, and flowering rush were the four-most frequently encountered species in 2022.

Coontail (*Ceratophyllum demersum*) was the most frequently encountered native aquatic plant species in Pigeon Lake in 2014 and 2022 with a littoral frequency of occurrence of 71.6% and 10.7%, respectively (Photograph 3.4-5). Coontail possess whorls of leaves which fork into two to three segments, and provides ample surface area for the growth of periphyton and habitat for invertebrates. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives most of its nutrients directly from the water (Gross, Erhard, & Ivanyi, 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in eutrophic waterbodies with higher nutrients and low water clarity. Coontail has the capacity to form dense beds that can float and mat on the water's surface. In 2022, coontail was found growing most of the littoral zone ranging from 1 to 6 feet.

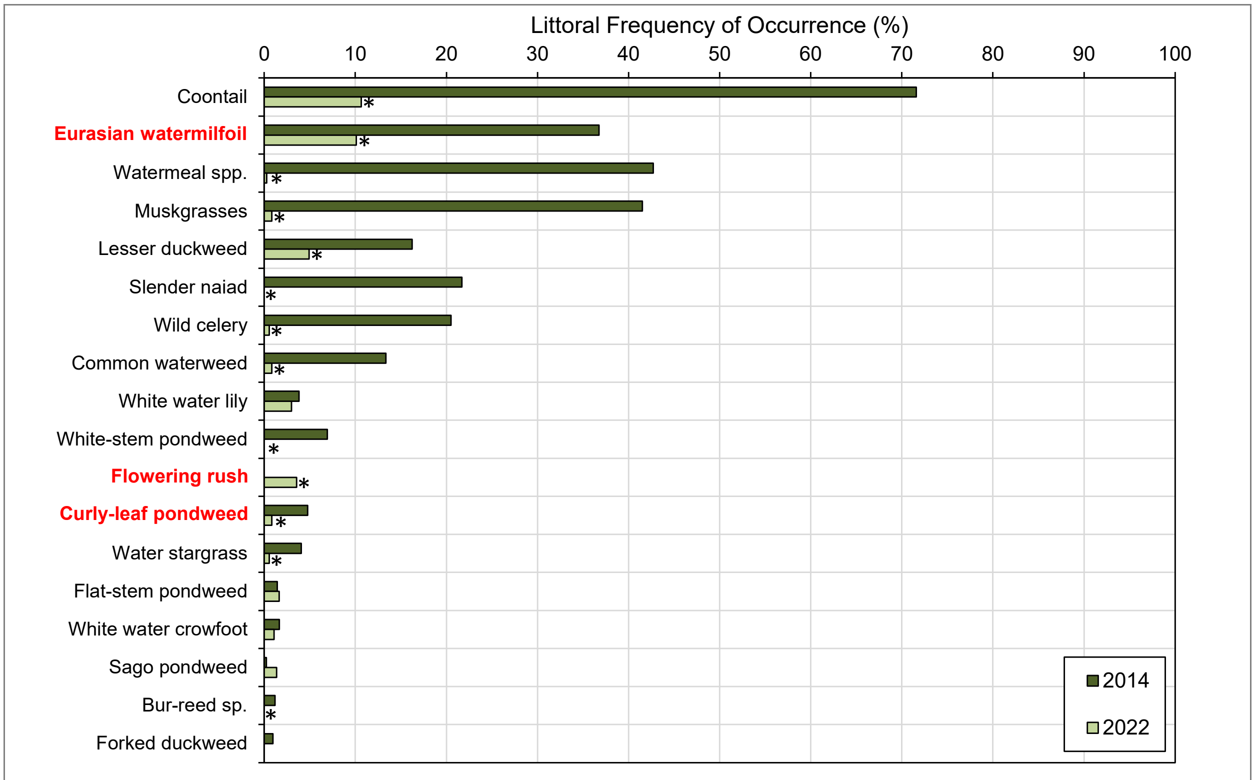
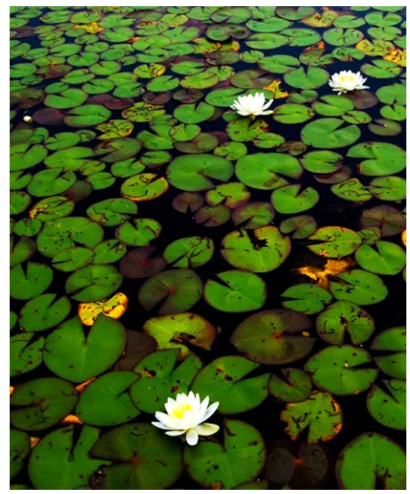


Figure 3.4-3. Pigeon Lake aquatic plant littoral frequency of occurrence. Created using data from 2014 and 2022 surveys with an LFOO >1%.

Lesser duckweed (*Lemna minor*) was the second most frequently encountered native aquatic plant species in Pigeon Lake in 2022 with a littoral frequency of occurrence of 4.9% (Photograph 3.4-5). Lesser duckweed is a free-floating aquatic plant meaning it floats on the water's surface (not rooted in sediment) and its location is largely determined by wind and wave direction. This free-floating species is most commonly confused with turion duckweed which usually exhibits a reddish underside as well as papules on its surface. In 2022 lesser duckweed was primarily found growing in shallow near shore areas where emergent and floating-leaf vegetation was also found.

White water lily (*Nymphaea odorata*) was the third most frequently encountered native aquatic plant species in Pigeon Lake in 2022 with a littoral frequency of occurrence of 3% (Photograph 3.4-5). White water lily is a floating-leaf species that produces broad, round leaves and a white flower. This plant is common in Wisconsin lakes around the shoreline, and in addition to creating shade for aquatic organisms it also serves as a food source. White water lily is most commonly confused with spatterdock whose leaves resemble a heart shape and produce yellow roundish flowers in the summer months. In 2022 white water lily was primarily found growing in shallow near shore area, the community map (Map 10) records a more complete census of white-water lily within Pigeon Lake.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while coontail was found at 11% of the sampling locations in Pigeon Lake, its relative frequency of occurrence is 26%. Explained another way, if 100 plants were randomly sampled from Pigeon Lake, 26 of them would be coontail. Looking at relative frequency of occurrence (Figure 3.4-4), five species comprise approximately 65% of the plant community in Pigeon Lake.

Coontail (*Ceratophyllum demersum*)	Lesser duckweed (*Lemna minor*)	White water lily (*Nymphaea odorata*)
		

Photograph 3.4-5. The three most common native plants in Pigeon Lake.

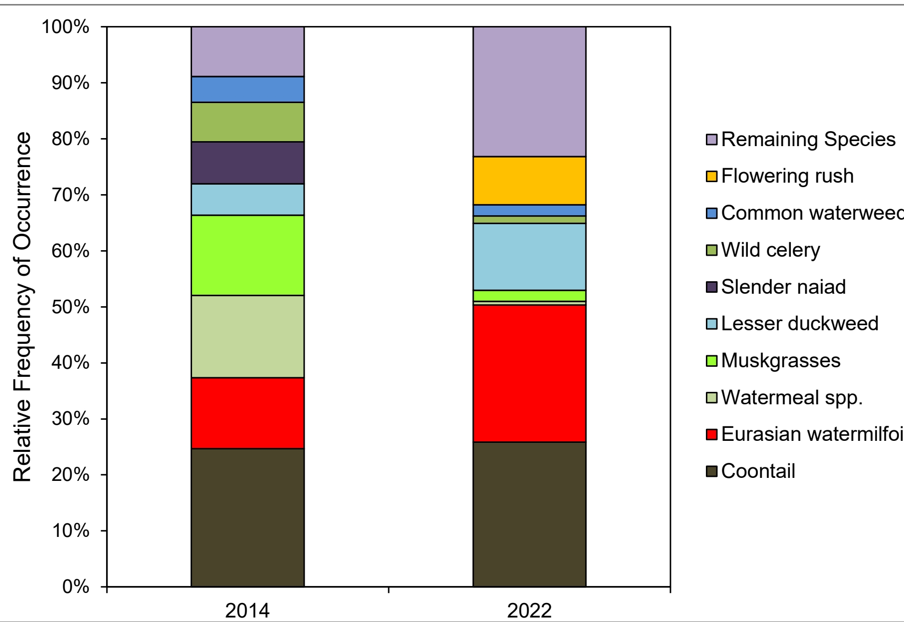


Figure 3.4-4. Pigeon Lake relative plant littoral frequency of occurrence. Created using data from the 2014 and 2022 surveys.

As discussed previously, the calculation used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. For example, while 28 native aquatic plant species were located in Pigeon Lake during the 2022 surveys, only 16 were encountered on the rake during the point-intercept survey. Figure 3.4-5 shows that the native species richness for Pigeon Lake is at the North Central Hardwood Forests (NCHF) Ecoregion and below the Wisconsin State median value.

Data collected from the aquatic plant surveys show that the average conservatism value for Pigeon Lake in 2022 was 5.6. This value is below the NCHF Ecoregion and Wisconsin State medians (Figure 3.4-5), indicating that the majority of the plant species found in Pigeon Lake are considered resilient to environmental disturbance. The presence of these plants, and lack of sensitive species, signifies current environmental conditions can mainly support aquatic plants robust to disturbance.

Combining Pigeon Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.4 (equation shown below); which is below the median values for the ecoregion and state (Figure 3.4-5), and further illustrating Pigeon Lake's plant community contains species vigorous to disturbance and of low species richness.

FQI = Average Coefficient of Conservatism (5.6) * √ Number of Native Species (16)
FQI = 22.4

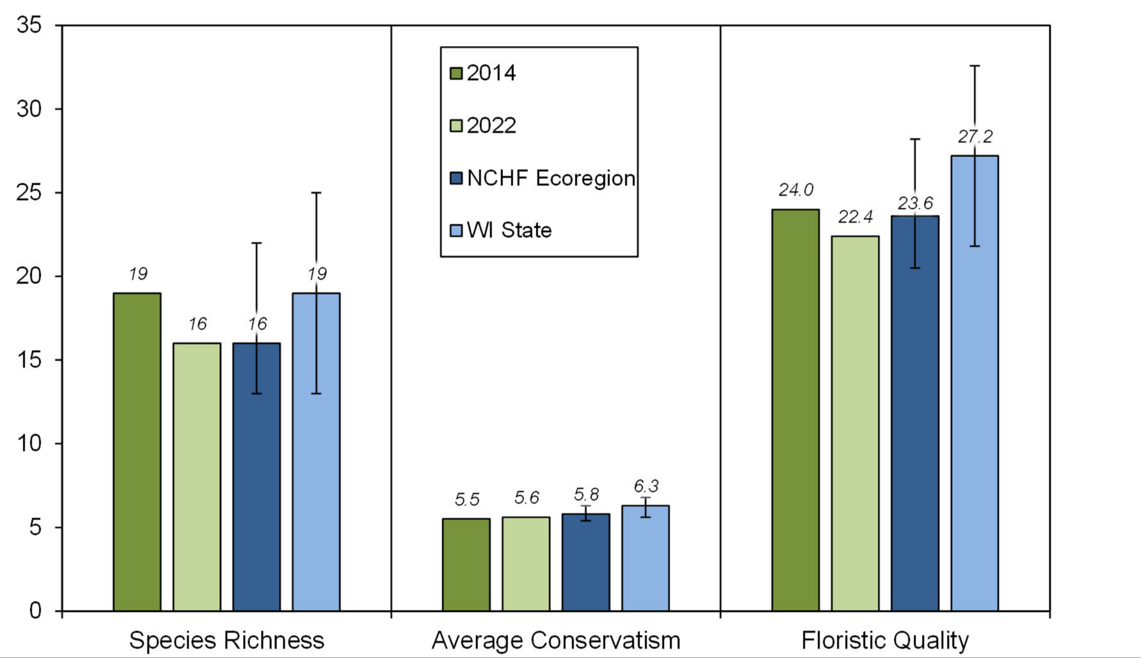


Figure 3.4-5. Pigeon Lake Floristic Quality Assessment. Created using data from 2014 and 2022 surveys. Analysis following (Nichols, 1999) where NCHF = North Central Hardwood Forests Ecoregion.

As discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community.

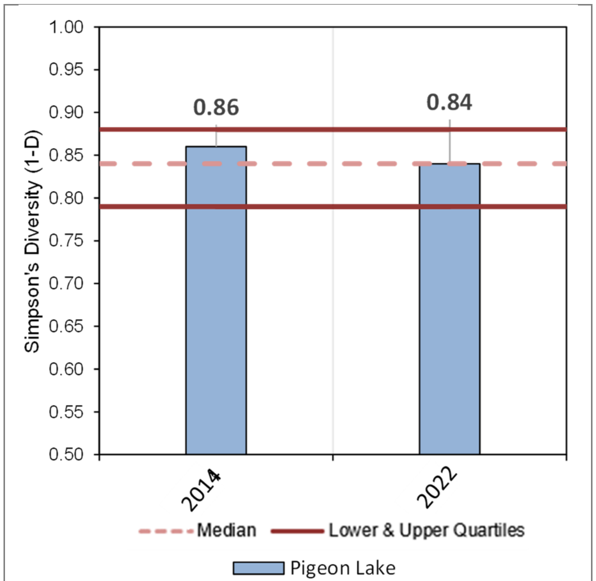


Figure 3.4-6. Pigeon Lake species diversity index. Created using data from the 2014 and 2022 aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

The aquatic plant community in Pigeon Lake was found to have moderate diversity, with a Simpson's diversity value of 0.84 in 2022 (Figure 3.4-6). This value ranks at the ecoregion median, a 0.2 decline from 2014. A plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish and other wildlife with diverse structural habitat and various sources of food. The lack of diversity in Pigeon Lake will reduce the availability of good habitat for aquatic organisms.

Pigeon Lake supports a population of the non-native common carp (*Cyprinus carpio*). Numerous studies have documented the deleterious effects these fish have on lake ecosystems. Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber & Brown, 2011). The low aquatic plant diversity is likely the result of a combination of factors such as common carp presence, poor water clarity, and the 2017-18 drawdown.

On Pigeon Lake, carp may have been a contributor in the loss of vegetation in much of the lake and inhibit the proliferation of newly established vegetation by uprooting and disturbing the sediment. The carp population likely impacted the water quality in a negative way as well through frequent sediment disruptions and re-suspending sediment into the water column resulting in a reduction in water clarity and thus a reduction in aquatic plant growth. For more information on carp and their population dynamics within Pigeon Lake, please refer to section *3.6 Fisheries Data Integration*.

On July 22, 2022, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf communities in Pigeon Lake (Map 10 and Figure 3.4-7). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plant communities, these communities provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosion control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also help stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

Because the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Pigeon Lake. This is important because these communities are often negatively affected by recreational use and shoreland development. One study found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes (Radomski & Goeman, 2001). Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

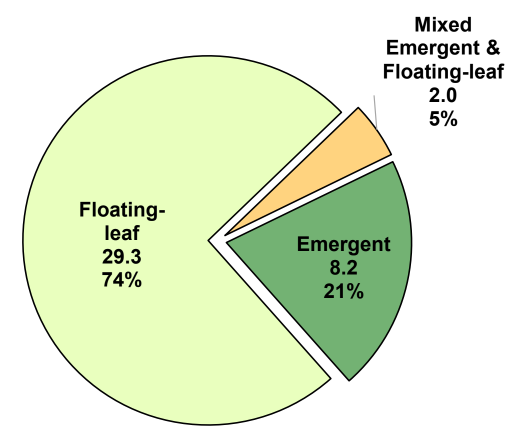


Figure 3.4-7. Pigeon Lake acres of plant community types. Created from the 2022 community mapping survey.

Pigeon Lake was found to support extensive emergent and floating-leaf marsh communities throughout shallow, near-shore areas around the lake (Figure 3.4-7). Approximately 39 acres or 23% of the lake was found to contain these plant communities. The emergent marshes were largely dominated by cattail communities while the floating-leaved marshes were largely comprised of white-water lily, common bur-reed, and spatterdock. The community map created in 2022 represents a 'snapshot' of the important plant communities in Pigeon Lake, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the lake. This is important because these communities are often negatively affected by recreational use and shoreland development.

Non-Native Aquatic Plants in Pigeon Lake

Eurasian watermilfoil (Myriophyllum spicatum)

One of the submersed non-native aquatic plants known to be present within Pigeon Lake is Eurasian watermilfoil (*Myriophyllum spicatum*). Eurasian watermilfoil (EWM) is an invasive species, native to Europe, Asia and North Africa, that has spread to most counties in Wisconsin (Photograph 3.4-6). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, EWM has two other competitive advantages over native aquatic plants: 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it sometimes does not stop growing like most native plants and instead continues to grow along the surface creating a canopy that blocks light from reaching native plants.

Photograph 3.4-6. Eurasian watermilfoil in a Wisconsin lake. Photo credit: Onterra.

Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating. However, in some lakes, EWM appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The data are clearest for unmanaged lakes in the Northern Lakes and Forests Ecoregion (NLF) and the North Central Hardwood Forests Ecoregion (NCHF) (Figure 3.4-8).

The results of the study clearly indicate that EWM populations in unmanaged lakes can fluctuate greatly between years (Figure 3.4-8). Following initial infestation, EWM expansion was rapid on some lakes, but overall was variable and unpredictable (Nault, 2016). On some lakes, the EWM populations reached a relatively stable equilibrium whereas other lakes had more moderate year-to-year variation. Regional climatic factors also seem to be a driver in EWM populations, as many EWM populations declined in 2015 even though the lakes were at vastly different points in time following initial detection within the lake. 2019 also experienced record rainfall which may have had an impact on the EWM population indirectly through a decrease in water clarity.

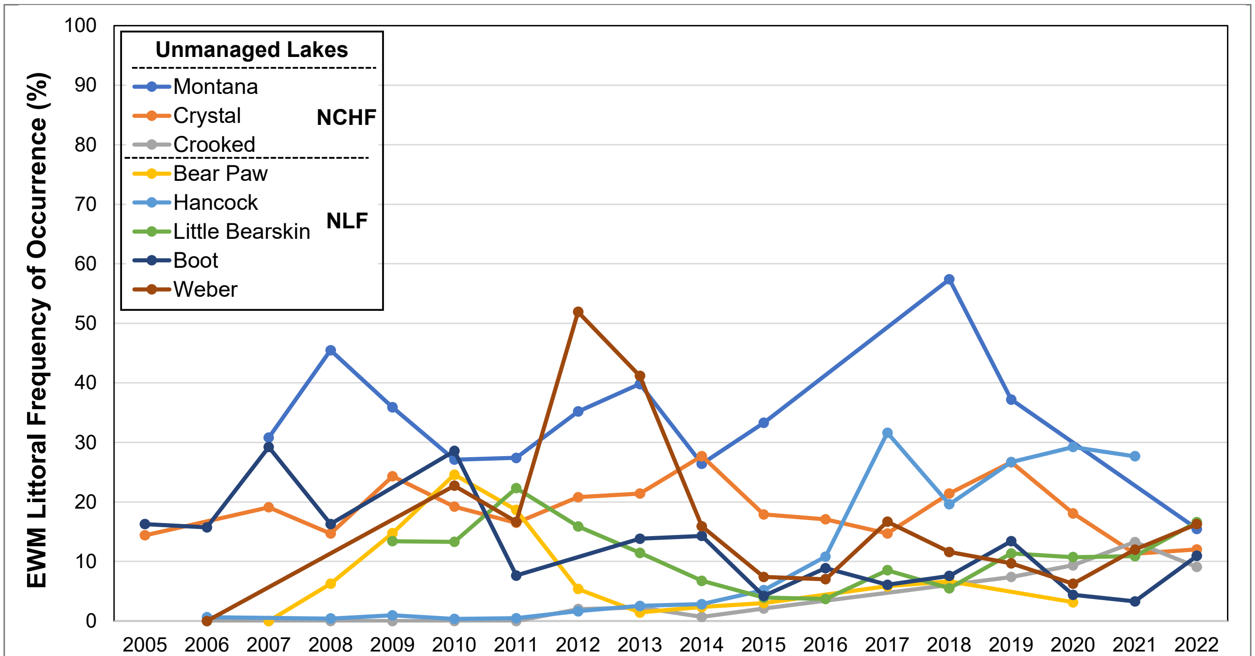


Figure 3.4-8. Littoral frequency of occurrence of EWM in the NLF and NCHF Ecoregions without management. Data provided by and used with permission from WDNR.

EWM population of Pigeon Lake

Using data from the point-intercept surveys that have been completed over the years, the littoral frequency of occurrence of EWM can be compared (Figure 3.4-8). The frequency of occurrence of EWM saw a statistically valid decrease in occurrence from 36.8% in 2014 compared to 10.1%

in 2022. The point-intercept survey found that EWM is found throughout the entire littoral area of Pigeon Lake up to 6 feet.

While the point-intercept survey is a valuable tool to understand the overall plant population of a lake, it does not offer a full account (census) of where a particular species exists in the lake to understand where recreation and navigation impairment exists and how to direct management activities. Within this project, an AIS mapping survey allowed this level of data to be obtained.

As a part of this project, EWM was mapped only during the Late-Season EWM Mapping Survey, completed in early-October. While EWM can be found throughout the littoral zone of Pigeon Lake, approximately 44 acres of contiguous EWM colonies were mapped in the early-October 2022 survey (Map 11). Approximately 10.5 acres were comprised of *dominant* or *highly dominant* EWM colonies located in the littoral zone of the lake during the Late-Season EWM Mapping Survey.

Stakeholder Survey Responses to Eurasian Watermilfoil Management

As discussed in Section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the 2022 survey was 12%. Because the response rate was below 60%, it is important to reiterate the stakeholder survey results need to be understood in the context of only the stakeholders who responded to the survey, not to the overall population sampled.

Respondents were asked if they believed EWM was present in or immediately around Pigeon Lake (Question 24). Of the 208 respondents who answered this question, 40% percent of those respondents indicated they believe EWM is present in Pigeon Lake. In an effort to gauge respondent support on previous EWM management within Pigeon Lake, the 2022 survey asked what their level of support is for various past management activities on the lake (Figure 3.4-9).

Queston 25 (2022): Before the present year, many techniques have been used to manage Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP) on Pigeon Lake. What is your level of support for the past use of previous management activities to manage AIS in previous years?

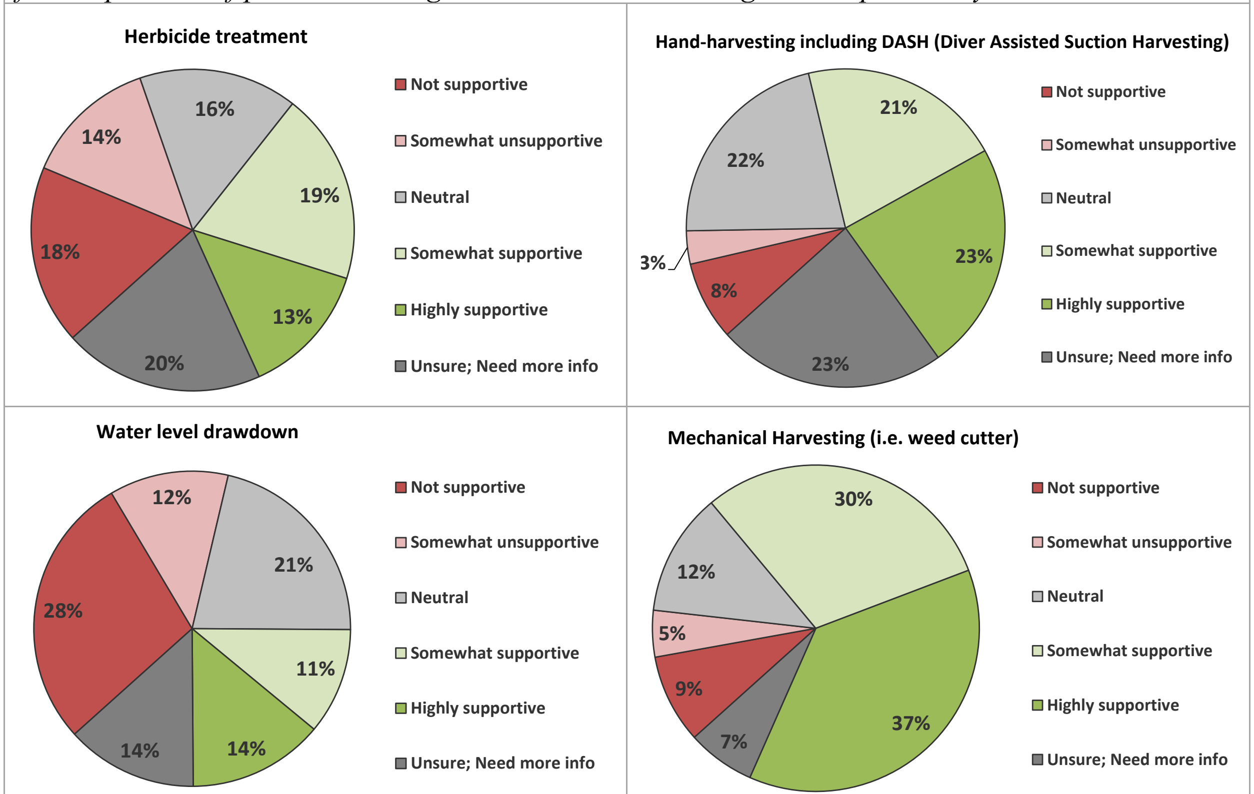


Figure 3.4-9. Select survey responses from the PLPRD Stakeholder Survey. Additional questions and response charts are found in Appendix B.

In 2022, respondents were asked about future management technique uses for managing EWM and/or CLP. Figure 3.4-10 highlights the level of support stakeholders have for each management technique offered. The respondents who selected *not supportive* or *somewhat unsupportive* indicated their reasons for opposing herbicide were *potential impacts to human health, potential impacts to native aquatic plant species, potential impacts to native (non-plant) species (fish, insects, etc.),* and *future impacts are unknown.*

Queston 26 (2022): The Pigeon Lake Protection & Rehabilitation District will begin assessing future techniques for managing the EWM and CLP population. What is your level of support for the future use of the following EWM/CLP management techniques in Pigeon Lake?

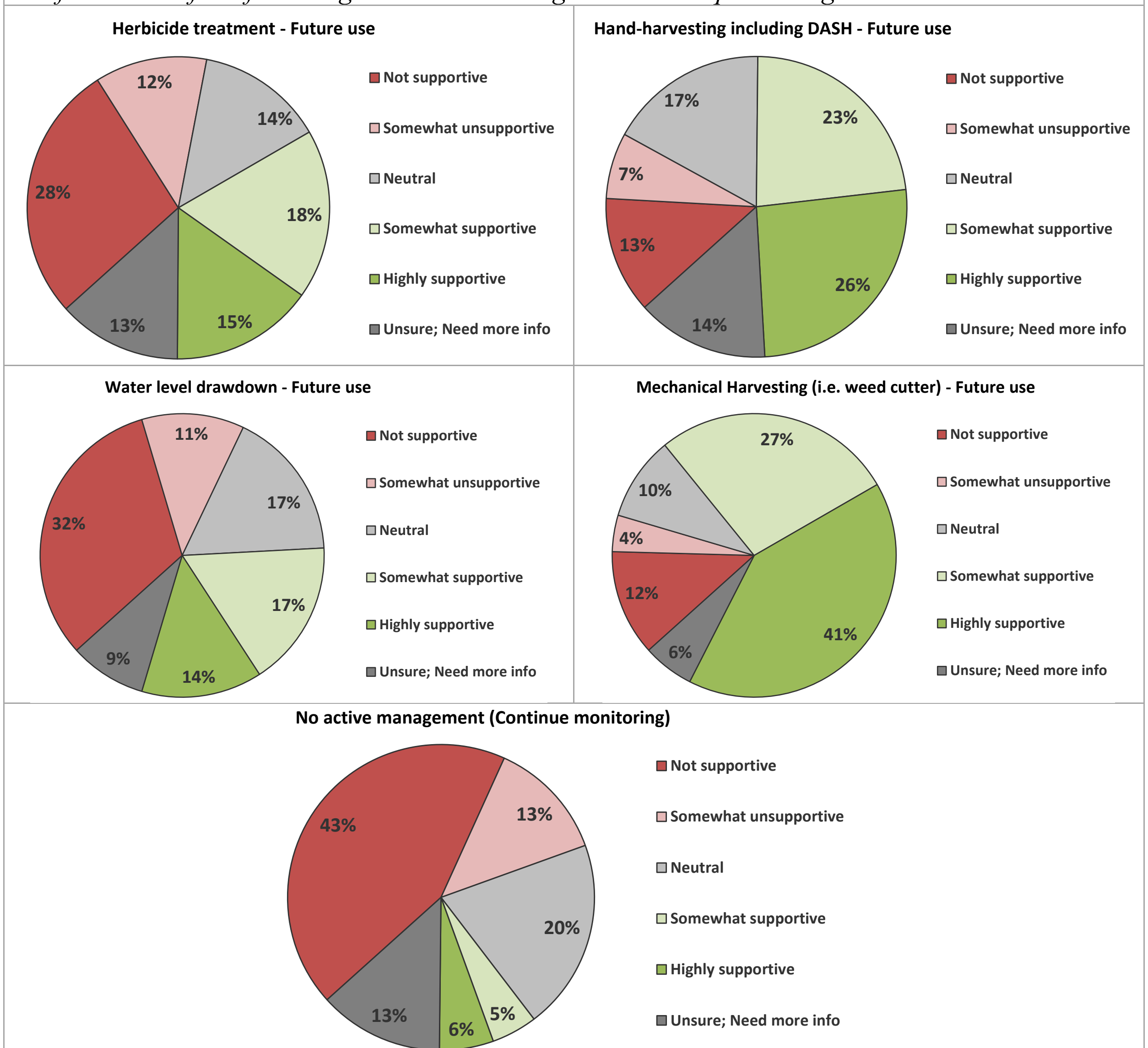


Figure 3.4-10. Select survey responses from the PLPRD Stakeholder Survey. Additional questions and response charts are found in Appendix B.

Curly-leaf pondweed (Potamogeton crispus)

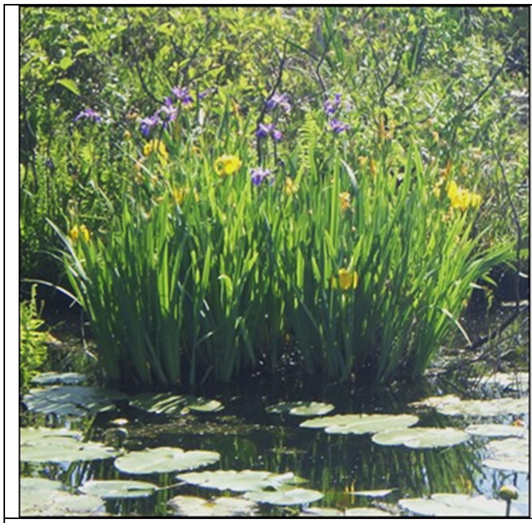

Photograph 3.4-7. Curly-leaf pondweed (Potamogeton crispus; CLP) growing amongst native floating-leaf plants (Left). Photo credit Onterra

Curly-leaf pondweed (CLP; Photograph 3.4-7) was first documented in Pigeon Lake in 2012. Curly-leaf pondweed's primary method of propagation is through the production of numerous asexual reproductive structures called turions. Once mature, these turions break free from the parent plant and may float for some time before settling and overwintering on the lake bottom. Once favorable growing conditions return (i.e., spring), new plants emerge and grow from these turions. Many of the turions produced by CLP begin to sprout in the fall and overwinter as small plants under the ice. Immediately following ice-out, these plants grow rapidly giving them a competitive advantage over native vegetation. Curly-leaf pondweed typically reaches its peak biomass by May to early-June, and following the production of turions, most of the CLP will naturally senesce (die back) by mid-July.

If the CLP population is large enough, the natural senescence and the resulting decaying of plant material can release sufficient nutrients into the water to cause mid-summer algal blooms. In some lakes, CLP can reach growth levels which interfere with navigation and recreational activities. However, in other lakes, CLP appears to integrate itself into the plant community and does not grow to levels which inhibit recreation or have apparent negative impacts to the lake's ecology. Because CLP naturally senesces in early summer, surveys are completed early in the growing season in an effort to capture the full extent of the population.

An Early-Season AIS Survey on Pigeon Lake was completed on June 8, 2022 to capture the full extent of the lake's CLP population. The 2022 survey recorded the CLP population in Pigeon Lake was primarily located within the western channel of the lake with localized dominant colonies (Map 12). The CLP population was comprised of approximately 1.4 acres of *dominant* or greater density. Isolated locations of *single or few plants* were also found in other areas of the lake.

Pale-yellow Iris (Iris Pseudacorus)



Photograph 3.4-8. Clump of the non-native pale-yellow iris mixed with the native blue-flag iris. Photo credit Onterra.

Pale yellow iris (*Iris pseudacorus*; PYI) is a large, showy iris with bright yellow flowers (Photograph 3.4-8). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species.

Pale-yellow iris is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (*Iris versicolor*) (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated. Pale-yellow Iris was documented on Pigeon Lake in 2022 by Onterra Ecologists. 2022 locations were mainly on the eastern portion of the lake with some occurrences found in other areas of the lake as well (Map 10). Overall, 36 single pale-yellow iris plants were found along the shores of Pigeon Lake.

Purple Loosestrife (Lythrum salicaria)

Photograph 3.4-9. Purple Loosestrife plant in flower. Photo credit Onterra

Purple loosestrife (Photograph 3.4-9) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. A small number of individual purple loosestrife plants were documented on Pigeon Lake in 2022 by Onterra Ecologists (Map 10).

Reed Canary Grass (Phalaris arundinaceae)

Reed canary grass is another large, coarse perennial grass that can reach three to six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. A small number of reed canary grass plants were documented during the community mapping survey. Onterra ecologists also noted many more plants were visible on shore (out of the water) and were not recorded.

Flowering Rush (Butomus umbellatus)

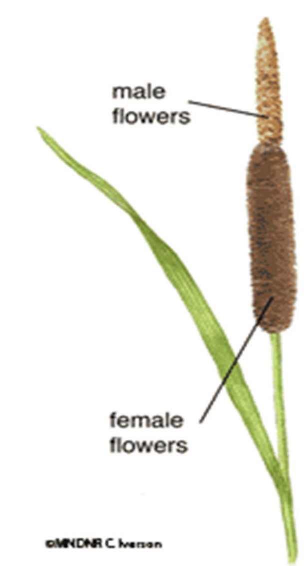
Flowering rush an invasive wetland/aquatic plant that is native to Europe (Photograph 3.4-10). This perennial plant flowers in late summer to early fall. It ranges in size from 1-5 feet, generally growing it shallow water, though it can be found growing submersed up 10 feet deep. Like other non-native invasive plants, flowering rush displaces native aquatic and wetland plants and can alter ecosystem functions.

Photograph 3.4-10. Flowering rush in a Wisconsin lake. Photo credit – Onterra.

Flowering rush populations have inhabited Pigeon Lake since 2011. The emergent life form of flowering rush was documented at two locations within the northwest channel of Pigeon Lake where the Pigeon River enters. The submergent life form was found at 12 locations on the whole-lake point intercept survey, again within the northwest channel. A littoral frequency of occurrence for flowering rush was 3.6% which was the fourth most common plant within Pigeon Lake in 2022. Herbicides have been used to control larger populations of flowering rush on Wisconsin lakes, while smaller populations are recommended for manual hand-removal for control.

Narrow-leaf Cattail (Typha angustifolia)

Two species of cattail can be found in Wisconsin, broad-leaved cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*). Broad-leaved cattail is considered to be indigenous to North America while narrow-leaved cattail is believed to have been introduced from Europe and is considered to be ecologically invasive. While there are certain characteristics that differentiate these two species, hybridization between them (*T. x glauca*) is believed to be common, making positive identification without DNA analysis difficult (Photograph 3.4-11). Both species have been identified in Pigeon Lake in similar areas so hybridization between these species may occur in the future making identification more difficult. Overall, only four occurrences of narrow-leaved cattail were identified along the shores of Pigeon Lake (Map 10).



Photograph 3.4-11. Cattail identification aid. Broad-leaved cattail shown, as there is no gap between male and female flowers. Narrow-leaf cattail would have a gap between male and female flowers. Photo credit Minnesota DNR.

3.5 Aquatic Invasive Species in Pigeon Lake

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

Table 3.5-1. AIS present within Pigeon Lake

Type	Common name	Scientific name	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Aquatic Plants
	Reed canary grass	*Phalaris arundinacea*	Section 3.4 – Aquatic Plants
	Curly leaf pondweed	*Potamogeton crispus*	Section 3.4 – Aquatic Plants
	Flowering rush	*Butomus umbellatus*	Section 3.4 – Aquatic Plants
	Pale yellow iris	*Iris pseudacorus*	Section 3.4 – Aquatic Plants
Invertebrates	Rusty crayfish	*Orconectes rusticus*	Section 3.5 – Aquatic Animals
	Banded mystery snail	*Viviparus georgianus*	Section 3.5 – Aquatic Animals
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 – Aquatic Animals
Fish	Common carp	*Cyprinus carpio*	Section 3.6 – Fisheries Data Integration

Figure 3.5-2 displays the aquatic invasive species that Pigeon Lake stakeholder survey respondents believe are in Pigeon Lake. Only the species known to be present in Pigeon Lake are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

Question #20. Which aquatic invasive species do you believe are in Pigeon Lake?

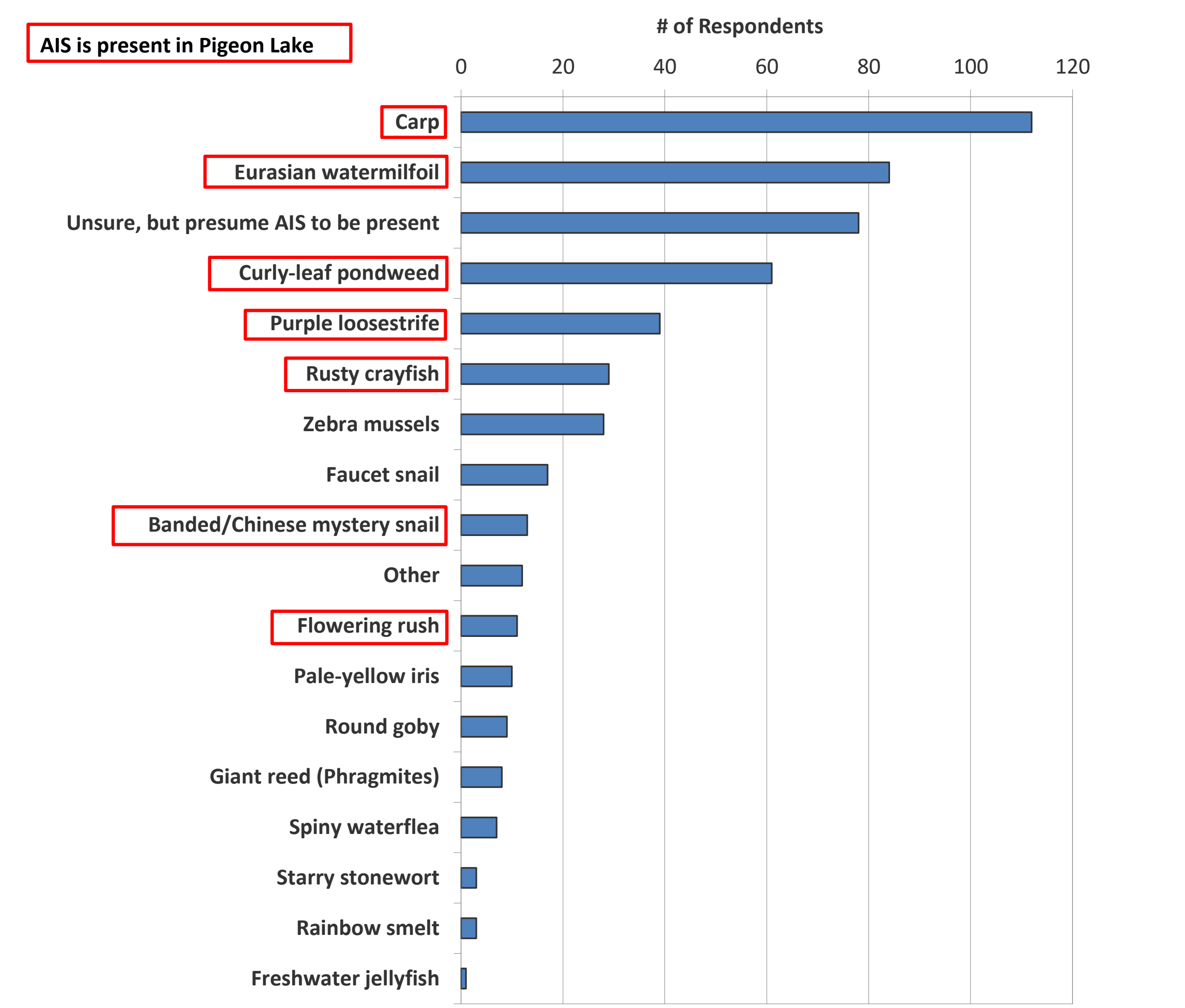


Figure 3.5-2. Select survey responses from the PLPRD Stakeholder Survey. Additional questions and response charts are found in Appendix B.

Aquatic Animals

Rusty Crayfish

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell. They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*) (Figure 3.5-1). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon, Olden, P.T.J, Dillion Jr., & Vander Zander, 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson, Olden, Solomon, & Vander Zanden, 2009).

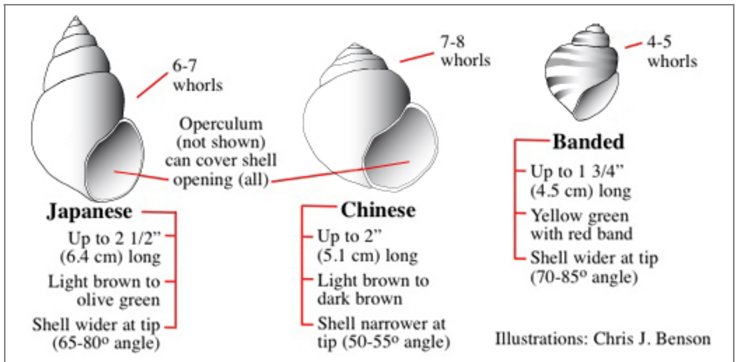


Figure 3.5-1. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (http://www.seagrant.umn.edu/ais/mysterysnail).

Aquatic Viruses and Parasites

Viral Hemorrhagic Septicemia

Viral hemorrhagic septicemia (VHS) is a deadly fish virus that can affect as many as 25 different fish species. First discovered in Lake Winnebago in 2006, it is unclear how this virus made its way to the Great Lakes. Humans are not susceptible to the virus but should be on the lookout for fish with the following symptoms: bleeding, bulging eyes, unusual behavior, anemia, bloating abdomens, and rapid onset of death. Infected fish spread the virus through their urine and reproductive fluids. Similar to zebra mussels, to help prevent the spread of VHS, boats should be bleached, power washed, and dried after leaving infected waterways and before entering any other waterways. While not confirmed in Pigeon Lake, the Pigeon River has confirmed presence of VHS.

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the WDNR biologists overseeing Pigeon Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) and personal communications with DNR Fisheries Biologist Aaron O'Connell (WDNR 2023).

Pigeon Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Pigeon Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

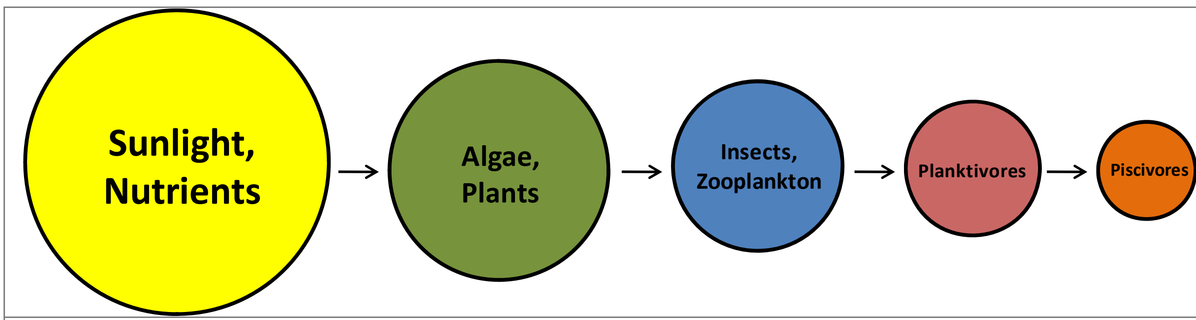


Figure 3.6-1. Aquatic food chain. Adapted from (Carpenter, Kitchell, & Hodgson, 1985)

As discussed in the Water Quality section, Pigeon Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Pigeon Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past

WDNR surveys of Pigeon Lake include bowfin (*Amia calva*) and white sucker (*Catostomus commersonii*).

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

Common Name (*Scientific Name*)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead (Ameiurus melas)	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie (Pomoxis nigromaculat	May - June	Near Chara or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill (Lepomis macrochirus)	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Brown Bullhead (Ameiurus nebulosus	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Green Sunfish (Lepomis cyanellus)	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass (Micropterus salmo	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike (Esox lucius)	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)	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)	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Warmouth (Lepomis gulosus)	Mid May - Early July	Shallow water 0.6 - 0.8 m, with rubble slightly covered with silt	Crayfish, small fish, odonata, and other invertebrates
Yellow Bullhead (Ameiurus natalis)	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish
Yellow Perch (Perca flavescens)	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

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

The other commonly used sampling method is electrofishing (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

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


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

Fish Stocking

Photograph 3.6-2. Muskellunge fingerling.

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Pigeon Lake has been stocked with multiple species of fish in recent years. For game fish, northern pike were stocked on four occasions between 2016-2021 (Table 3.6-2). Largemouth bass stocking occurred on three occasions between 2019-2021 (Table 3.6-3). Two panfish stocking events have also occurred. Bluegill and black crappie were stocked in 2019 and yellow perch were stocked in 2020.

Table 3.6-2. Stocking data available for Northern Pike in Pigeon Lake (2016-2021).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
2021	NORTHERN PIKE	LAKE MICHIGAN	LARGE FINGERLING	3,731	8.1
2020	NORTHERN PIKE	MUD LAKE - MADISON CHAIN OF LAKES	LARGE FINGERLING	4,326	9.6
2019	NORTHERN PIKE	MUD LAKE - MADISON CHAIN OF LAKES	LARGE FINGERLING	1,730	7.7
2016	NORTHERN PIKE	MUD LAKE - MADISON CHAIN OF LAKES	LARGE FINGERLING	2,500	7.7

Table 3.6-3. Stocking data available for Largemouth Bass in Pigeon Lake (2019-2021).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
2021	LARGEMOUTH BASS	LARGE FINGERLING	6,510	2.8
2020	LARGEMOUTH BASS	LARGE FINGERLING	4,314	2.3
2019	LARGEMOUTH BASS	LARGE FINGERLING	4,315	2.7

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water and ice) was the most important reason for owning property on or near Pigeon Lake (Question #2). Over 59% of respondents have fished Pigeon Lake in the last three years (Question 3). Figure 3.6-2 displays the fish that Pigeon Lake stakeholders enjoy catching the most, with bluegill/sunfish and yellow perch being the most popular. The vast majority of respondents (94%) believe the current quality of fishing is somewhere between poor and fair (Figure 3.6-3). Approximately 67% of respondents who fish Pigeon Lake believe the quality of fishing has gotten worse to some degree since they first started to fish the lake (Figure 3.6-3).

Question 4 (2022): What species of fish do you like to catch on Pigeon Lake?

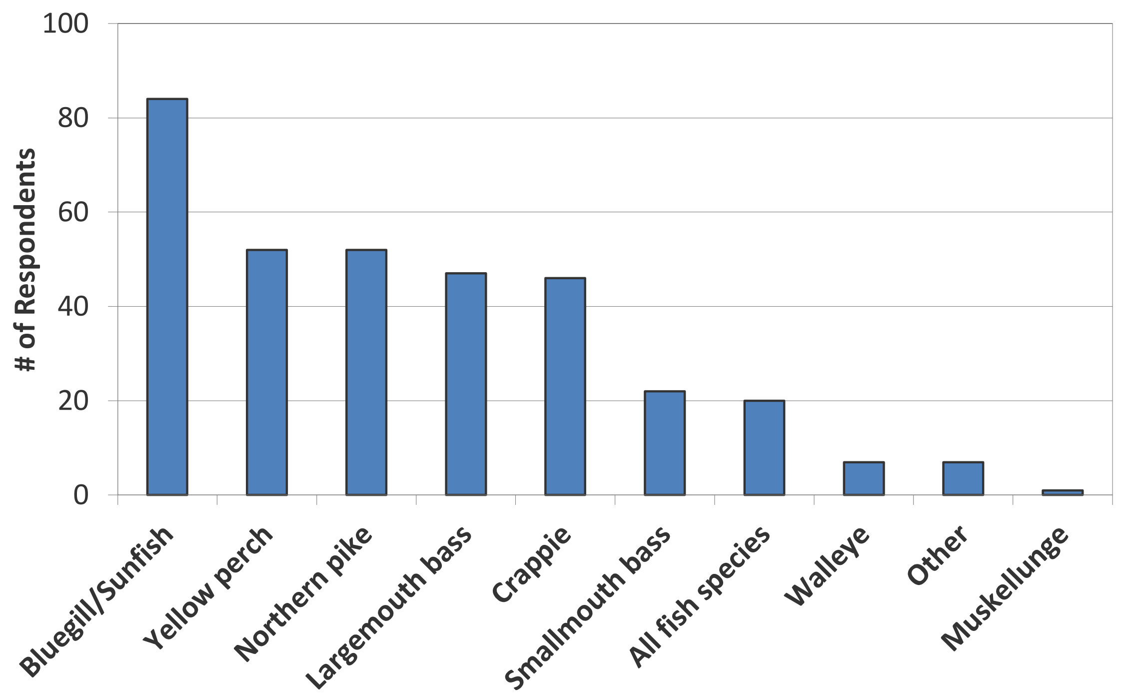


Figure 3.6-2. Select survey responses from the PLPRD Stakeholder Survey. Additional questions and response charts are found in Appendix B.

Question 5 (2022): How would you describe the current quality of fishing on Pigeon Lake?	*Question 6 (2022): How has the quality of fishing changed on Pigeon Lake since you started fishing the lake?*

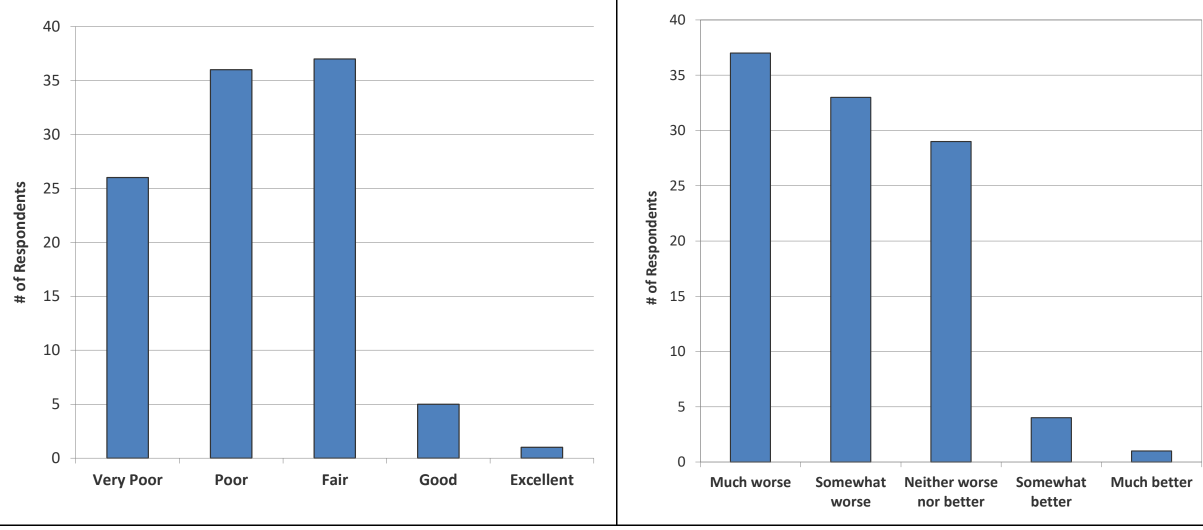


Figure 3.6-3. Select survey responses from the PLPRD Stakeholder Survey. Additional questions and response charts are found in Appendix B.

Gamefish

The gamefish present on Pigeon Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch northern pike and largemouth bass on Pigeon Lake (Figure 3.6-2). Brief summaries of gamefish with fishable populations in Pigeon Lake are provided based information from WDNR fisheries biologist Aaron O'Connell.

Largemouth Bass are considered common in Pigeon Lake and one of the lake's main predators. Similarly, **northern pike** are also common and a top predator within the system. Both of these fish species are commonly pursued by Pigeon Lake stakeholders. Since 2016, a total of 12,287 northern pike have been stocked in the lake. Since 2019, 15,139 largemouth bass have been stocked. Both of these species play an important ecological role in controlling panfish populations.

Panfish

The primary panfish in Pigeon Lake are **bluegill, black crappie, and pumpkinseed** (sunfish). Yellow perch have also been documented in the system, but at low densities. In 2019, 10,544 fingerling bluegill were stocked. Almost 14,000 black crappies were stocked in that year as well. In 2020, the DNR stocked 4,314 perch into Pigeon Lake.

Common Carp

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

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

Common carp numbers have been a common complaint from Pigeon Lake stakeholders after witnessing a population explosion following the 2017-18 water drawdown. There have been several carp removals in attempting to reduce populations to manageable levels, including a fishing tournament directly aimed at catching and harvesting carp and other rough fish species. Current DNR management goals aim to keep trying to reduce carp levels and bring back the native fishery. In the summer of 2022, the carp in Pigeon Lake experienced a large die-off contributed to Koi Herpesvirus Disease (KHVD). KHVD does not harm gamefish or forage species and should not pose any risks to humans. Future surveys focused on carp populations will be needed to assess the affect this disease has had on the carp population.

Pigeon Lake Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2022, 96% of the substrate sampled in the littoral zone of Pigeon Lake were soft, organic sediments. Only 3% were rocky substrates and the last 1% was sand.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass, 2009). A 2022 survey documented 167 pieces of coarse woody along the shores of Pigeon Lake, resulting in a ratio of approximately 24 pieces per mile of shoreline. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how Pigeon Lake's coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.6-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.


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

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

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

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

Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

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

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested.

If interested, the Pigeon Lake District, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Pigeon Lake.

Fishing Regulations

For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information. Table 3.6-4 displays specific fishing regulations for Pigeon Lake.

Table 3.6-4. WDNR fishing regulations for Pigeon Lake (As of March 2023).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	May 7, 2022 to March 5, 2023
Smallmouth bass	5	14"	May 7, 2022 to March 5, 2023
Largemouth bass	5	14"	May 7, 2022 to March 5, 2023
Muskellunge and hybrids	1	40"	May 28, 2022 to December 31, 2022
Northern pike	5	None	May 7, 2022 to March 5, 2023
Walleye, sauger, and hybrids	3	18"	May 7, 2022 to March 5, 2023
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10	None	Open All Year

Mercury Contamination and Fish Consumption Advisories

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

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-4. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

Figure 3.6-4. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

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

Fishery Management & Conclusions

Pigeon Lake is a warmwater fishery that, like many other millponds in Waupaca County, is managed as largemouth bass and panfish fishery. Currently, the main management goal in Pigeon Lake is to control and reduce common carp populations.

4.0 SUMMARY AND CONCLUSIONS

In spring 2022, the Pigeon Lake Protection and Rehabilitation District (PLPRD) was awarded a Wisconsin DNR Surface Water Grant to develop a comprehensive management plan for Pigeon Lake. The planning project included two primary components; 1) the collection of information about the lake itself, as well as the people who utilize and manage the waterbody, and 2) the development of a realistic and implementable management plan for the waterbody. During 2022 and 2023, several studies were completed on Pigeon Lake, including four aquatic plant surveys, seven water quality collections, and the development of a surface watershed model. Historical water quality and fishery information was also compiled. In addition, a user survey was initiated to collect information from Pigeon Lake stakeholders regarding their use of the lake, how they believe it has changed over the years, and how they would like to see it managed.

During the spring and summer of 2023, a planning committee comprised of district commissioners, district members, and citizens learned about the biological, physical, and chemical aspects of Pigeon Lake, the tremendous impact the lake's large watershed has on the waterbody, and realistic options available to improve recreational opportunities on and around the lake. The development of the plan began by creating a list of challenges facing the lake and the lake district. Those challenges were converted to goals and a list of actions was created that would allow the district to achieve those goals.

At about 174 acres, Pigeon Lake is not considered a large waterbody; however, it is highly complicated. First and foremost, it is a manmade feature, so it does not function like a natural lake, and that is an important consideration because it cannot be managed like a natural lake either. When a natural lake is created, Mother Nature's goal is to fill it in. For the most part, a lake is not filled in by dirt arriving from the lake's drainage basin (watershed). It is actually the build-up of partially decomposed organic material the settles to the lake's bottom. Most of the organic material is developed within the lake when aquatic plants, both simple plants, like algae, and more complicated vascular plants utilize dissolved nutrients that originate in the lake's watershed to grow. In other words, dissolved ingredients from the watershed are made into biological solids (plants and animals) that eventually die, are partially decomposed and then settle to the bottom of the lake. This process of filling in a natural lake takes thousands of years, but in a manmade lake, like a flowage or millpond, it may take only a lifetime. This is the case because in a flowage, like Pigeon Lake, the watershed is much larger than would be able to occur naturally, and as a result, the inflow of those nutrients is unnaturally high. The higher levels of nutrients lead to higher plant production in the waterbody, which fills in the basin faster. Also, unlike a natural lake, the greater rate of inflow often allows for sediment from the watershed to be added to the flowage basin, so that too increases the rate at which the basin is filled. It is important to note that when a flowage basin "fills in" it doesn't completely fill in, the basin actually returns to more river-like conditions.

Pigeon Lake's surface watershed spans over 68,200 acres (106.6 sq.mi.), yielding a watershed to lake area ratio of 378:1. This means that each surface acre of the lake has 378 acres of land draining to it. This is a tremendously large watershed draining to a small waterbody. About 18% of Pigeon Lake's watershed area drains through the Marion Millpond. Marion Millpond acts as a sedimentation basin intercepting phosphorus from its own watershed before sending it downstream to Pigeon Lake. In fact, of the 5,853 pounds of phosphorus that loads to Marion Millpond, only 27% continues downstream to Pigeon Lake.

The watershed acreage that drains to Pigeon Lake without going through Marion Millpond is Pigeon Lake's direct watershed. Of the 55,800 acres that drain directly to Pigeon Lake, 44% is utilized for row crop production. This exacerbates the impact of the large watershed and accounts for nearly 80% of the phosphorus that enters the lake on an annual basis. The total annual phosphorus load is estimated to be about 25,600 pounds. Wetlands, forests, and grasslands make up about 57% of the lake's direct watershed but account for 13% of the lake's annual load.

Phosphorus feeds the highly productive aquatic plant growth in Pigeon Lake; including algae and vascular plants. There is not a lot of historical water quality available for Pigeon Lake; however, the available data indicates that the lake's phosphorus levels are much higher than those found in other lakes of the same type in Wisconsin and all types of lakes within the region.

Unfortunately, correcting the high phosphorus levels is not as simple as just replacing row crop acreage with forests or grasslands. The sheer size of the Pigeon Lake watershed plays a very important role in the amount of phosphorus that enters the lake. In fact, if 50% of the row crop acreage could be converted to forested areas, the lake would still receive enough phosphorus to remain highly productive. If all of the row crops in the watershed were converted to forests, the lake would still be considered moderately productive. This means that with even unrealistic work being completed in the watershed, the lake would have many of the same issues with occasional algae blooms and typically high vascular plant biomass.

The large watershed does deliver a very large volume of water to the lake, and as a result, the lake's flushing rate is typically high. During years with normal rainfall, Pigeon Lake's water is replaced about once every three and a half days. That high flushing rate reduces the opportunity for the build-up of free-floating algae, which reduces the frequency of nuisance algae blooms. The greatest chance for nuisance algae blooms is during dry summer months that reduce the lake's flushing rate and increases the water residency to greater than two weeks.

The aquatic plant studies completed during the summer of 2022 documented that the plant community of Pigeon Lake is made up of 26 native aquatic plant species and seven non-native species. The native species coontail is the most abundant plant in the lake along with the non-native Eurasian watermilfoil. These two species hamper recreation on the lake. Lake-wide control of Eurasian watermilfoil is impossible regardless of control technique, so continued use of the district's mechanical harvester is the best option to reduce the exotic's impact on the lake recreation.

Aquatic plant data collected during 2022 showed a large reduction in vascular plant biomass compared to data collected in 2014 prior to the 2019 drawdown of Pigeon Lake. It is likely that the drawdown reduced the vascular plant biomass in the short-term following the drawdown, but the lake's abundant carp population has prevented the plant community from recovering. There is also some evidence that portions of the lake, primarily the main channel, were deepened as a result of the drawdown.

The management plan developed for Pigeon Lake includes five goals and thirteen management actions focusing upon increasing recreational opportunities on and around the lake, reducing nutrient and sediment pollution from the watershed, and developing a long-term water quality and aquatic plant database. The plan was approved by the PLPRD Board of Commissioners in November 2023 and will begin being implemented in 2024.

5.0 IMPLEMENTATION PLAN

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

Management Goal 1: Assure Navigational Access on Pigeon Lake

Management Action:	Utilize district-owned and operated mechanical harvester to provide access to open water for riparians and transient boaters.
Timeframe:	Continuation of current efforts.
Facilitator:	District Board of Commissioners
Description:	The Pigeon Lake Protection & Rehabilitation District understands the importance of native aquatic vegetation within Pigeon Lake; however, nuisance aquatic plant conditions exist in certain parts of the lake, sometimes caused by Eurasian watermilfoil, and heavy native vegetation including coontail, southern naiad, and common waterweed. The Pigeon Lake Protection & Rehabilitation District supports the reasonable and environmentally sound actions to facilitate navigability on Pigeon Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those that meet WDNR regulatory and permitting requirements and do not impact any more shoreland or lake surface area than absolutely necessary. The Pigeon Lake Protection & Rehabilitation District owns a conventional cutting-head style mechanical harvester and it is maintained and operated by the district with paid operators. Harvesting operations begin after June 1 and continue into September on an as-needed basis. With an approved plan, the Pigeon Lake Protection & Rehabilitation District is seeking to obtain a 5-year permit moving forward until an updated aquatic plant management plan is requested. A five-year permit would span from 2024-2028. During the final year of the five-year permit, the district would plan to collect data necessary to update the mechanical harvesting plan prior to 2029. This would include a whole-lake point-intercept survey in 2028 and a strategic meeting with the district board to review the data and determine if any changes should be made to the mechanical harvesting plan prior to

	applying for another multi-year permit. The bulleted list below outlines a condensed version of the WDNR's conditions on similar harvesting permits in the WDNR's Northeast Region: • Paper or electronic copy of approved permit must be with the individual conducting the harvesting • Harvesting must comply with Wisconsin regulations and state statutes • An annual report must be submitted within 30 days of the last harvest that includes details of harvested plant material weight, volume, and species, total acres harvested, and non-target impacts and number of fish encountered. Map 13 displays the district's Updated Mechanical Harvesting Plan. The harvesting plan includes 75-foot-wide access lanes within the main body of the lake and extending to the primary boat landings. Riparian and near-shore access at Pickerel Point Memorial Park and Picnic Point is provided by 50-foot-wide lanes near the most densely developed areas and are maintained as close to pier heads as possible. Two 20-foot-wide lanes provide access for two properties along the lake's north shore in a sparsely developed area. A larger area is harvested at the Wayside Park access for fishing and because the harvester is stored there. All harvesting areas are placed in waters of at least three feet of depth. In total, 35.5 acres are included within the harvesting plan, the locations of which are similar compared to previously permitted harvesting activities that have occurred in past years. The Pigeon Lake Protection & Rehabilitation District disposes of harvested aquatic plants at several farms in the Clintonville area. The district keeps a detailed log of harvesting activities that ensures the efforts are organized and efficient. The district will continue to generate an annual report that details the harvesting activities to satisfy the permit reporting requirements.
Action Steps:	See description above.

Management Action:	Control dense areas of AIS that are at nuisance densities.
Timeframe:	As needed.
Facilitator:	District Board of Commissioners
Description:	Two potentially troublesome submergent AIS, Eurasian watermilfoil (EWM), and curly-leaf pondweed (CLP), were mapped in varying densities during 2022 (Maps 11 & 12). In the lakes that these exotics are well-established, like Pigeon Lake, both of these species fluctuate in density over several years. Meaning that dense areas may occur in specific areas of the lake over 2-4 years, then decrease in density for several more years in those areas. In Pigeon Lake, these dense areas may hinder recreation, including

	navigation and angling. CLP typically causes a nuisance early in the year between late-May and early-July, while EWM causes an issue mid-July through September. During the 2022 surveys, CLP was not mapped at nuisance densities; however, EWM was highly dominant near the Wayside Park public access. Two control methods will be considered in reducing the negative impacts of these species on Pigeon Lake, early-season mechanical harvesting and herbicide applications. Both of these methods require WDNR permits. It is important to note that the objective of these two alternate control options is not to reduce the overall population of these species in Pigeon Lake. In other words, these are not AIS population control options, they are options to control nuisance areas of AIS. The CLP and EWM populations in Pigeon Lake are well-established and beyond control on a system-wide basis; therefore, the district's objective is to reduce impacts of these species on navigation and other recreational activities in limited areas. Early-season mechanical harvesting would be completed prior to the typical June 1 start date for harvesting activities. The early-season mechanical harvesting would only occur in the navigation lanes included in Map 13 and would only be implemented in highly dense areas of CLP that occur in those lanes. Early-season harvesting would occur no earlier than May 1. Dense areas of EWM would be considered for herbicide control. ProcellaCOR or alternative herbicides used in current best management practices would be utilized. Herbicide use would be limited to low-flow areas, such as Wayside Park. In these low-flow and enclosed areas, treatment areas would still need to be a half-acre or larger to produce even seasonal impacts that would relieve navigation issues. Dense areas in high-flow areas, such as the main basin of the lake containing the natural channel, are not typically applicable to herbicide control and would continue to be managed with mechanical harvesting of predetermined navigation lanes. Very large, dense areas of 10-acres or more may be considered for herbicide control in the main basin if the application can be completed in tandem with water level control at the dam during the treatment. These potential large control areas in the main basin would need to be implemented early in the growing season, likely late-May, or early-June; therefore, a late-season EWM mapping survey would need to be completed the year previous to the treatment to document EWM densities and provide the information necessary to plan an effective treatment.
Action Steps:	See description above.

Management Action:	Determine feasibility of small-scale dredging in specific areas of Pigeon Lake to decrease watercraft navigation issues.
Timeframe:	2025
Facilitator:	District Board of Commissioners
Description:	Several areas of Pigeon Lake have high accumulations of organic sediments brought on by the decomposition of dense native and non-native plant populations. This is a common occurrence in impoundments with large watersheds. Some of these areas, for example the small basin off of the Wayside Park public landing, and the channel leading to it, may have long-term benefits to navigation and access to the main basin if sediments were removed to increase water depth. Mechanical and hydraulic dredging are expensive methods to improve navigation, but if planned correctly, that expense may be spread over years or even decades. The use of dredging on Pigeon Lake has been investigated in the past; therefore, some background information exists. The feasibility of dredging on Pigeon Lake would be determined through an engineering study that would include preliminary dredging designs and estimates using current rates for mechanical and/or hydraulic dredging and disposal options. Disposal options would include geotextile tubes, direct injection, and retention basins. Once completed, the district would use those figures to determine if the potential project would provide sufficient benefit to lake users to justify the cost. An excellent source of information on dredging in Wisconsin Lakes can be found at: https://dnr.wisconsin.gov/topic/Waterways/dredging.
Action Steps:	1. Determine areas where navigation is typically desired by the public but is limited by water depth, not just nuisance levels of aquatic vegetation. Harvester operators and frequent users of the lake would be good sources of information for this determination. 2. If navigation is limited by water depth in high-use areas, the district would request proposals from three or more engineering firms detailing their project designs and costs of completing a dredging feasibility study. 3. If the cost of a dredging feasibility study is acceptable to the district, the study would be completed with the final deliverable being a preliminary dredging design and cost estimate with sufficient detail to not only determine the fiscal feasibility of completing the project, but also to complete WDNR Form 3500-178, Dredging Pre-Application Information Form (https://apps.dnr.wi.gov/doclink/forms/3500-178.pdf). 4. Following the submittal of Form 3500-178, the district would schedule a pre-application meeting with Scott Koehnke, WDNR Water Reg/Zoning Specialist. Mr. Koehnke would then guide the district through subsequent steps.

Management Goal 2: Enhance Pigeon Lake Protection & Habilitation District's Capacity to Interact with and Inform Its Members

Management Action:	Hire a Special Projects Manager to establish and organize a physical office space to conduct Pigeon Lake PRD business.
Timeframe:	2024.
Facilitator:	District Board of Commissioners
Description:	The Special Projects Manager of the Pigeon Lake Protection and Rehabilitation District will recruit and coordinate volunteers, including working with existing local agencies and interested individuals. The manager will develop an email list of volunteers and stakeholders, develop standing committees, and coordinate communications across various media. In addition to keeping regular office hours as posted to the public, he or she will organize files and historical documents for current efficiencies and for accurate reporting. They will help the board and other professionals to plan and implement educational events and grant-writing, in addition to other community engagements (Spring Planting Party, Ruff Fish Tourney, Cops 'n' Bobbers, Kayak Race, etc). The Special Projects Manager will be an ex-officio (non-voting) member of the board, but will be expected to attend board meetings. The ultimate purpose of this office is to expand the "workforce" available to protect and to rehabilitate Pigeon Lake, beyond the existing board, with secondary purpose to provide a stable and visible public presence for the lake district.
Action Steps:	See description above.

Management Action:	Develop consistent communication strategy to deliver information in a timely and efficient manner.
Timeframe:	Continuation and expansion of ongoing effort.
Facilitator:	District Board of Commissioners
Potential Grant:	Surface Water Education Grant
Description:	A primary function of the Pigeon Lake Protection & Rehabilitation District is to provide its members with information about the lake, its protection, and the business of the district. Quality, consistent communications between district members and district leadership assures transparency in district operations and increases trust in district administration. To assure that this will happen in an efficient manner and that the content of the communications is timely and useful, the district will develop a consistent communication strategy. That strategy will include the following: • Scheduled updates of the newly revamped district website. • Development of social media streams to deliver time-sensitive information quickly and to direct readers to broader information and updates on the district website.

	• Create and maintain district-wide email address database. • Continue bi-weekly newspaper article submissions. Potential topics for these media include: • District events, such as meetings and socializing opportunities • Specific topics brought forth in other management actions • Aquatic invasive species identification • Pale yellow iris identification and management • Basic lake ecology • Advantages and disadvantages of mechanical harvesting • Sedimentation • Boating safety • Shoreline habitat restoration and protection • Noise and light pollution • Non-riparian property owner access opportunities • Fishing regulations • Minimizing disturbance to spawning fish • Recreational use of the lake
Action Steps:	1. District Board of Commissioners develops communication strategy and schedule or assigns task to *Communications and Education Standing Committee*. 2. Develop annual budget. Start-up costs for certain aspects of communications strategy, like a postcard mailing to solicit member email addresses, would be applicable to Surface Water Education Grant funding. 3. Recruit volunteers and assign tasks. 4. Implement communications strategy and monitor effectiveness to determine how the strategy can be tuned.

Management Action:	Assure Pigeon Lake Protection & Rehabilitation District involvement in community events.
Timeframe:	Continuation of existing effort.
Facilitator:	District Board of Commissioners
Description:	Pigeon Lake is a focal point for many Clintonville activities and events. For decades, the district has sponsored and participated in community-wide events on and around the lake. This participation maintains a positive light on the district, provides opportunity for partnerships and education, and fosters trust among district members and commissioners. The district's participation in the events listed below will continue and the district will seek similar opportunities for involvement: • Spring Planting Party • Cops n Bobbers • Rough Fish Tournament • Kayak Race

	• Rubber Duck Race
Action Steps:	See description above.

<u>Management Action:</u>	Participate in annual Wisconsin Lakes & Rivers Convention.
Timeframe:	Annually
Facilitator:	District Board of Commissioners
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events within the state. The primary event is the Wisconsin Lakes & Rivers Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and districts. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/district. The Pigeon Lake Protection & Rehabilitation District will sponsor the attendance of 3-5 district members annually at the convention. Following the attendance of the convention, the members will report specifics to the board of commissioners regarding topics that may be applicable to the management of Pigeon Lake and operations of the district. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the district membership at the annual meeting. Information about the convention can be found at: https://wisconsinwaterweek.org/.
Action Steps:	See description above.

Management Goal 3: Maximize Pigeon Lake Fishery

Management Action:	Develop open line of communication with Wisconsin Department of Natural Resources fisheries staff.
Timeframe:	Begin 2024
Facilitator:	District Board of Commissioners
Description:	Open water fishing was by far the top reason why stakeholder survey respondents owned property on or near Pigeon Lake. Developing a consistent line of communication with the local WDNR fisheries biologist (currently Aaron O'Connel, aaronr.oconnell@wisconsin.gov), ensures that Pigeon Lake stakeholders will have access to the best and most current information regarding the lake's fishery and its management. To foster this relationship, a current commissioner(s), or district member(s) under the direction of the board of commissioners, will contact Mr. O'Connel via email to set up an introductory phone call or face-to-face meeting. By setting up the introductory meeting via email, Mr. O'Connel will have time to compile information and prepare some initial thoughts, which lead to a more productive meeting. During that meeting, the district representative should ask if the fisheries biologist has a preferred communication method and schedule. A brief summary of the other actions under this goal should also be provided by the district representative during this meeting to alert the biologist about potential support needs.
Action Steps:	See description above.

Management Action:	Enhance Pigeon Lake fishery through proper stocking and coarse woody habitat additions.
Timeframe:	Initiate 2024
Facilitator:	District Board of Commissioners
Description:	Pigeon Lake is a relatively productive system with excellent capacity and habitat diversity to produce a high-quality fishery. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Many anglers assume that a lake's fishery can be 'forced' to its potential through stocking efforts. This is not the case in any lake as habitat availability, existing fish populations, level and make up of forage fish populations, and of course angler pressure, are critical to reaching and maintaining fishery potential. A primary objective of this action is to initiate frequent and productive communications with WDNR fisheries personnel to; 1) provide information regarding Pigeon Lake's fishery potential to district members, 2) assure that the district is doing what it can to aid local fisheries staff in performing their duties, and 3) that the WDNR staff understands the goals and concerns of the district regarding Pigeon Lake's fishery.

<table>
<tr><td></td><td>Ultimately, this will lead to a productive and effective stocking program on Pigeon Lake.

Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. Or, which is the case regarding some of Pigeon Lake’s shoreline, prior to the lake being created, the area was a wetland that did not support large tree growth, so there is little natural CWH. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section (3.3) and Fisheries Data Integration Section (3.6) discuss the benefits of coarse woody habitat in detail.

The WDNR’s Healthy Lakes Initiative Grant allows partial cost coverage for coarse woody habitat improvements (referred to as “fish sticks”). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
The landowner would need to commit to leaving the area un-mowed
The landowner would need to implement a native planting (also cost share through this grant program available)
Coarse woody habitat improvement projects require a general permit from the WDNR
Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years</td></tr>
<tr><td>Action Steps:</td><td></td></tr>
<tr><td>1.</td><td>Recruit facilitator from Planning Committee or Board of Commissioners to direct this initiative.</td></tr>
<tr><td>2.</td><td>Facilitator contacts WDNR lakes coordinator and WDNR fisheries biologist to gather information on current stocking efforts, future stocking efforts and regarding initiating and conducting coarse woody habitat projects on Pigeon Lake.</td></tr>
</table>

	3.	The district will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites for future projects.
	4.	The district promotes a better understanding of the lake's fishery and its capacity via educational topics included in electronic and hardcopy communications with district members.

Management Action:	Work with WDNR fisheries staff to determine appropriate methods of carp control.
Timeframe:	Begin 2024
Facilitator:	District Board of Commissioners
Description:	The full impact of carp on Pigeon Lake's aquatic plant community is not fully understood, but it is likely that the 2017 drawdown reduced the aquatic plant population and now the carp are preventing it from recovering. The district will work with WDNR fisheries staff to discover the best methods to minimize the carp population in Pigeon Lake. While carp cannot be eradicated from the lake, the WDNR may be able to offer advice on enhancing carp removal beyond that of the annual carp hunt event. One method may be commercial netting. The WDNR staff would likely be able to advise the district on possible contractors and the most effective time of year for the removal efforts to be implemented.
Action Steps:	See description above.

Management Goal 4: Reduce Nutrient and Sediment Pollution Originating from Pigeon Lake Watershed

Management Action:	Support the creation and implementation of Nine-Key Elements Plan for Pigeon River.
Timeframe:	2024
Facilitator:	District Board of Commissioners in partnership with Waupaca County LWCD
Potential Grant:	Wisconsin Surface Water Planning Grant
Description:	Screening-level modeling of the Pigeon Lake surface watershed indicates that it is the source of the lake's high nutrient levels. Studies completed as a part of the Wolf River TMDL project confirm high nutrient as well as sediment loads occur within the regional watershed as well. Development of a 9 Key Element Watershed Plan for the Pigeon River watershed would

	document loading sources and determine measurable steps to reduce those loads. According to the WDNR, "Watershed plans consistent with EPA's nine key elements provide a framework for improving water quality in a holistic manner within a geographic watershed. The nine elements help assess the contributing causes and sources of nonpoint source pollution, involve key stakeholders, and prioritize restoration and protection strategies to address water quality problems." Completing a WDNR-approved 9 Key Element plan qualifies the watershed to receive specific funding, such as Targeted Runoff Management and WDNR Lake Protection Grants. The Waupaca County LWCD has completed approved 9 Key Element Plans for three watersheds in Waupaca County. The Pigeon Lake Protection & Rehabilitation District will partner with the county and financially support a project to create and implement a 9 Key Element Plan for the Pigeon River (North and South Branches).
Action Steps:	1. Contact Waupaca County LWCD to discuss the development of a 9 Key Element Plan for the Pigeon River. 2. Pass a resolution stating the district's level of financial support. 3. Work with the county to obtain a Wisconsin Surface Water Planning Grant to partially fund the development of the plan. 4. Work with the county to inform district members and watershed property owners about the project and its benefits to Pigeon Lake and other waterbodies in the watershed. 5. Continue partnership with the county to obtain additional funding to implement the 9 Key Element Plan.

Management Goal 5: Develop and Maintain a Long-Term Environmental Monitoring Program on Pigeon Lake

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	2024
Facilitator:	District Board of Commissioners
Potential Grant:	N/A
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. The lack of this type of historical information hampered the water quality analysis and watershed modeling during this project. Early discovery of negative trends may lead to the reason as to why the trend is developing. Stability will be added to the program by selecting

	an individual from the district to coordinate the district's volunteer efforts and to recruit additional volunteers to keep the program fresh. The WDNR will first require the district to collect Secchi disk transparencies during the first year, then, if openings exist, would let the group into the Advanced Water Quality Program, in which a volunteer collects water quality samples for processing by the Wisconsin State Laboratory of Hygiene (WSLH) once during the spring and three times during the summer months (June, July, and August). A distinct advantage of processing the samples through the WSLH is that the results are automatically loaded into the Surface Water Integrated Management System (SWIMS), the WDNR statewide database. Currently, the WDNR is allowing lake groups to participate in the Advanced Water Quality Program for three years out of every ten years. During the years that the district cannot participate in the WDNR-funded program, the district can continue to collect water quality samples for analysis by the WSLH, by utilizing the Pigeon Lake Protection & Rehabilitation District's account number (357233) obtained as a part of this program. The samples would be shipped to the WSLH (2601 Agriculture Dr, Madison, WI 53718) with a completed Inorganic Test Form (4800-024), listing Pigeon Lake's WBIC of 293300, and Station ID of 693176.
Action Steps:	1. District recruits volunteer(s) for water quality sample collection. 2. District contacts WDNR water resource specialist, Ted Gansberg to enroll in Citizen Lake Monitoring Network. 3. Volunteer collects water quality data and reports data to WDNR and Pigeon Lake Protection & Rehabilitation District.

Management Action:	Conduct periodic quantitative vegetation monitoring on Pigeon Lake.
Timeframe:	Point-Intercept Survey every 5 years, Community Mapping every 10 years, AIS surveys as deemed necessary by the Pigeon Lake Protection & Rehabilitation District.
Facilitator:	District Board of Commissioners
Potential Grant:	Wisconsin Surface Water Planning Grant
Description:	As part of the ongoing aquatic plant management program, a whole-lake point-intercept survey will be conducted at a minimum once every 5 years. This will allow a continued understanding of the submergent aquatic plant community dynamics within Pigeon Lake and allow for periodic, lakewide surveillance of the lake for new AIS. If will also provide the aquatic plant data required for future renewals of the district's mechanical harvesting permit. The latest point-intercept survey was conducted on Pigeon Lake in

	2022 as a part of this management planning project, therefore, the next anticipated point-intercept survey on the lake would be in 2027. In order to understand the dynamics of the emergent and floating-leaf aquatic plant community in Pigeon Lake, a floating-leaf and emergent aquatic plant community mapping survey would be conducted approximately every 10 years. A community mapping survey was conducted on the lake in 2022 as a part of this management planning effort. The next community mapping survey will be completed in 2032 to coincide with the point-intercept survey that would potentially occur 5 years after the 2027 point-intercept survey discussed above. Note that the community mapping survey should be done during the same summer as a point-intercept survey, so the schedule of point-intercept surveys, as laid out above, would be the determinant of the community mapping survey. If the district feels that Eurasian watermilfoil and/or curly-leaf pondweed populations are becoming an issue and as a result, the mechanical harvesting plan should be altered to reduce their impact on navigation, the appropriate mapping survey(s) (early-season/late-season) would be completed during the same year the point-intercept survey is completed.
Action Steps:	See description above.

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