Pigeon Lake

Manitowoc County, Wisconsin

Comprehensive Management Plan

July 2014

Sponsored by:

Pigeon Lake of Manitowoc County, Inc.
WDNR Grant Program

AEPP-401-13

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Onterra LLC
Lake Management Planning

Pigeon Lake

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Funded by: Pigeon Lake of Manitowoc County, Inc.
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This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

Pigeon Lake Planning Committee

Steve Meidl
Monty Meister
Todd Zorn
Jerry Lenz
Jerry "Gus" Gospodarek

Organization

Town of Liberty
Manitowoc County Land and Water Conservation Department
Manitowoc County Lakes Association

Wisconsin Dept. of Natural Resources

Mary Gansberg
Steve Hogler

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1.0 INTRODUCTION

Pigeon Lake, Manitowoc County, is an 86-acre seepage lake with a maximum depth of 62 feet and a mean depth of 20 feet (Map 1). This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Pigeon contains 19 native plant species, of which slender naiad is the most common plant. Six exotic species* are known to exist in Pigeon Lake.

Field Survey Notes

Clear-water lake, surrounded by beautiful rolling farmland hills. Sediment was observed to be primarily sand and marl, with many pondweed and several milfoil species found in the softer sediment areas. Dense shoreland development surrounds the lake.

Photograph 1.0-1 Pigeon Lake, Manitowoc County

Lake at a Glance - Pigeon Lake

Morphology	
Acreage	86
Maximum Depth (ft)	62
Mean Depth (ft)	20
Shoreline Complexity	1.7
Vegetation	
Early-Season AIS Survey Date	June 6, 2013
Comprehensive Survey Date	Sept. 5, 2012 (WDNR)
Number of Native Species	19 (including incidentals)
Threatened/Special Concern Species	-
Exotic Species	Banded mystery snail, Curly-leaf pondweed*, Eurasian water milfoil, Purple loosestrife, Pale yellow iris, Zebra mussel
Simpson's Diversity	0.82
Average Conservatism	22.7
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	3:1

**Curly-leaf pondweed not observed since 2005 WDNR survey*

The project sponsor, Pigeon Lake of Manitowoc County, Inc (PLMC), first established in 1951 and incorporated in 2005, was created with the purpose of "*protecting the sports, recreation and habitat of Pigeon Lake for current residents and future generations to come*." The PLMC has gone to great lengths to protect the lake and preserve natural habitat. In 2002, a lake protection grant funded shoreland restoration project was conducted on a private parcel on Pigeon Lake, as well as other Manitowoc County lakes. In a project led by NES Ecological Services, a completely mowed shoreland (Photograph 1.0-2) was transformed into a shoreland with many native species, including the many black-eyed Susans that are apparent in Photograph 1.0-2. Sadly, during surveys in 2013 it appeared as though this restoration site had been mowed over.

Pigeon Lake shoreland property before restoration.

Pigeon Lake shoreland property following restoration.

Photograph 1.0-2 Pigeon Lake shoreland restoration. Photograph credit: Manitowoc County Shoreland Restoration Demonstration Project report, NES Ecological Services, June 2006.

Two previous management planning efforts have taken place on the lake, one in 1995 and one in 2005, both conducted by Northern Environmental Technologies, Inc. (Gruenewald et al. 2005). The most recent of these studies concluded that the lake is mesotrophic, though decomposition of aquatic plant material (in particular Eurasian water milfoil) is contributing to winter dissolved oxygen depletion and a reported fish kill in 2010. The 2005 report goes on to state that total phosphorus concentrations have increased over time in Pigeon Lake, and that both external and internal sources are contributing nutrients to the lake.

The PLMC realizes the importance of monitoring watercraft coming to and leaving from Pigeon Lake for AIS, and thus have completed six years of volunteer work in Manitowoc County's Clean Boats/Clean Waters (CBCW) program. In addition to this, the group is active in the Wisconsin Department of Natural Resources's (WDNR) Citizens Lake Monitoring Network (CLMN). Volunteers through this program visit the deep hole location of the lake and collect water quality data. During the initial stage of the program, Secchi depth clarity and other visual/observational data are recorded. Upon completion of one year of efforts, dedicated groups may continue to the advanced portion of this program, in which water chemistry samples are collected. Pigeon Lake now has an active volunteer collecting samples through the CLMN's advanced program. Data from these collections as well as discussions with PLMC members was invaluable in the planning process of this project.

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

Kick-off Meeting

On May 24, 2013, a project kick-off meeting was held to introduce the project to the general public. The meeting was announced through a mailing and personal contact by PLMC board members. The attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session.

Planning Committee Meeting I

Tim Hoyman met with the Pigeon Lake Planning Committee on April 16, 2014 to present the results of the studies that had taken place on the lake in 2013. Regional WDNR Lakes Coordinator Mary Gansberg was in attendance as well. During the presentation, topics spanning from water quality, the lake's watershed, shoreland condition, aquatic plants and fisheries were discussed. In particular, many questions were fielded by Mr. Hoyman regarding the water quality of the lake and threat of Eurasian water milfoil.

Planning Committee Meeting II

On May 8, 2014, Tim Hoyman and Dan Cibulka met with members of the planning committee and WDNR Lakes Coordinator Mary Gansberg once again to discuss the Pigeon Lake project. First, a brief discussion was held on the concluding remarks from Planning Meeting I. This was followed by a question and answer session. Then, the committee, Ms. Gansberg and Onterra staff began developing the framework of the Implementation Plan by identifying challenges that Pigeon Lake and the PLMC face. These challenges were assigned Management Goals and Actions, which were discussed at length to determine if they were feasible for Pigeon Lake and also for the PLMC to implement.

Project Wrap-up Meeting

On June 18, 2014, Tim Hoyman met with over 20 PLMC members to deliver the project's Wrap-up presentation. During the presentation, highlights from the study were discussed as well as a thorough explanation of the Management Goals and Actions the PLMC Planning Committee had created during the planning project. The topic of EWM management was thoroughly discussed, along with other matters including water quality and shoreline development, between Mr. Hoyman and the meeting attendees.

Management Plan Review and Adoption Process

Prior to Planning Meeting I, Onterra staff created the Results Section (Section 3.0) of this document and distributed it to the planning committee members. The planning committee reviewed the document in preparation for Planning Meeting I, and provided comments on this portion of the plan. During Planning Meeting II, the framework of the Implementation Plan was created through discussions of efforts the PLMC would pursue to protect Pigeon Lake. Following Planning Meeting II, Onterra staff developed the Implementation Plan and sent out an official first draft on May 16, 2014 to the PLMC and WDNR. Once comments were received from the PLMC, copies of the draft plan with the PLMC comments integrated within it were provided to the Town of Liberty and Manitowoc County for their review. Comments from those entities, along with those from the WDNR were integrated within the final draft of the management plan in July of 2014.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

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

> **Phosphorus** is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading*

**Lack of summer months temperature/dissolved oxygen profiles and hypolimnetic phosphorus data prevents these analyses from being performed. The explanation provided under this heading is strictly for the information of the reader.*

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

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

Candidate Lakes

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

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

If the lake is considered a candidate for internal loading, modeling procedures are used to estimate that load.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of 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, hydrology. An equation developed by Lathrop and Lillie (1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

Because of its depth, small watershed and hydrology, Pigeon Lake is classified as a deep seepage lake (category 7 on Figure 3.1-1).

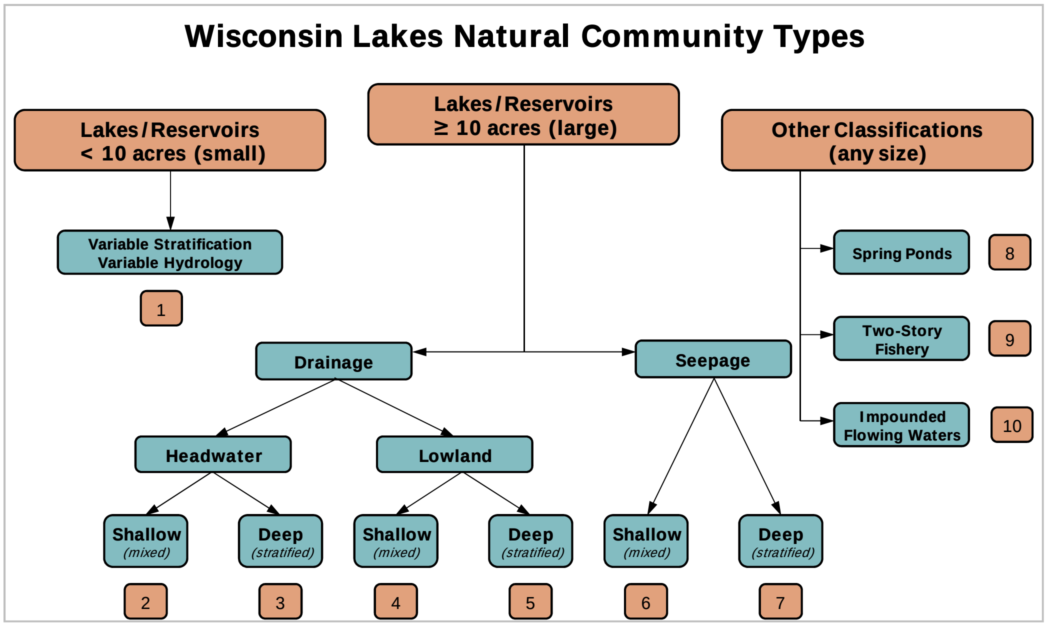

Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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

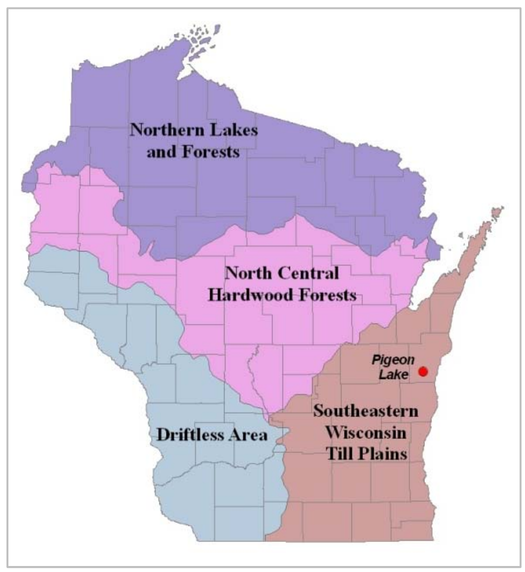

Figure 3.1-2. Location of Pigeon Lake within the ecoregions of Wisconsin. After Nichols 1999.

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

Pigeon Lake water quality data is presented along with comparable data from similar lakes throughout the state and ecoregion in Figures 3.1-3 - 3.1-6. Please note that the data in these graphs represent samples 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 Long-term Trends

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation or lack thereof, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, as whether the lake health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, one can determine what the status of the lake is by comparison.

Volunteers continue to collect data from Pigeon Lake through the Citizens Lake Monitoring Network (CLMN). Through this program, volunteers are trained to collect water quality data on their lake. Samples are analyzed through the State Lab of Hygiene in Madison, WI and data are entered into the Surface Water Integrated Monitoring System (SWIMS), an online database which allows for quick access to all current and historical water quality data. This process allows stakeholders to become directly engaged in protecting their lake, while producing reliable and comparable data that managers may recall through a streamlined website.

Volunteers have collected surface total phosphorus, chlorophyll-*a* and Secchi disk clarity data from Pigeon Lake since 2004. Additional data collection has occurred through previous Pigeon Lake planning or statewide projects. During this time, surface total phosphorus concentrations have fluctuated on an annual basis between 10.0 and 24.0 μg/L (Figure 3.1-3). A weighted summer average over all years was determined to be 15.4 μg/L. This value falls within the *Good* category and is comparable to the median of other deep seepage lakes within Wisconsin, and is lower than the median concentration for all lakes in the Southeastern Wisconsin Till Plains ecoregion.

Upon first glance, the total phosphorus values have somewhat of a downward trend. Influencing the dataset, however, are single values from 1978 and 1979 as well as several data points in 1994, 1995 and 1996. The dataset are not contiguous, meaning that concentrations between these large data gaps are unknown. In examining the contiguous dataset from 2004 – 2013, no statistically significant trend was detected (Mann-Kendall test, $\alpha=0.05$).

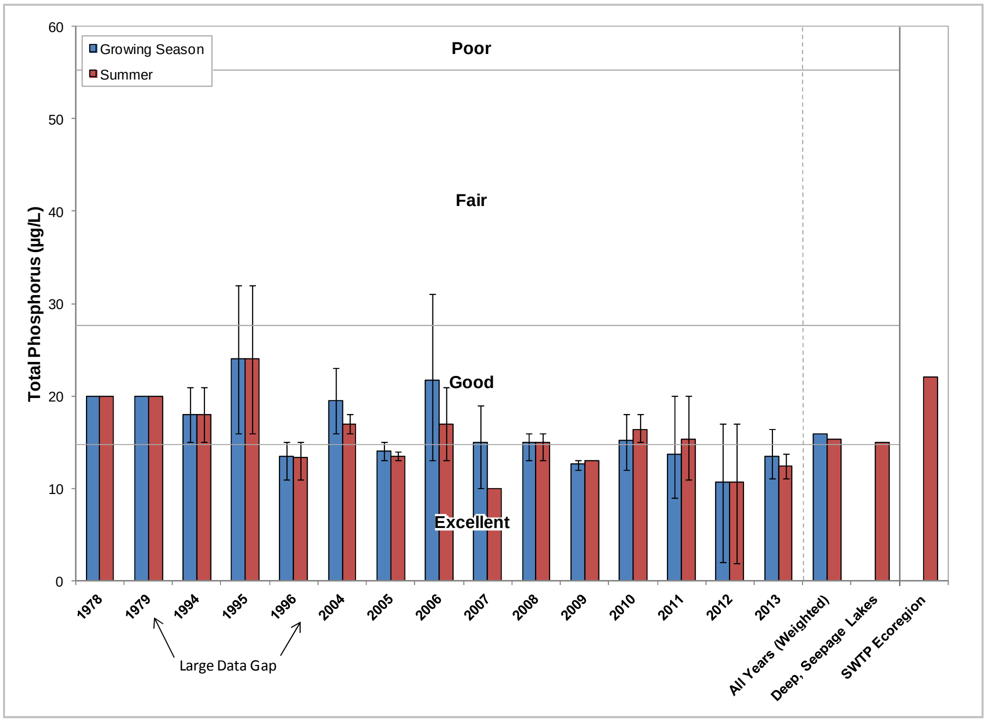

Figure 3.1-3. Pigeon Lake phosphorus concentrations. Mean values calculated with surface sample data. Comparables includes state-wide deep seepage lake median and SWTP ecoregion median. Water Quality Index adapted from Garrison et. al (2008).

There are many factors that determine algal abundance; nutrients, such as phosphorus and nitrogen, are a large factor because algae feed on these elements. However, water temperature, sunlight penetration (water clarity) and presence of very small crustaceans called zooplankton influence algal abundance as well. Water temperature will determine the overall biological activity (reproduction, nutrient-uptake rates, etc.) of algae. Algae need to photosynthesize to create energy and thus are dependent upon sunlight. For this reason, algae are often most prevalent in the late summer when water temperatures are high and daylight hours are still long. During the summer months, the abundance of zooplankton typically increases as well. Many zooplankton species feed upon algae, so they may regulate algal abundance through predator-prey interactions.

Chlorophyll-*a* concentration data collected since 1979 (intermittently) show a bit of fluctuation (Figure 3.1-4). This fluctuation is most likely due to environmental factors such as those described above, which may change drastically from year to year. A weighted summer average over this time period was calculated to be 5.2 µg/L, which is slightly higher than what is typically seen in deep seepage lakes but similar to all lakes in the Southeastern Wisconsin Till Plains ecoregion. Most summer averages and the weighted average over all years fall within the *Good* category for deep seepage lakes.

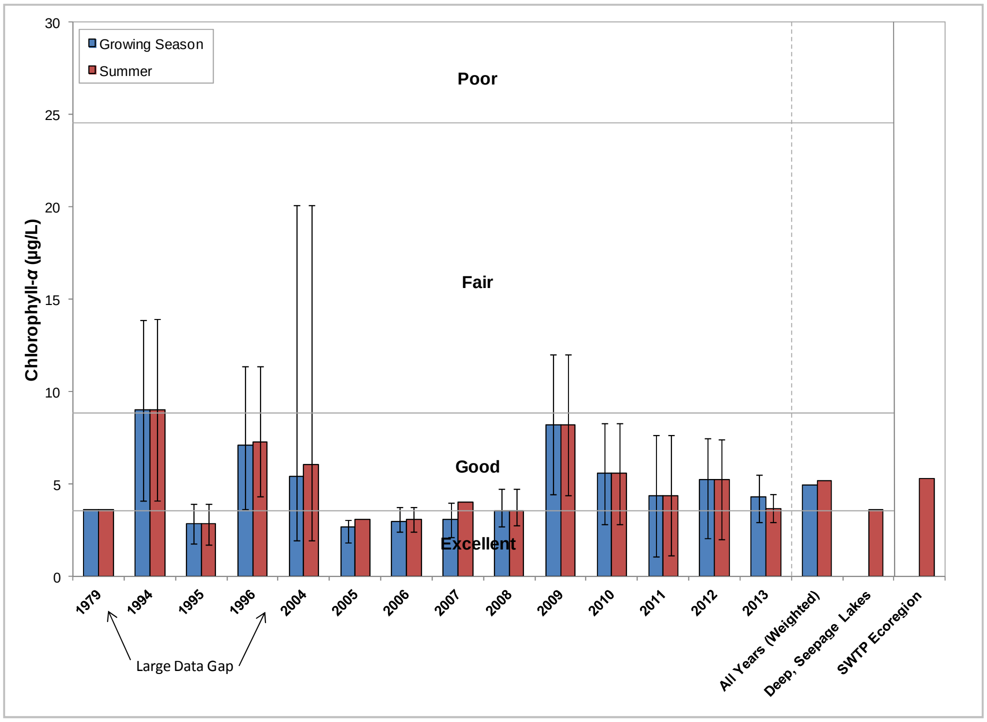

Figure 3.1-4. Pigeon Lake chlorophyll-*a* concentrations. Mean values calculated with surface sample data. Comparables includes state-wide deep seepage lake median and SWTP ecoregion median. Water Quality Index adapted from Garrison et. al (2008).

The third primary water quality parameter, water clarity, is measured through the use of a Secchi disk. The water clarity of a lake is heavily influenced by many characteristics. For example, water clarity is influenced by algal concentration; the more algae in the water column, the less visibility there is. Dissolved organic substances may also reduce the clarity by changing the color of the water in a lake.

Summer average Secchi disk depths in Pigeon Lake have ranged between 2.5 and 12.4 feet from 1979-2012, while a weighted average over all years was calculated to be 8.4 feet (Figure 3.1-5). This value ranks as *Good* for deep seepage lakes in Wisconsin, but is lower than the median value. The average does however rank well against other lakes in the Southeastern Wisconsin Till Plains.

Zebra mussels were first confirmed in Pigeon Lake in 2007. Pigeon Lake has had clear water for quite some time, according to data collected in the mid-1990's and anecdotal accounts. Zebra mussels feed as other mussels do, by drawing water into their bodies and filtering out suspended microscopic plants, animals and other debris for food. It is undetermined if zebra mussels have had an impact on water clarity in Pigeon Lake. As filter feeders, zebra mussels are effective at removing free-floating algae from the water column. Species of filamentous algae (which are not believed to impact Secchi disk readings) however are not susceptible to zebra mussel feeding and can remain within a lake.

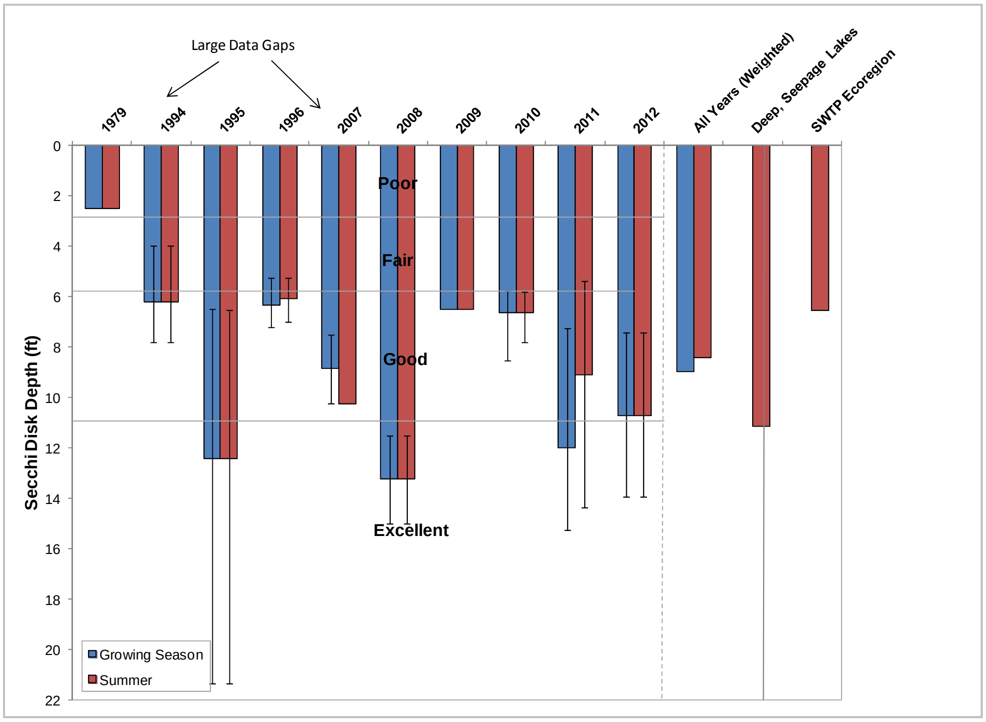

Figure 3.1-5. Pigeon Lake Secchi disk clarity values. Mean values calculated with surface sample data. Comparables includes state-wide deep seepage lake median and SWTP ecoregion median. Water Quality Index adapted from Garrison et. al (2008).

Limiting Plant Nutrient of Pigeon Lake

When determining the limiting nutrient of a lake, a nitrogen:phosphorus ratio is calculated. In 2004, Northern Environmental reported a 52:1 ratio for Pigeon Lake (Gruenewald et. al. 2005). This finding indicates that Pigeon Lake is indeed phosphorus limited as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lake.

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 range in values spanning from upper oligotrophic to eutrophic. 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 a mesotrophic state.

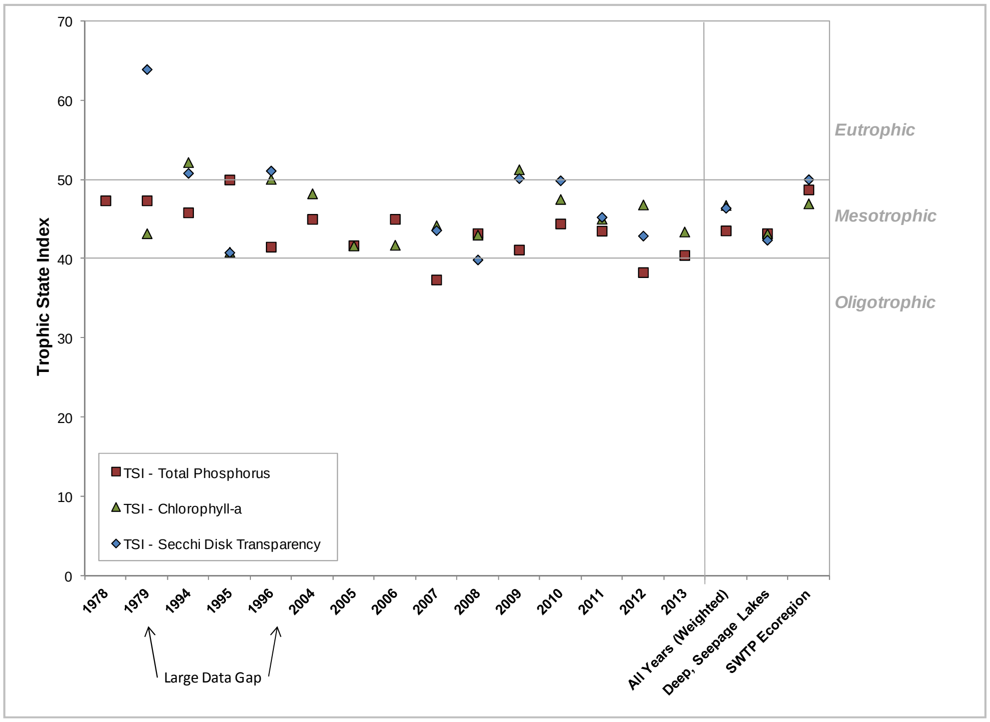

Figure 3.1-6. Pigeon Lake Trophic State Index values. Mean values calculated with surface sample data. Comparables includes state-wide deep seepage lake median and SWTP ecoregion median. Water Quality Index adapted from Garrison et. al (2008).

Impaired Waters Designation

Pigeon Lake was listed in 1998 as being on the Environmental Protection Agency's Impaired Waters List, or 303(d) list after the Clean Water Act chapter it is discussed within. The lake was included on this list for mercury contaminated fish tissue, as testing had confirmed levels exceeded thresholds for fish consumption. Certain fish consumption restrictions now exist on Pigeon Lake.

One third of the nation's lake waters and one quarter of its rivers are contaminated with mercury. The element mercury is a naturally occurring compound, though it commonly has impaired waterways through the burning of fossil fuels. Mercury is released to the atmosphere during the combustion process, and can be carried great distances on wind currents before binding with rain or snow. Once in the water, mercury can convert to methylmercury, where it then accumulates in smaller animals (zooplankton, insects) which are consumed by larger animals (fish). This process of bioaccumulation means that larger animals accumulate methylmercury within their tissues, so larger fish could carry more methylmercury. It is the methylmercury that poses a health risk to humans. Fetuses, nursing infants, children under 15 and people who rely on fish for much of their diet are most at risk from methylmercury, which can hamper normal development of the central nervous system.

3.2 Watershed Assessment

Watershed Primer

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

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

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

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

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

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

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

Modeling Preparation – Watershed Delineation & Lake Volume Calculations

A 2004 Northern Environmental report on Pigeon Lake was reviewed in preparation for modeling procedures on Pigeon Lake (Gruenewald et. al. 2005). Northern Environmental reported the entire watershed (surface and groundwater contributions) to be roughly 1,200 acres in size. The surface water contributing section of the watershed was estimated to be 196 acres in size, not including the size of Pigeon Lake (86 acres). This consisted of an 86 acre section that drains directly to Pigeon Lake through surface water overland flow, and a 110 acre section that drains to an intermittent inlet stream located at the north east corner of the lake. This surface watershed was modified from the findings reported in a WDNR study, in which a 216 acre watershed was reported (Olson and Helsel 1997). Several explanations were given in the 2004 report as to changes that may have occurred in the watershed, or other observations made to justify the change in watershed boundaries. As discussed further on below, the lake and watershed was modeled with a direct input component and a tributary input component, using data collected by Northern Environmental in 2004.

In the 2004 Northern Environmental report, the volume of the lake was reported to be 743 acre feet (242 million gallons). It was noticed during modeling procedures that this volume seemed unreasonable and inconsistent with volume calculations made by Onterra staff. Onterra calculations determined the lake volume to be 1,734 acre feet (565 million gallons), over double the volume reported in 2004. It is believed that volume in the 5-40 ft region is largely unrepresented in the Northern Environmental report, which is the reason for this calculation error. Pigeon Lake estimated bathymetric data is available in Figure 3.2-1.

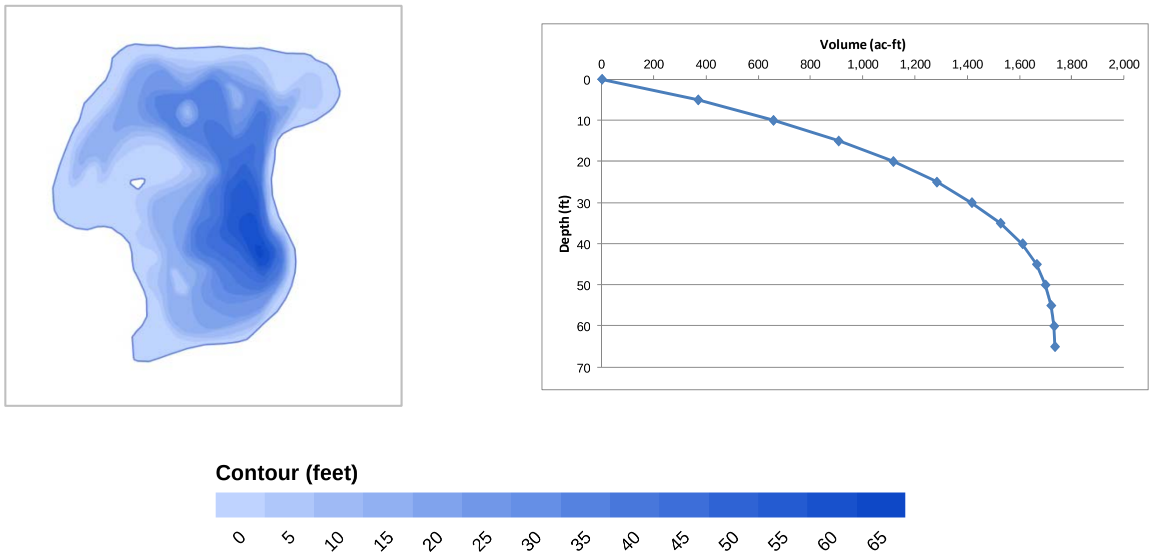

Figure 3.2-1. Pigeon Lake bathymetry and volume at depth. 2004 bathymetric map digitized from (Gruenewald et. al. 2005). Volume at depth calculated by Onterra (2014).

Pigeon Lake Watershed

Pigeon Lake's direct watershed consists of 180 acres (Map 2). Within the relatively small watershed, the lake itself occupies the most area, with 48% coverage of the watershed (Figure 3.2-2). Pasture/grass covers roughly 14% (26 acres) of the watershed, with forest (14%), wetlands (11%) and rural residential lands (9%) comprising significant areas of the watershed also. The small amount of golf course property located in the direct watershed is classified under "rural residential" for modeling purposes. Overall, the watershed is always equally the size of the lake (watershed to lake area ratio of 1:1). With this amount of land draining towards the lake, WiLMS calculated that Pigeon Lake is able to completely exchange its volume of water every 9.3 years (water residence time).

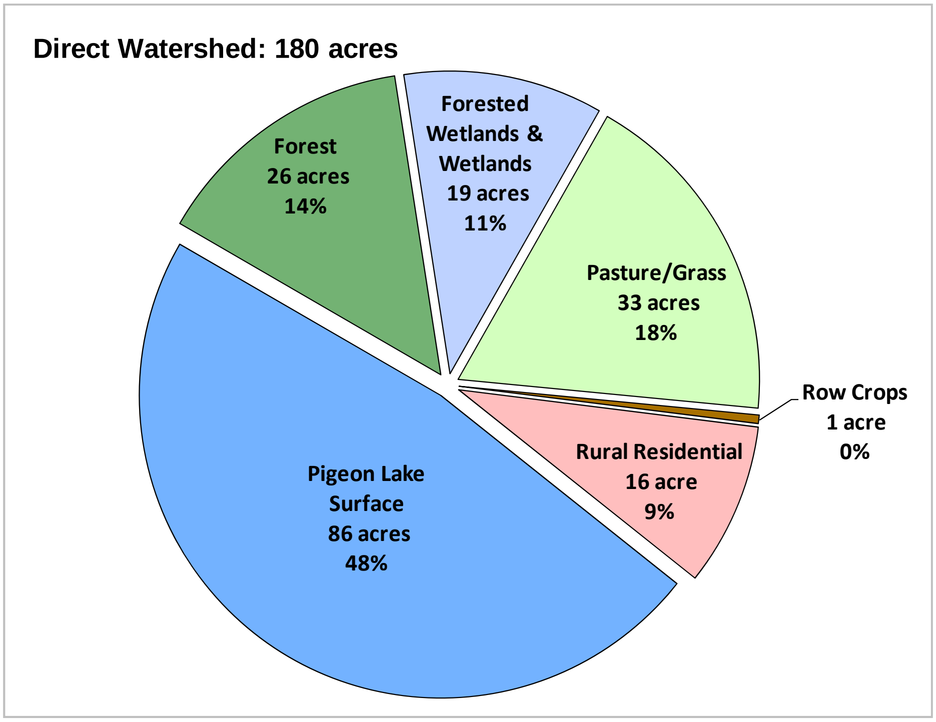

Figure 3.2-2. Pigeon Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The direct watershed was modeled utilizing WiLMS and 2006 land cover data. The direct watershed contributes 37 lbs of phosphorus annually to Pigeon Lake (Appendix C). In 2004, Northern Environmental estimated that the inlet stream from the eastern sub-basin contributed roughly 19 lbs of phosphorus. For the purposes of this baseline modeling exercise, this is assumed to be an average annual amount from this source. Realistically, the phosphorus input from the eastern sub-basin is likely highly variable and dependent upon precipitation patterns. Also, changes in the watershed may have modified slopes and flow patterns which could impact surface water flow quality and quantity substantially.

Figure 3.2-3 indicates that the lake's surface is actually the largest contributing area in the watershed, as it collects 22 lbs of phosphorus on its surface each year through atmospheric deposition. As stated before, the east basin tributary delivered an estimated 19 lbs of phosphorus in 2004. Pasture and grass land contributes another 9 lbs, while the remaining land cover types deliver an estimated 18 lbs of phosphorus, collectively, in a given year. Septic sources from homes were not accounted for within this modeling procedure as a lack of information existed on the number of systems and residential usage. Also not accounted for in the modeling procedure is the contribution of phosphorus from internal sources, which may occur to some extent in Pigeon Lake as determined by the 2004 Northern Environmental report. Data required for quantifying this contribution was not collected as part of this study.

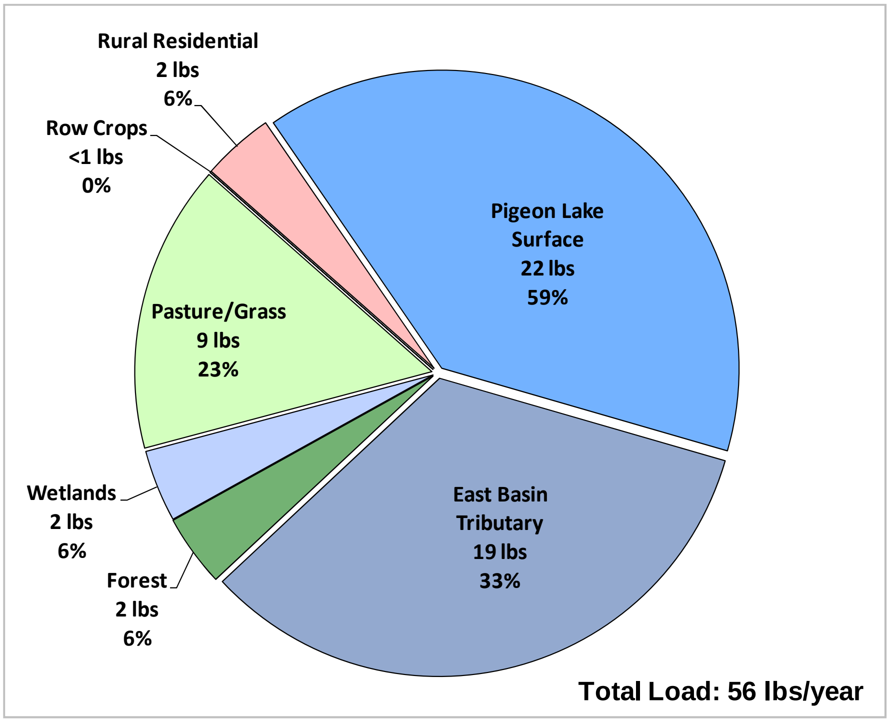

Figure 3.2-3. Pigeon Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

During modeling procedures, WiLMS compares observed (measured in the field) and predicted (model-calculated) growing season mean and spring overturn phosphorus concentrations to determine the accuracy of the model. The growing season mean phosphorus concentration is defined as the mean of all surface water data collected from March 31-November 1 in a year. The spring overturn phosphorus concentration is defined as the concentration of phosphorus that is collected while the lake is completely mixed, as it typically is during the spring. This value is a good representation of the phosphorus content of the lake, because during this time the water is thoroughly mixed which means phosphorus is fairly similar within the entire water column.

Utilizing land cover types proportions and hydrologic data, as well as flow and nutrient data from the 2004 study, WiLMS was able to predict what the phosphorus content of Pigeon Lake should be and then compare these values to observed values obtained through volunteer-based water quality sampling. A predictive equation within WiLMS (Canfield-Bachman, 1981) estimated that the growing season mean value should be 20 µg/L in Pigeon Lake. Comparatively, Pigeon Lake's most recent observed growing season mean phosphorus concentration was found to be 15.4 µg/L. Therefore, the predicted value is higher than what was observed, but not completely beyond the level of error associated with a baseline screening model such as WiLMS.

It is often difficult to model lakes such as Pigeon Lake, which have an intermittent tributary stream. WiLMS must assume that the stream is running at all times; if the stream is not transporting water, than the phosphorus accumulation that WiLMS is predicting cannot be realized within the model. It is for this reason that WiLMS is better accustomed to modeling drainage lakes and not seepage lakes or lakes with an intermittent inlet stream.

Along with the variability of modeling a lake with an intermittent stream, one other factor not accounted for within the model is the loss of phosphorus to the hypolimnion, or bottom layer of water in the lake. Back-calculations were conducted with Canfield-Bachman's 1981 lake model to determine what phosphorus load would be required to produce a growing season mean phosphorus value of 15.4 µg/L. The result of this calculation yielded 21 lbs of phosphorus. In other words, if the actual annual contribution of phosphorus to Pigeon Lake via its direct and tributary fed watershed is 56 lbs, roughly 35 lbs are lost to the depths of Pigeon Lake. Lakes tend to act as sinks; they receive nutrients and sediments from their watershed and deposit a portion of them to the deeper areas. In-lake activities such as turnover and internal nutrient loading can release these nutrients to the surface waters, however how often Pigeon Lake actually turns over is unknown. In summary, the Pigeon Lake watershed contains only a small amount of highly developed land and is relatively small compared to the size of the lake. Both of these conditions are beneficial to Pigeon Lake's ecology and health. However, as the next section highlights, one area of focus for the watershed might be the lake's immediate shoreland zone, which is highly developed and may pose a threat to the lake's ecology and habitat potential.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmers itch. Development such as rip rap or masonary, 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 more strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. County ordinances may be more restrictive than NR 115, but not less so (though Act 170 allows for less restrictive standards for existing non-conforming structures). These policy regulations require each county to amend ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, NR 115 is under review by the State of Wisconsin and updates will likely occur in February of 2014.

- Contact the county's regulations/zoning department for county-specific requirements.

- 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface (but not more than 30%) on a lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner.

- 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. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
  - No expansion or complete reconstruction within 0-35 feet of shoreline
  - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
  - Construction may occur if mitigation measures are included either within the existing footprint or beyond 75 feet.
  - Vertical expansion cannot exceed 35 feet

- Mitigation requirements: New 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, dependent on the county.

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

Cost

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

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

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

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

- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (rip-rap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

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

Pigeon Lake Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On Pigeon Lake, the development stage of the entire shoreland was surveyed during Fall of 2013, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

Pigeon Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.4 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state. During the survey, 1.1 miles (65%) of urbanized and developed–unnatural shoreland were observed. This level of development is harmful to the Pigeon Lake ecology by negatively impacting the lake's habitat value and by increasing shoreland nutrient and sediment inputs. If restoration of the Pigeon Lake shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

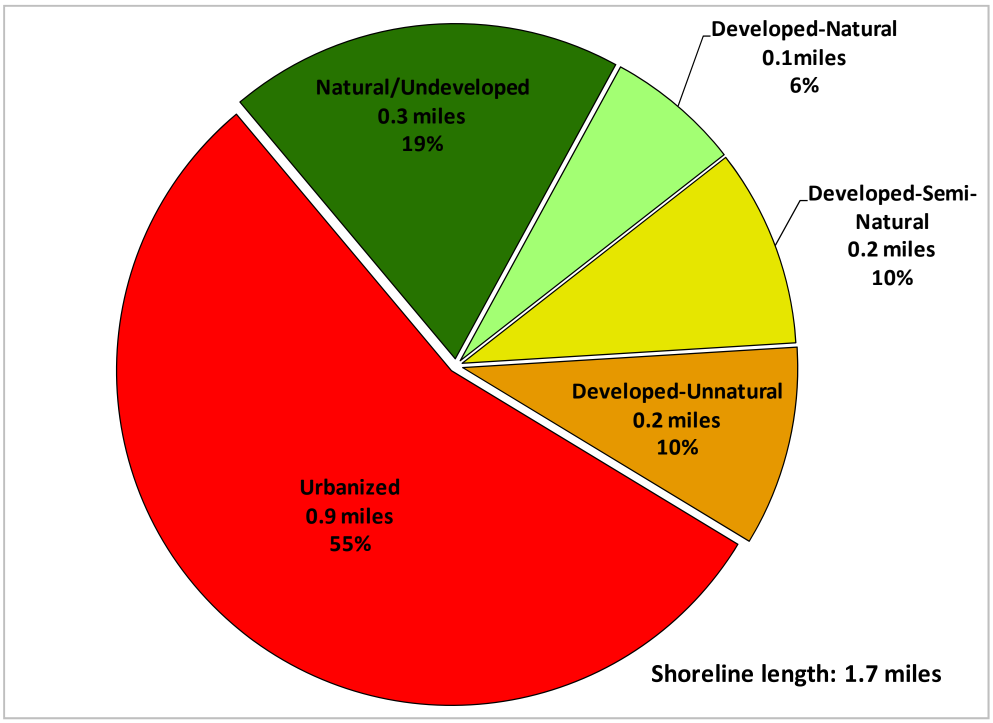

Figure 3.3-2. Pigeon Lake shoreland categories and total lengths. Based upon a fall 2013 survey. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

Pigeon Lake was surveyed in fall 2013 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in three size categories (2-8 inches diameter, >8 inches diameter, and cluster of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 36 total pieces of coarse woody habitat were observed along 1.7 miles of shoreline, which gives Pigeon Lake a coarse woody habitat to shoreline mile ratio of 21:1 (Figure 3.3-3). Locations of coarse woody habitat are displayed on Map 4. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

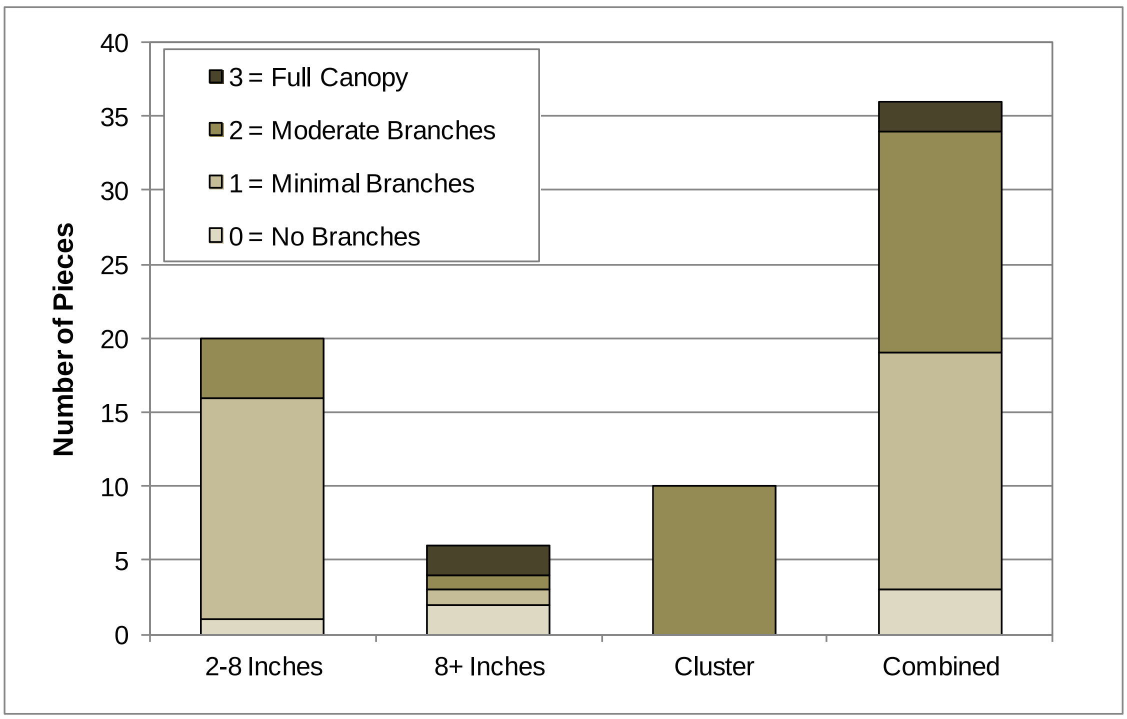

Figure 3.3-3. Pigeon Lake coarse woody habitat survey results. Based upon a fall 2013 survey. Locations of Pigeon Lake coarse woody habitat can be found on Map 4.

3.4 Aquatic Plants

Introduction

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

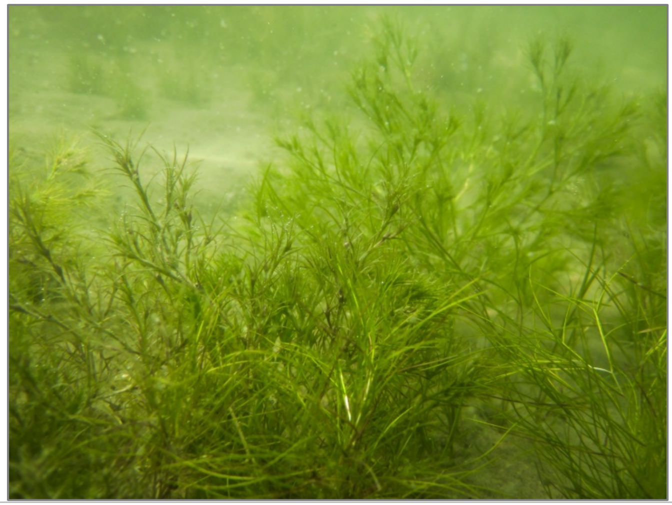

Photo 3.1-1. Pigeon Lake aquatic plants - slender naiad and sago pondweed. Native aquatic plants are an important component in maintaining a healthy aquatic ecosystem.

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

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

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

Aquatic Plant Management and Protection

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 that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

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

Manual Removal

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

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

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

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

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

Cost

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

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

Herbicide Treatment

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

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

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

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

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

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

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many 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 water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, 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 strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of Pigeon Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, two types of data are displayed: littoral frequency of occurrence and relative frequency of occurrence. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are less than the maximum depth of plant growth (littoral zone). Littoral frequency is displayed as a percentage. Relative frequency of occurrence uses the littoral frequency for occurrence for each species compared to the sum of the littoral frequency of occurrence from all species. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

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

Species Diversity and Richness

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

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

Simpson's diversity index is used to determine this diversity in a lake ecosystem. Simpson's diversity (1-D) is calculated as:

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

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. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Pigeon Lake. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion (Figure 3.4-1) and in the state.

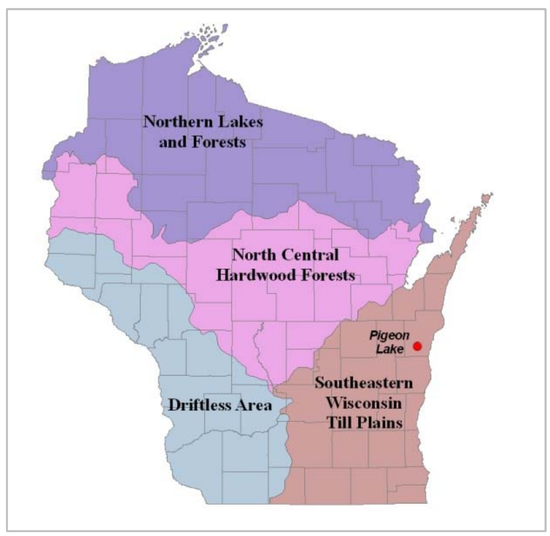

Figure 3.4-1. Location of Pigeon Lake within the ecoregions of Wisconsin. After Nichols 1999.

As previously stated, species diversity is not the same as species richness. One factor that influences species richness is the "development factor" of the shoreland. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreland may hold. This value is referred to as the shoreland complexity. It specifically analyzes the characteristics of the shoreland and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreland complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreland complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine, lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality of Pigeon Lake will be compared to lakes in the same ecoregion and in the state (Figure 3.4-1).

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

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species coefficient of conservatism value indicates that species likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. 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 survey and does not include incidental species or those encountered during other aquatic plan surveys.

Community Mapping

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

Exotic Plants

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

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

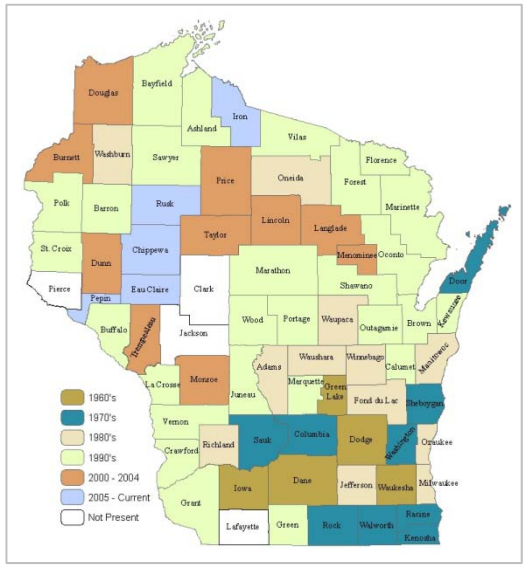

Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

As mentioned earlier, numerous aquatic plant surveys were completed as a part of this project. On June 13, 2013, an early-season aquatic invasive species (AIS) survey was completed on Pigeon Lake. While the intent of this survey is to locate any potential non-native species within the lake, it's primarily focused on locating any occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed. Eurasian water milfoil was mapped initially, then revisited during its peak growth period, in August. Eurasian water milfoil is discussed in depth towards the end of this section.

The point intercept survey was conducted on Pigeon Lake on September 5, 2012 by the WDNR (Appendix D). Additional surveys were completed by Onterra on Pigeon Lake in 2013 to create the aquatic plant community map (Map 5) during August of 2013. During the point-intercept and aquatic plant mapping surveys, 22 species of plants were located in Pigeon Lake (Table 3.4-1), three are considered non-native species: Eurasian water milfoil, pale yellow iris and purple loosestrife. Of the 19 native species found in Pigeon Lake, 15 were sampled directly during the point-intercept survey, not located incidentally. As these 15 species were quantified through the direct sampling, they are used in much of the analysis that follows. Additionally, efforts are made to compare the aquatic plant community between 2012 and 2005 WDNR point-intercept surveys.

Table 3.4-1. Pigeon Lake aquatic plant species. Data collected during WDNR 2012 and Onterra 2013 surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2005 WDNR	2012 (WDNR) & 2013 (Onterra Incidentals)
Emergent	*Iris pseudacorus*	Pale yellow iris	Exotic		*I*
	Lythrum salicaria	Purple loosestrife	Exotic		*I*
	Schoenoplectus acutus	Hardstem bulrush	5	*I*	*I*
	Schoenoplectus tabernaemontani	Softstem bulrush	4		*X*
	Typha spp.	Cattail spp.	1	*I*	*I*
FL	*Nuphar variegata*	Spatterdock	6	*I*	*X*
	Nymphaea odorata	White water lily	6	*X*	*X*
FL/E	*Sparganium eurycarpum*	Common bur-reed	5		*I*
Submergent	*Ceratophyllum demersum*	Coontail	3	*X*	*X*
	Chara spp.	Muskgrasses	7	*X*	*X*
	Myriophyllum sibiricum	Northern water milfoil	7	*X*	*X*
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	*X*	*X*
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	*X*	*X*
	Nitella sp.	Stoneworts	7	*X*	*X*
	Najas flexilis	Slender naiad	6	*X*	*X*
	Potamogeton natans	Floating-leaf pondweed	5	*X*	*I*
	Potamogeton amplifolius	Large-leaf pondweed	7		*X*
	Potamogeton crispus	Curly-leaf pondweed	Exotic	*X*	
	Potamogeton zosteriformis	Flat-stem pondweed	6		*X*
	Potamogeton gramineus	Variable pondweed	7	*I*	*X*
	Potamogeton illinoensis	Illinois pondweed	6	*X*	*X*
	Stuckenia pectinata	Sago pondweed	3	*X*	*X*
	Vallisneria americana	Wild celery	6	*X*	*X*

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

Data from the 2012 point-intercept survey indicate that approximately 99% of the sampling locations located within the littoral zone consisted of a sandy substrate, while two locations held fine organic sediment (muck) and no locations consisted of rock (Figure 3.4-3). Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

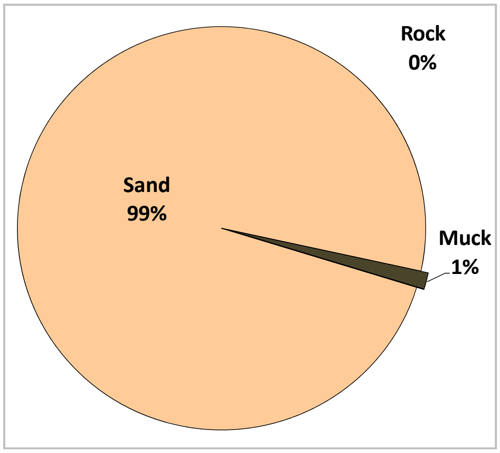

Figure 3.4-3. Pigeon Lake proportion of substrate types within littoral areas. Created using data from a WDNR 2012 aquatic plant point-intercept survey.

Approximately 80% of the point-intercept sampling locations that fell within the maximum depth of aquatic plant growth (20 feet), or the littoral zone, contained aquatic vegetation. During the 2012 point-intercept survey, the majority of the aquatic vegetation in Pigeon Lake was located within the shallow bays and near-shore areas. As discussed in the water quality section, the water clarity in Pigeon Lake is relatively high which allows sunlight penetration and aquatic plant growth into deeper areas of the lake. Figure 3.4-4 shows that the majority of the aquatic vegetation in Pigeon Lake grows between three and 13 feet.

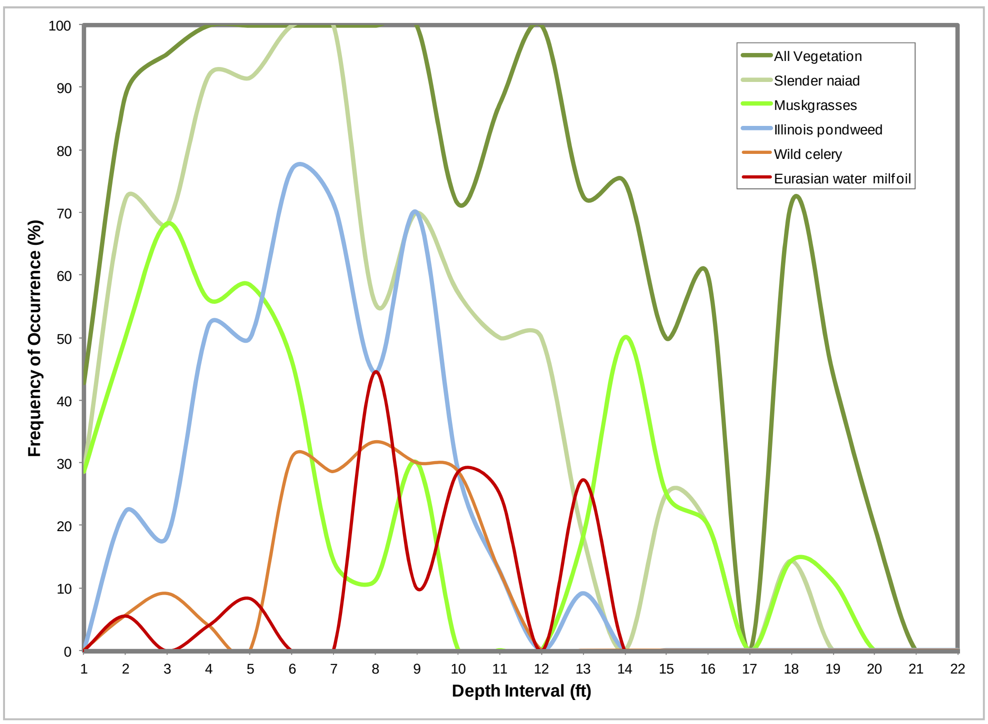

Figure 3.4-4. Frequency of occurrence at littoral depths for several Pigeon Lake plant species. Created using data from a WDNR 2012 aquatic plant point-intercept survey.

Of the 15 native aquatic plants found in Pigeon Lake during the 2012 point-intercept survey, slender naiad, members of the muskgrass family and Illinois pondweed were the most common (Figure 3.4-5). Slender naiad is a submersed, annual plant that may reach lengths of 6-8 feet. It is sometimes called bushy pondweed as its small leaves branch out in numerous directions and become stiff and recurved as it ages. Muskgrasses, or species of the genus *Chara*, are actually a form of macro algae, not an actual aquatic macrophyte. They are grey to green colored and grow in large clumps in shallow to deep water. As well as providing a food source for waterfowl, muskgrass often serves as a sanctuary for small fish and other aquatic organisms. Illinois pondweed has stout stems that emerge from a thick fibrous rhizome (root). Most of the submerged leaves are lanced shaped to oval and either attached directly to the stem or have a short stalk. This plant provides important food and cover for aquatic animals, and the roots can be an important food source for waterfowl.

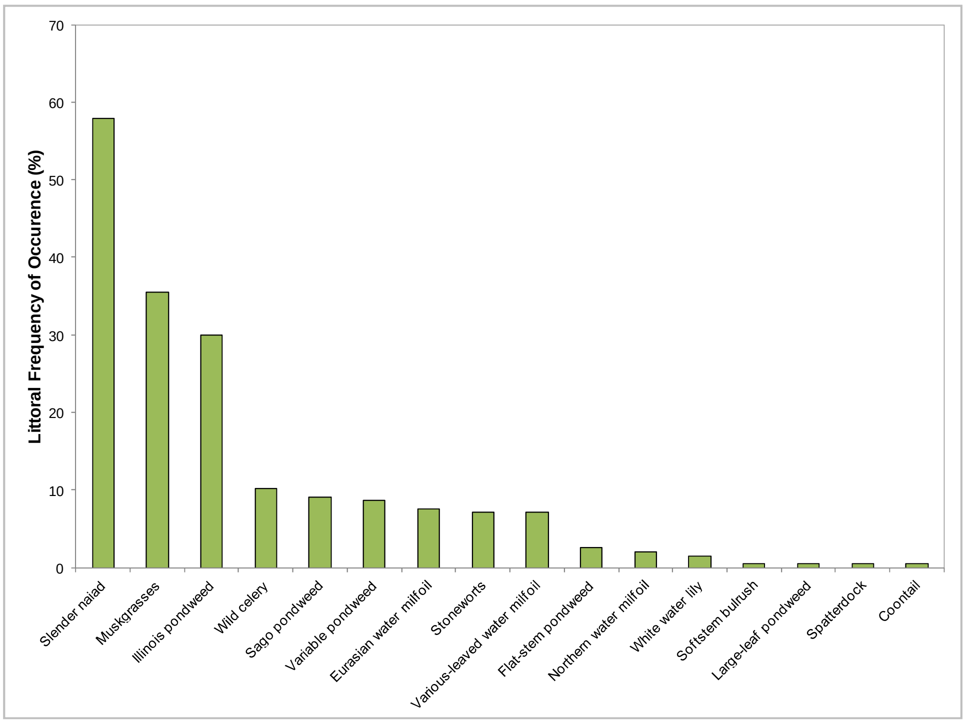

Figure 3.4-5 Pigeon Lake aquatic plant littoral frequency of occurrence. Created using data from a WDNR 2012 survey.

A previous survey conducted by the WDNR in 2005 found many of the same plant species as those found in 2012. The abundance of many of these species has changed between these time periods (Figure 3.4-6). A Chi-square distribution analysis (α=0.05) was used on the point-intercept data collected during these years. Between these two time periods, seven species saw a statistically significant change in their littoral frequency of occurrence. Eurasian water milfoil and muskgrasses were the only two species to experience a statistically significant decline, while slender naiad, Illinois pondweed, wild celery, sago pondweed and variable pondweed all displayed a statistically significant increase in their frequency of occurrence between 2005 and 2012 (Figure 3.4-6). It should be noted that the maximum depth of plant colonization was different between these time periods; plants were found growing to 28 feet in 2005 and to 20 feet in 2012. This resulted in 220 littoral sampling points in 2005 and 197 littoral points in 2012.

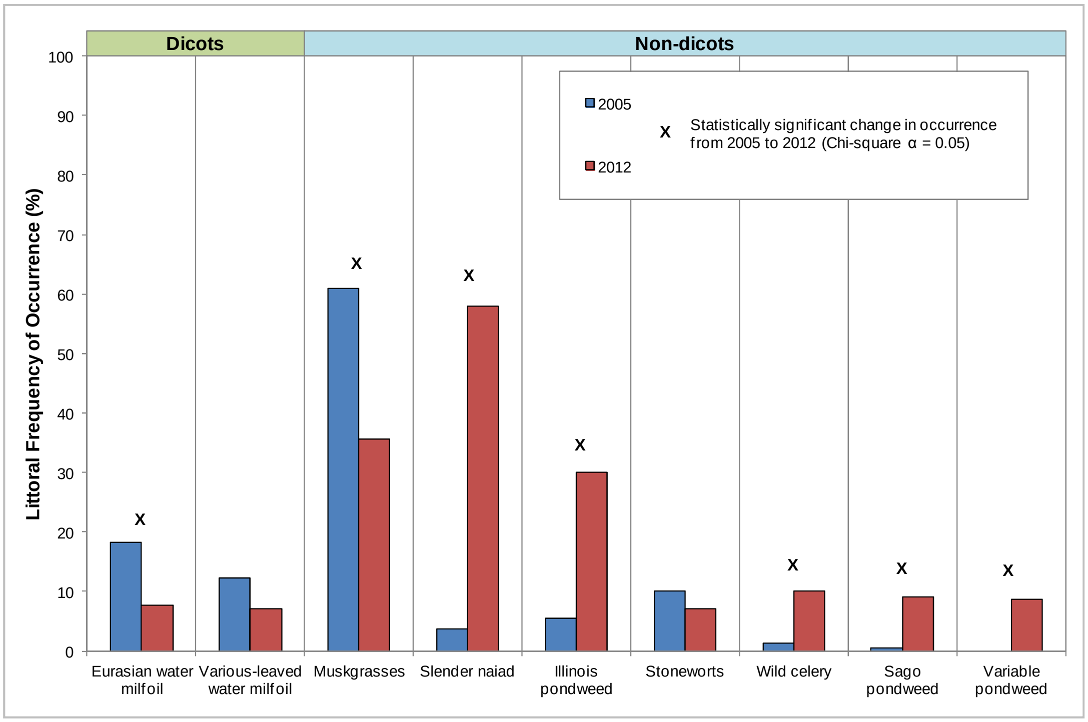

Figure 3.4-6 Pigeon Lake littoral frequency of occurrence statistical comparison. Created using data from a 2005 and 2012 WDNR surveys.

The littoral frequency of occurrence shows 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 slender naiad was found at 58% of the sampling locations in Pigeon Lake, its relative frequency of occurrence is 32%. Explained another way, if 100 plants were randomly sampled from Pigeon Lake, 32 of them would be slender naiad. Looking at relative frequency of occurrence (Figure 3.4-7), three species comprise approximately 68% of the plant community in Pigeon Lake in 2012.

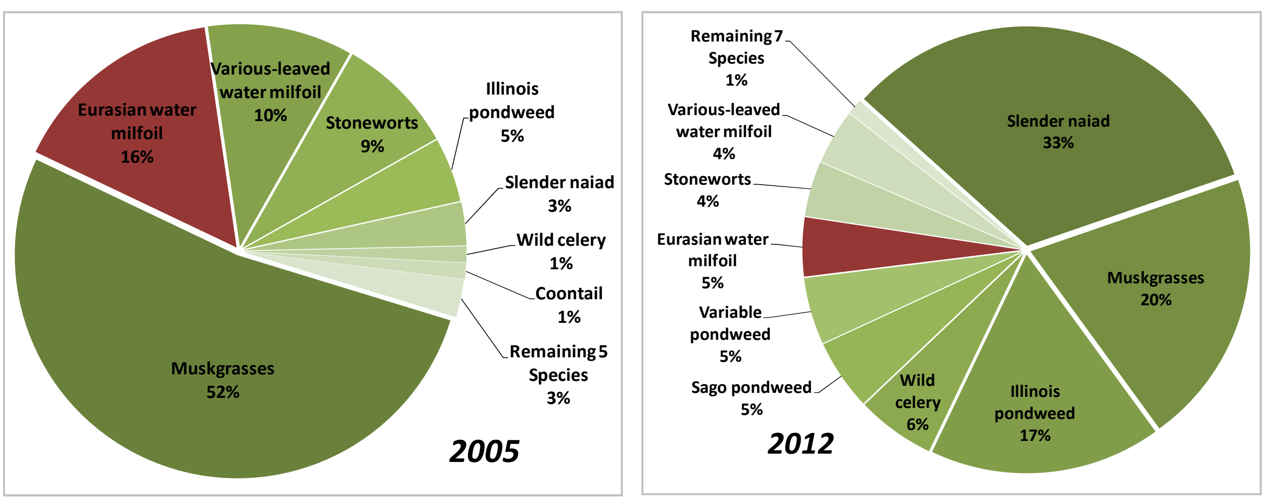

Figure 3.4-7 Pigeon Lake relative plant littoral frequency of occurrence. Created using data from 2005 and 2012 WDNR point-intercept surveys.

As discussed previously, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were sampled directly on the rake during the point-intercept survey and does not include incidental species. For example, while 19 native aquatic plant species were located in Pigeon Lake during the 2012 surveys, 15 were sampled on the rake during the point-intercept survey. Figure 3.4-8 shows that the native species richness for Pigeon Lake was slightly above the North Central and Southeastern Till Plain Lakes Ecoregion and Wisconsin State medians in 2012. In 2005, 11 species were sampled in Pigeon Lake.

Data collected from the aquatic plant surveys show that the average conservatism value (5.7 in 2005, 5.9 in 2012) is comparable to the ecoregion and state medians (Figure 3.4-8), Combining Pigeon Lake's aquatic plant species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.7 (19.0 in 2005; equation shown below). This value is slightly higher than the median values for the ecoregion and state. (Figure 3.4-8),

FQI = Average Coefficient of Conservatism (5.9) * √ Number of Native Species (15)
FQI = 22.7

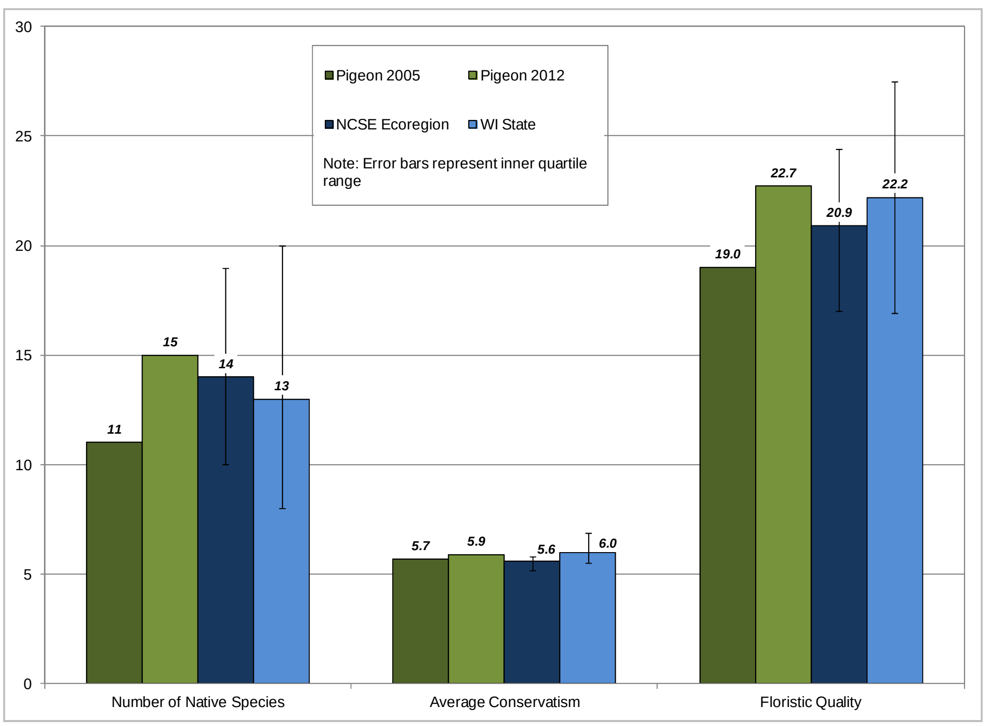

Figure 3.4-8. Pigeon Lake floristic quality assessment. Created using data from a 2005 and 2012 WDNR survey. Analysis following Nichols (1999) where NCSE = North Central and Southeast Lakes Ecoregion.

Because Pigeon Lake contains a high number of native aquatic plant species (i.e. more than the state and ecoregion medians), one may assume their aquatic plant communities have high species diversity. However, as discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community. The aquatic plant community in Pigeon Lake was found to be more diverse in 2012 compared to 2005, with a Simpson's diversity value of 0.82 and 0.68, respectively (Figure 3.4-9). As can be observed from Figure 3.4-7, the aquatic plant community in 2005 was dominated by muskgrasses which resulted in the lower diversity value. In 2012, there was a more even distribution, resulting in a diversity value that ranks close to the ecoregion median (slightly above) and state median (slightly below). Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. 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.

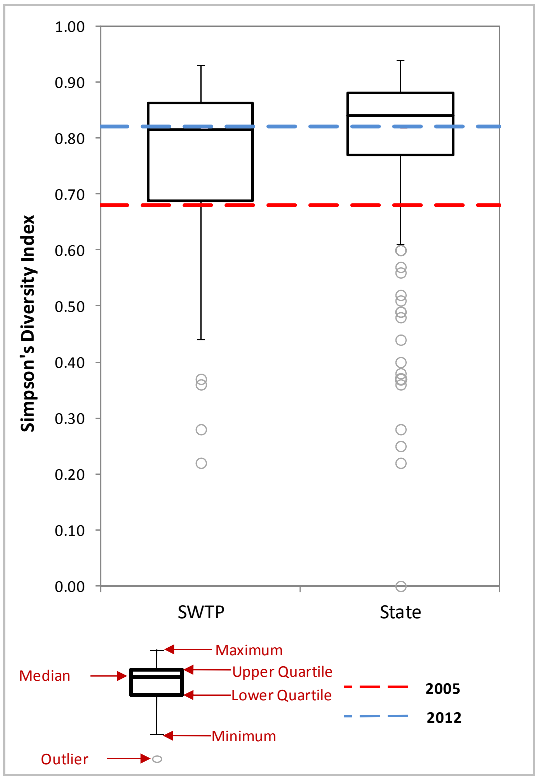

Figure 3.4-9. Pigeon Lake species diversity index. Created using data from 2005 and 2012 WDNR aquatic plant surveys. Ecoregion data provided by WDNR Science Services.

In 2012, Pigeon Lake's plant community was assessed for its emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2013 Onterra community mapping survey indicated that approximately 2.7 acres (3.0%) of the 86 acre-lake contain these types of plant communities (Table 3.4-2 and Map 5). Four native floating-leaf and emergent species were observed on Pigeon Lake, providing valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

Table 3.4-2. Pigeon Lake acres of plant community types. Created from an Onterra August 2013 community mapping survey.

Plant Community	Acres
Emergent	1.2
Floating-leaf	1.0
Mixed Floating-leaf and Emergent	0.5
Total	2.7

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. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-Native Aquatic Plant Species

Pale-yellow iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering throughout shoreline areas on Pigeon Lake during the June Early Season Aquatic Invasive Species survey (Map 5). At the time of this report, it appears that the only means of control are continual hand removal and monitoring.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) 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 single purple loosestrife plant was observed along the western shore of Pigeon Lake (Map 5).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. At this time, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Pigeon Lake.

Curly-leaf pondweed

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

Curly-leaf pondweed was documented as being present in the lake during an August 1994 survey (Gruenewald et. al. 2005), and was found in two locations during the WDNR's 2005 point-intercept survey. It was not however found during the WDNR's 2012 point-intercept survey or Onterra's 2013 Early Season AIS survey, which specifically focused on locating this species. It is currently believed that a small population existed in Pigeon Lake but may have been overcome by competition from native plants or Eurasian water milfoil, or remains at a very small abundance in the lake. Further monitoring for this species is important in order to document any reoccurrences so that the PLMC can act accordingly.

Eurasian water milfoil

Eurasian water milfoil was first confirmed in Pigeon Lake in 1994. During 2013 surveys, a sample was sent into the Annis Water Resource Institute at Grand Valley State University in Michigan for DNA analysis. The analysis confirmed that the sample was pure strain Eurasian water milfoil and not a hybrid species. Hybrid water milfoil, (*M. sibiricum X spicatum*), a cross between Eurasian water milfoil and the indigenous northern water milfoil, is commonly mistaken for Eurasian water milfoil or northern water milfoil. Unfortunately, it is common in lakes in southeastern Wisconsin. Nearby Manitowoc County lakes with hybrid water milfoil include Silver Lake, Shoe Lake, Carstens Lake and English Lake. Hybrid water milfoil threatens ecosystems in the same manner as Eurasian water milfoil, with abundant growth and the ability to displace native species and alter water quality and ecosystem components. Hybrid water milfoil has been shown to grow much faster than EWM, potentially causing increased ecological and recreational conflicts in many Wisconsin Lakes. Some researchers are also beginning to look at matching hybrid water milfoil genetics to effective herbicide rates. Early research may suggest that some genetic strains require higher herbicide concentrations to reach satisfactory levels of efficacy, especially in the case of low-dose whole-lake 2,4-D treatments (LaRue et. al. 2012).

Eurasian water milfoil was located in numerous areas of the lake in both 2005 and 2012. As Figure 3.4-5 indicates, its presence as determined by the point-intercept survey methodology has decreased between these years. Figure 3.4-10 displays the spatial distribution of Eurasian water milfoil in Pigeon Lake during these years. As mentioned above, the littoral zone differed by eight feet between 2005 and 2012, with a 28 maximum depth of plant growth in 2005 and a 20 foot maximum depth in 2012. This could likely be the result of a difference in water clarity during these times, as clearer water would allow for greater light penetration into the water column and thus establishment of aquatic plants deeper into the lake. No Secchi disk clarity data was available from 2005, so any differences in water clarity between these years remain unknown.

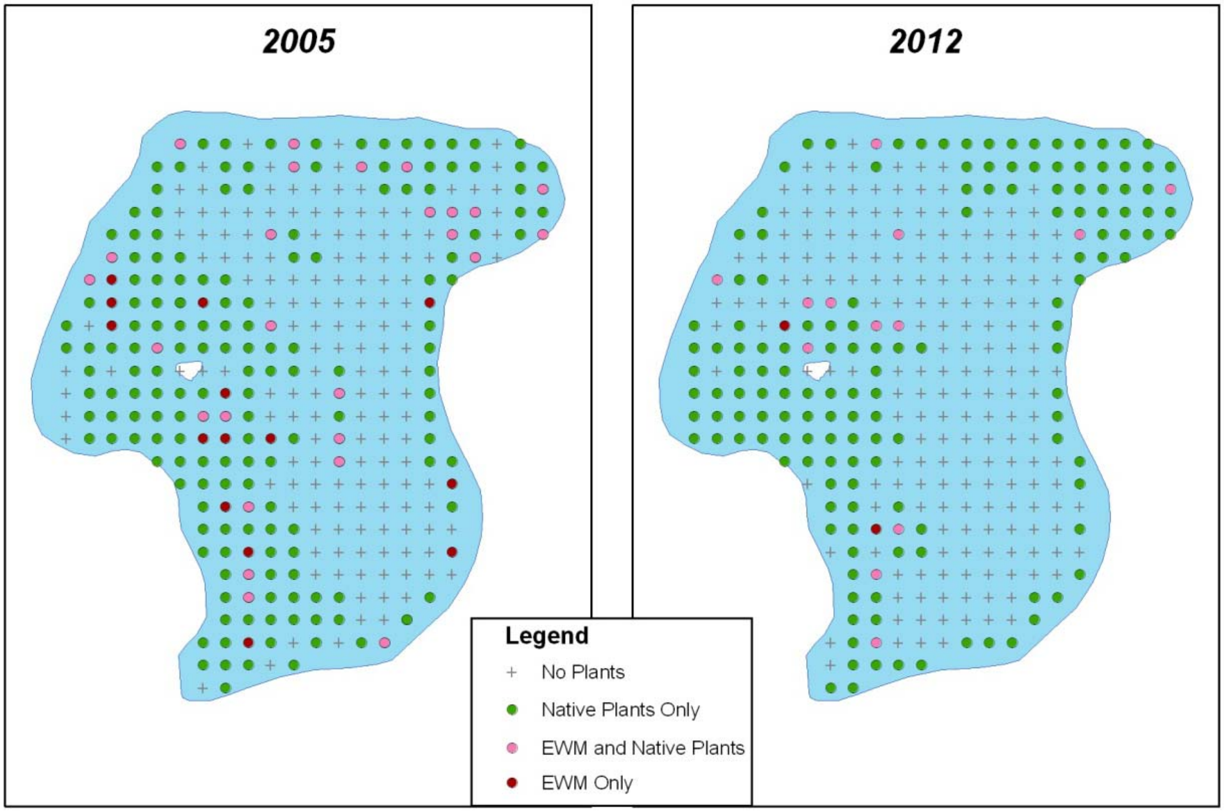

Figure 3.4-10. Pigeon Lake aquatic plant locations, 2005 and 2012. Created using data from a 2005 and 2012 WDNR survey.

Onterra staff mapped the Eurasian water milfoil on Pigeon Lake first in June of 2013, then in August of that same year in an effort to qualitatively examine its density and spatially map its distribution and extents in the lake. The results of this survey are presented within Map 6. In all, 3.1 acres of colonized Eurasian water milfoil were mapped within Pigeon Lake, along with numerous *Single/Few Plants, Clumps of Plants* and *Small Plant Colonies*. EWM colonies were assigned density categories on a five-tiered scale, ranging from *Highly Scattered* to *Surface Matted*. As Map 6 indicates, no Eurasian water milfoil colonies were dense enough to be placed in the highest density category (*Surface Matted*). This methodology is thought to more accurately portray the extent and density of Eurasian water milfoil in a lake than the point-intercept method, as it is commonly found in colonial fashion which can escape point-intercept locations easily.

The PLMC has contracted to have Eurasian water milfoil treated several times before. WDNR records indicate that the non-native plant was targeted for treatment in 2006, 2010 and 2012. The largest treatment occurred in 2006, with four acres (4.6 % of the lake surface area) targeted at that time with 200 lbs per acre. Table 3.4-3 displays previous treatments that have occurred in Pigeon Lake, along with the estimated 2,4-D concentration within the epilimnion at that time.
It should be noted that the calculated concentration would vary upon where the seasonal thermocline was determined to be present; herbicide theoretically would not break the thermal "barrier" of different density water and dilute with the colder waters of the hypolimnion. Also, factors such as herbicide degradation and loss of 2,4-D granules to the sediment are not

accounted for and thus could potentially decrease the concentration. Anecdotal reports indicate that control from these treatments was variable and short-lived, likely indicating insufficient concentration and exposure times occurred to result in plant death. The injured plants rebounded in 1-2 years following the treatment.

Table 3.4-3. Pigeon Lake herbicide treatment history. Treatment specifics provided by WDNR (herbicide permit records). Estimated concentrations calculated by Onterra, 2014.

Year	Acres	Herbicide Product	Total lbs of herbicide	Estimated lake-wide epilimnetic concentration (ppm)
2006	4.00	2,4-D (Navigate)	800	0.06
2010	1.70	2,4-D (Navigate)	300	0.02
2012	1.44	2,4-D (Navigate)	288	0.02

**Assumes an eplilimnetic volume of 1205 acre-feet and stratification occurring at 15 ft*

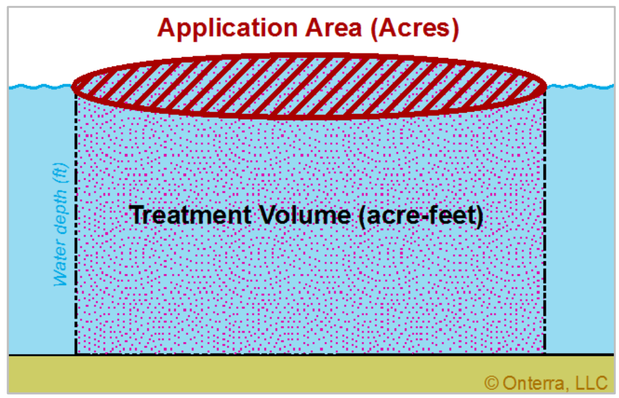

Figure 3.4-11. Herbicide spot treatment diagram.

Herbicide application rates for spot treatment are formulated volumetrically, typically targeting 2,4-D at 3.0-4.0 ppm ae. This means that sufficient 2,4-D is applied within the *Application Area* such that if it mixed evenly with the *Treatment Volume*, it would equal 3.0-4.0 ppm ae. This standard method for determining spot treatment use rates is not without flaw, as no physical barrier keeps the herbicide within the *Treatment Volume* and herbicide dissipates horizontally out of the area before reaching equilibrium (Figure 3.4-11). While lake managers may propose that a particular volumetric dose be used, such as 3-4.0 ppm ae, it is understood that actually achieving 3-4.0 ppm ae within the water column is not likely due to dissipation and other factors.

The spot treatments conducted in 2006, 2010, and 2012 were a small percent of the surface acreage of the lake. If the amount of herbicide applied to the treatment area distributed evenly within the upper mixing zone of the lake (epilimnion) the concentrations would be far insufficient to cause native or non-native plant impacts outside of the targeted areas. However, research suggests that the levels shown in Table 3.4-3 are overstated compared to what would actually be measured due to factors such as herbicide degradation and the availability of 2,4-D granules that sunk into the sediment. That being said, it is a good exercise to understand potential herbicide concentrations in non-targeted areas.

The most feasible control strategy for targeting widespread EWM populations on a system like Pigeon Lake is with herbicide treatments. Aggressive hand-removal methods may be able to reduce localized populations of Eurasian water milfoil, but the amount of effort required to reduce a population as widespread as shown on Map 6 would be immense.

Whole-lake treatments are typically conducted when the target plant is spread throughout much of the lake, as is the case for Pigeon Lake. A whole-lake herbicide treatment would be appropriate for Pigeon Lake if active management towards Eurasian water milfoil is determined to be a goal by the association.

Provided in the following text is a rough estimate of what a whole-lake treatment plan would consist of. This information was discussed within the management planning meetings:

> If a 40-foot buffer was placed around all mapped Eurasian water milfoil colonies, regardless of density, that would be about 12.9 acres. Sufficient liquid 2,4-D would be applied over these application areas such that it reached equilibrium with the upper stratified water layer (epilimnion, 15 feet deep in this example) such that it would result in a whole-lake 2,4-D concentration of 0.35 ppm ae. Budgetary cost estimates indicate that this treatment would cost around $10,000 including WDNR permit fees. The cost of conducting the appropriate treatment monitoring components would also need to be considered.

As discussed in the Implementation Plan, discussions were held with this planning project on the potential of conducting a whole-lake herbicide program. It was decided upon in 2014 that at the time, the impact of Eurasian water milfoil upon Pigeon Lake's ecology and recreation was not sufficient to warrant an ecosystem-wide control strategy. The Implementation Plan describes the PCLA's management strategy of continued monitoring of Eurasian water milfoil populations while preparations for a whole-lake treatment are outlined, should the action be deemed necessary in the future.

Though there is little primary literature on the subject matter, managers overseeing whole-lake 2,4-D treatments have documented changes in native plant occurrence following herbicide applications. Unpublished data indicates that northern water milfoil, coontail, slender naiad, leafy pondweed, and small/slender pondweed are species that may to decline following herbicide management actions. Of these species, northern water milfoil, coontail and slender naiad are located in Pigeon Lake. Ongoing studies indicate that some native species rebound quickly, whereas other species are slower to recover. In any large-scale management activity, the proper monitoring of environmental variables is very important. In addition to outlining a potential whole-lake treatment strategy for Pigeon Lake, the Implementation Plan also includes a strategy for the pre-treatment and post-treatment monitoring of the native aquatic plant community. This aspect, along with strategic dosing of the 2,4-D herbicide and monitoring of 2,4-D concentrations, will be crucial in evaluating and understanding a potential whole-lake treatment on Pigeon Lake.

3.5 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 reference. The following section is not intended to be a comprehensive plan for the lake's fishery; those aspects are being conducted by WDNR biologists overseeing Pigeon Lake. This section is to provides an overview of some of the data that exists, particularly in regards to issues that were brought forth by the PLMC stakeholders within this project. The following information was compiled based upon data available from the WDNR (WDNR 2013).

Pigeon Lake Fishery

Pigeon Lake Fishing Activity

Table 3.5-1 shows the popular game fish that are present in the system. When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its 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 (Figure 3.5-1). Because algae and plant matter are generally small in energy content, it takes a large amount of this food type to support zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the chain.

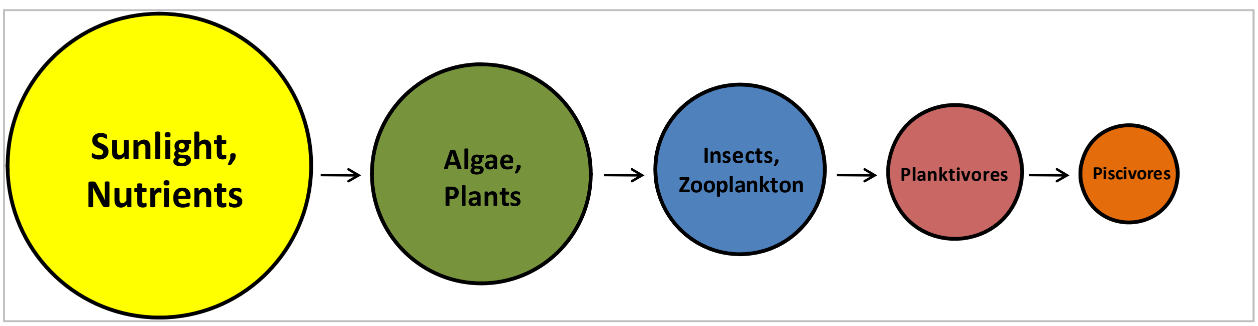

Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

Pigeon Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of productivity. An oligotrophic system contains fewer nutrients (less productive) while a eutrophic system contains more nutrients (more productive). This means Pigeon Lake should be able to support an appropriately sized population of piscovores when compared to eutrophic or oligotrophic systems.

Table 3.5-1. Gamefish present in Pigeon Lake with corresponding biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Brown Bullhead	*Ameiurus nebulosus*	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation	Insects, fish, fish eggs, mollusks and plants
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Green Sunfish	*Lepomis cyanellus*	7	Late May - Early August	Shelter with rocks, logs, and clumps of vegetation, 4 - 35 cm	Zooplankton, insects, young green sunfish and other small fish
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish

Pigeon Lake Fish Stocking

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

In the 1950's, rainbow and brown trout were stocked in the lake in hopes of developing a two-story fishery. Few trout were found in future surveys, indicating no establishment had taken place. Stocking of trout was recommended to be discontinued at that time. During the 1970's lake residents requested that fisheries managers begin a walleye stocking program. Fisheries surveys since the 1970's have found that a naturally reproducing walleye population has not been established in the lake. To provide a fishable walleye population, stocking has continued since the start of the program. Stocking records are available in Table 3.5-2

Table 3.5-2. Fish stocking data available from the WDNR (WDNR 2013).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Brown Trout	Yearling	7,000	7
1973	Brown Trout	Yearling	5,000	13
2001	Largemouth Bass	Large Fingerling	3,850	1.3
2002	Largemouth Bass	Large Fingerling	882	5
2003	Largemouth Bass	Small Fingerling	1,925	2.2
1973	Walleye	Fry	750,000	
1980	Walleye	Fry	150,000	
1984	Walleye	Fingerling	3,800	3
1985	Walleye	Fingerling	3,800	4
1987	Walleye	Fingerling	1,140	7
1989	Walleye	Fry	3,800	3
1990	Walleye	Fingerling	230	5
1992	Walleye	Fingerling	2,211	3
1994	Walleye	Fingerling	2,368	2.5
1995	Walleye	Fingerling	1,911	2.8
1997	Walleye	Large Fingerling	2,150	2.7
1999	Walleye	Fry	130,000	
1999	Walleye	Small Fingerling	7,700	1.5
2001	Walleye	Small Fingerling	7,700	1.6
2002	Walleye	Small Fingerling	7,550	2.2
2003	Walleye	Small Fingerling	7,700	1.5
2005	Walleye	Small Fingerling	3,835	1.4
2009	Walleye	Small Fingerling	3,000	1.8
2011	Walleye	Small Fingerling	3,306	1.9
2013	Walleye	Small Fingerling	2,995	2

Pigeon Lake Substrate and Near Shore Habitat

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

According to the point-intercept survey conducted by the WDNR, 99% of the substrate sampled in the littoral zone on Pigeon Lake was sand, with 1% being classified as muck and no rocky substrates encountered. Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. 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 is 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 in muck as well.

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.

Pigeon Lake Regulations and Management

Because Pigeon Lake is located within southern Wisconsin, special regulations may occur that differ from those elsewhere. Table 3.5-3 displays the 2014-2015 regulations for species that may be found in Pigeon Lake. Please note that this table is intended to be for reference purposes only, and that anglers should visit the WDNR website for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Table 3.5-3. WDNR fishing regulations for Pigeon Lake, 2014-2015.

Species	Season	Regulation
Panfish	Open All Year	No minimum length limit and the daily bag limit is 25.
Largemouth bass*	May 3, 2014 to March 1, 2015	The minimum length limit is 14" and the daily bag limit is 5.
Northern pike	May 3, 2014 to March 1, 2015	The minimum length limit is 26" and the daily bag limit is 2
Walleye, sauger, and hybrids	May 3, 2014 to March 1, 2015	The minimum length limit is 15" and the daily bag limit is 5.
Bullheads	Open All Year	No minimum length limit and the daily bag limit is unlimited.
Rock, yellow, and white bass	Open All Year	No minimum length limit and the daily bag limit is unlimited.

**During the harvest season, there is a daily bag limit of five bass in total*

A 2006 WDNR survey report (Appendix E) discusses the management, as well as the challenges of the Pigeon Lake fishery. One of the critical challenges biologist Steve Hogler noted in this summary was the loss of habitat due to shoreline development. As discussed within this report, this is a critical area of habitat within a lake but also its development may impact the in-lake habitat. Aquatic plants form another type of habitat that can be impacted by recreational activities or other human disturbances. Mr. Hogler noted within the 2006 survey report that concerns were had regarding the aquatic plant community and its response to a Eurasian water treatment program that had occurred in 2006. While it is never the intention of herbicide treatments to impact native species, this may occur if treatments are not planned properly. Should further actions be implemented to control Eurasian water milfoil, proper planning of those actions as well as pre and post monitoring of the native aquatic plant community should take place to ensure that this important habitat type is not compromised.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Pigeon Lake ecosystem.
2) Collect detailed information regarding the presence of any invasive plant species within the lake, and gain an understanding regarding the extent of Eurasian water milfoil.
3) Integrate sociological information from Pigeon Lake stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of much of the Pigeon Lake's ecosystem, the folks that care about the system, and what needs to be completed to protect and enhance it.

A review of the historical water quality indicates that Pigeon Lake is in good condition with respect to this ecological component. Total phosphorus concentrations rank well when compared to other deep seepage lakes in Wisconsin, as do chlorophyll-*a* levels and water clarity. With the addition of zebra mussels to the ecosystem, it will be interesting to see the results of continued monitoring of these parameters and observe the impact on the lake's water chemistry and clarity. Through this planning project, two crucial areas were identified by Onterra ecologists regarding the lake's water quality: continued monitoring and improvement of the lake's shoreland condition. Continued monitoring of the lake's water quality through the Citizens Lake Monitoring Network is important because it provides continuous, reliable data for managers to use in trend analysis. Similar to a person monitoring their weight or cholesterol for health, monitoring the water quality of a lake is vital in making determinations of trends and sound management decisions.

The watershed of a lake influences the water quality in many ways. Large watersheds may drain many square miles of land, emptying surface water runoff to a lake through tributary streams. In smaller watersheds, less water is received by a lake as these streams are less developed. In the watershed analysis, it was determined the Pigeon Lake watershed has a direct draining component as well as an area that is drained by a small, intermittent stream that enters at the northeastern corner of the lake. The contribution of water and nutrient content from this stream can be estimated, but is largely unknown as it is variable depending on weather conditions, soil conditions, and human development in that part of the watershed.

While the bulk of the current direct watershed is largely in land cover types that typically export lower levels of nutrients, such as wooded and grassland areas, the intense level of residential development occurring immediately on the Pigeon Lake shoreline impacts the lake harshly in the form of diminished habitat value and unnaturally inflated nutrient and sediment runoff levels. In 2013, 65% of the shoreline was found to be in a highly developed state. A developed shoreline has little or no buffering capacity against surface runoff; the small plants, often turf grass, and their root structures found in urbanized areas, are unable to filter nutrients and sediment from runoff as do natural landscapes. A natural shoreland area has a variety of shrubs, grasses and trees with complex branching and root structures. This type of natural vegetation filters surface runoff and slows erosion of the shoreline. It also provides important habitat for terrestrial and aquatic animals.

As mentioned above, at this time, the water quality of Pigeon Lake is considered to be good. However, spotty historical data only stretches back to the early 1970's; therefore, the lake's water quality prior to that time is not known, but was likely better. As time continues, the impacts of the urbanized landscape occupying Pigeon Lake's shoreline will be seen in decreased water quality. A great deal of research has shown the negative impacts that highly developed shorelines have on lakes, so while the impacts of Pigeon Lake's urbanized shoreline are not necessarily apparent now, they most certainly will be sometime in the future. It is important that Pigeon Lake riparians understand the impacts their properties have on the lake and begin taking actions to minimize those impacts before the symptoms appear in the lake's water quality.

The aquatic plant community of Pigeon Lake has been comprehensively studied several times, most recently in 2012 and in 2005. An analysis of these data indicates that the aquatic plant community in Pigeon Lake has improved since 2005, with species diversity, richness and quality improving. The aquatic plant community now ranks as average when compared to the communities found in lakes within the same ecoregion and across the state. Of greatest concern to many Pigeon Lake stakeholders is the Eurasian water milfoil that is known to exist in the lake. Small spot treatments have been utilized by the PLMC in recent years, targeting colonies of Eurasian water milfoil in various areas of Pigeon Lake. These treatments have ended with seasonal or limited success (anecdotal accounts). The difficulty with spot treatments is that a sufficient concentration of herbicide is rarely seen within the treatment area, due to the dilution of the chemical product into non-treatment area portions of the lake. Research indicates that this dilution occurs immediately, and may completely reduce the concentration of herbicide in a treatment location within a matter of hours.

While the Eurasian water milfoil is certainly a threat to Pigeon Lake, the current population in the lake is not at a level in which recreational activity or the ecology of the lake is impacted. Therefore, the PLMC has options to consider for managing this invasive plant. In the past, spot treatments of Eurasian water milfoil were conducted on the lake. These treatments were met with limited and seasonal success; rebounding of the plants were observed in the same areas the following year. In order to effectively treat Eurasian water milfoil, a whole-lake approach is the best way in which more than seasonal control can be obtained.

During a whole-lake treatment, the herbicide is applied to the designated treatment areas but is expected to spread throughout the epilimnion of the lake. Anticipating this spread of herbicide, a strategy can be enacted that would result in an expected whole-lake epilimnetic concentration of herbicide that is smaller than what would normally be seen in a spot treatment scenario, but would persist for a longer period of time. The benefit is that this treatment would likely be less than twice the cost of an annual spot treatment, but would very likely control Eurasian water milfoil for a number of years. The downside of this strategy is the waiting game that ensues; Pigeon Lake stakeholders must tolerate a growing Eurasian water milfoil population to the point at which it warrants a wide-scale treatment and ensures the greatest "bang for the buck", or more plants to treat with the same amount of herbicide. Monitoring of the population will be important in years to come, with proper planning crucial for success.

Pigeon Lake is a heavily visited and utilized lake, for fishing, watercraft use, swimming, entertaining, relaxing, etc. In any lake that hosts a variety of activities, user conflict is likely to occur. A Town of Liberty ordinance currently states the "No-Wake" hours for the lake, which are between 6pm and 11am. Though this plan does not recommend changing these hours by any means, it is important for Onterra ecologists to discuss information on the importance of following Wisconsin boating regulations, both from a safety and legal perspective but also from an ecological perspective. Those wishing to operate boats and personal water craft must abide by State of Wisconsin boating regulations. These regulations include:

- It is illegal for vessels to operate at "excessive" speeds
- It is illegal to operate a boat or personal watercraft (PWC) within 100 feet of any dock, raft, pier, restricted area, swimmer or lake shoreline at greater than a no-wake speed.
- PWCs may not operate at greater than no-wake speed within 200 feet of a shoreline, and may only operate between sunrise and sunset.

\- *Wisconsin Boating Regulations and Handbook, 2014*

As stated above, current state law requires a slow-no-wake zone for PWC within 200 feet of the shoreline. This law was enacted for personal safety reasons as well as to reduce the impacts of PWCs, which can negatively affect near-shore ecosystems due to their ability to navigate in relatively shallow water. A slow-no-wake bill (enacted as 2009 Wisconsin Act 31) took effect in February 2010 which establishes a slow-no-wake zone within 100 feet of the shoreline for all watercraft. Boating close to the shoreline can cause shoreline erosion, stir up lake bottom sediments causing turbidity and release nutrients such as phosphorus which can contribute to algal growth. In addition, boating in these areas can be harmful to fish habitat as propellers uproot emergent plant populations. It is up to Pigeon Lake stakeholders to obey the law and also be conscientious of the impact they may be having on other lake users as well as the health of the Pigeon Lake ecosystem.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Pigeon Lake Planning Committee and ecologist/planners from Onterra. It represents the path the PLMC 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 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: Maintain Current Lake Health

Management Action: Continue monitoring of water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Volunteers from the PLMC have collected Secchi disk clarities and water chemistry samples during this project and in the past through the WDNR Citizens Lake Monitoring Network (CLMN). Stability will be added to the program by selecting a core group of 2-3 individual from the PLMC to coordinate the lake's volunteer efforts. These volunteers will ensure that appropriate data is collected, and also entered into the WDNR's online data warehouse, SWIMS (Surface Water Integrated Monitoring System). Additionally, should turnover of water quality volunteers occur, there will be a number of people trained in CLMN protocols which will ease the transition to newly recruited volunteers.

Action Steps:

1. Board of directors recruits 2-3 volunteers to conduct lake sampling.
2. Volunteers direct water quality monitoring program efforts.
3. Volunteers collect data and coordinator/volunteers report results to WDNR and to association members during annual meeting.

Management Action: Update Management Plan in five years (2019).

Timeframe: Initiate in 2018.

Facilitator: Board of Directors

Description: While monitoring water quality and other lake parameters is the first step in understanding a complex lake ecosystem, analyzing these data in an objective manner is a crucial step that is required for proper lake management. Detection of trends is an important step to establish before actions can be taken to correct issues that may arise. With management actions such as Eurasian water milfoil management taking place on Pigeon Lake, it is even more important to identify any changes that are taking place in the lake's water quality or aquatic plant community. Finally, given the role a watershed plays in a lake's condition, it is important to periodically identify changes in the watershed with periodic assessments.

The PLMC wishes to continue to manage their lake in a responsible manner, and address potential issues before they arise. With this mindset, discussions took place at the second Planning Meeting about revisiting the PLMC's management plan in the future to ensure that monitoring of the lake is up to date and management actions fully address the issues that are present. The management planning process would allow for continued input from lake residents on management activities as well. It is recommended that the PLMC initiate this management planning update project in 2019, with planning for the project to begin in 2018.

Action Steps:

1. Board of directors select professional consultant to oversee process.
2. Prepare Lake Planning grant application for December 10, 2018 deadline.

Management Goal 2: Monitor and Control Aquatic Invasive Species within Pigeon Lake

Management Action: Continue Clean Boats Clean Waters watercraft inspections at the Pigeon Lake public access.

Timeframe: Continuation of current effort

Facilitator: Board of Directors

Description: Members of the PLMC have been trained on Clean Boats Clean Waters (CBCW) protocols and complete inspections at the public landings during the open water season. Additionally, the public access point has been monitored by personnel involved with the Manitowoc County Lakes Association (MCLA) through a county-wide effort. Because this system holds several aquatic invasive species, the intent of the boat inspections is to prevent additional invasives from entering the lake and also to keep watercraft users from transporting these species to other lakes. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of aquatic invasive species on lakes and educating people about how they are the primary vector of transmittance. In 2013 the level of effort was the greatest in the six years since watercraft inspections began; 103 boats were inspected and 260 people contacted during 52 hours of watercraft inspections.

This approach to informing lake users about the dangers of aquatic invasive species has proven to be effective on a statewide basis. The PLMC will continue CBCW inspections at its public access location, and will more importantly continue to pursue volunteers through its membership and partnering organizations to staff the public landing for this effort. This program should be run in parallel to the MCLA county-wide program to ensure that efforts are spent most efficiently.

The PLMC can take advantage of a new streamlined CBCW application process, through the WDNR's Aquatic Invasive Species Control grant program. This program provides grant funding of 75% of total project costs not to exceed $4,000 for each boat landing with a CBCW inspection program. More information is available by contacting Gary Hanson, WDNR Environmental Grant Specialist at (920) 662-5123 or visiting http://dnr.wi.gov/Aid/AIS.html.

Action Steps:

1. Trained CBCW volunteer(s) conduct inspections during high-risk weekends, report results to WDNR and to association members.
2. Volunteer data collected are automatically added to the WDNR database and available through SWIMS by the volunteer.
3. Members of association periodically attend CBCW training session through AIS Coordinator Tom Ward.
4. Promote enlistment and training of new of volunteers

Management Action: Reduce occurrence of purple loosestrife and pale yellow iris on Pigeon Lake shorelands.

Timeframe: Continuation of current effort.

Facilitator: Board of Directors.

Description: Purple loosestrife and pale yellow iris are two wetland species that have migrated from Europe and Asia to the United States, where they can aggressively out-compete native shoreland and wetland species for space and resources. Both of these species were observed flowering along the Pigeon Lake shorelands in several areas (Map 5).

Manually removing pale yellow iris plants is likely the best control strategy for this species. Manitowoc County Aquatic Invasive Species Coordinator Tom Ward can provide technical advice hand removal techniques as well as proper disposal methods. PLMC members have utilized *Galerucella sp.* beetle releases to effectively combat purple loosestrife along the Pigeon Lake shoreline in the past. This method is recommended for continuation in larger colonies, while smaller colonies or single plants can be addressed with herbicide use and manual removal. Again, AIS Coordinator Tom Ward would be able to provide PLMC volunteers with resources and other forms of assistance for purple loosestrife management.

As most of the pale yellow iris and purple loosestrife colonies are likely found on private land, it will be up to the PLMC Board of Directors to facilitate property owner permission before volunteers address AIS populations on these shorelands. Another aspect of this management action will be the monitoring and record keeping that should occur in association with the control efforts. These records would include maps indicating infested areas and associated documentation regarding the actions that were used to control the areas, the timing of those actions, and the results of the actions. These maps and records will be used to track and document the successfulness of the program and to keep the PLMC and other management entities updated.

Action Steps:

1. Board of directors select 2-3 volunteers to oversee pale yellow iris and purple loosestrife management..
2. Volunteer team contacts Tom Ward to discuss monitoring and management strategies.
3. Property owner permission and effort documentation plan established by volunteer team prior to completing control efforts.
4. Team provides annual update to PLMC Board of Directors on activities.

Management Action: Develop monitoring and control strategy for Eurasian water milfoil within Pigeon Lake.

Timeframe: Begin summer 2014.

Facilitator: Board of Directors

Description: Eurasian water milfoil is one of the most concerning of all of Wisconsin's aquatic invasive species, due to its rapid spread and impact on recreational areas. According to the WDNR website (accessed May 2014) Eurasian water milfoil has been documented in 674 Wisconsin lakes and rivers. While it has been found in the Midwest for decades, much is still being learned about its distribution, environmental preferences/tolerances, interaction with native species and management.

During 2013 studies, Onterra ecologists mapped the locations and densities of Eurasian water milfoil within Pigeon Lake (Map 6). In lakes without aquatic invasive species, early detection of pioneer colonies can lead to successful control and possibly even eradication. When the level of invasive plant colonization reaches a whole-lake level, the "fix" is far beyond a rapid and aggressive management action. At this point in time the level of Eurasian water milfoil has surpassed the point by which hand-removal or small herbicide treatment methodologies would be beneficial in management of this species.

Treatments using United States Environmental Protection Agency (USEPA) approved herbicides have been used on Wisconsin lakes to control aquatic invasive species such as curly-leaf pondweed and Eurasian water milfoil. 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 dilute herbicide concentration within aquatic systems. Understanding concentration-exposure times are important considerations for aquatic herbicides. Successful control of the target plant is achieved when it is exposed to a lethal concentration of the herbicide for a specific duration of time. Much information has been gathered in recent years, largely as a result of a joint research project between the WDNR and the US Army Corps of Engineers (USACE). Based on their preliminary findings, lake managers have adopted two main treatment strategies; 1) whole-lake treatments, and 2). spot treatments. These strategies are discussed extensively within this report's Aquatic Plant Section.

During the planning meetings associated with this project, the Eurasian water milfoil population in Pigeon Lake was discussed extensively. One aspects that was focused upon was the approaches to managing the population through herbicide use. Eurasian water milfoil grows rapidly after ice-off on a lake and is often spotted from the surface ahead of the native plants. Eurasian water milfoil spreads rapidly through auto-fragmentation, a process where the plant produces shoots from its structure that break off and float into the water. These shoots have the ability to start new plants when they reach the lake bottom. Though auto fragmentation is thought to be the primary means of reproduction, Eurasian water milfoil is also known to reproduce through seed production and through horizontal connections called stolons. Thus, Eurasian water milfoil is treated in the early spring with herbicides to kill the plant before it is able to auto fragment. An added benefit of this timing is that the native plant biomass is still low at this time, resulting in less exposure of the herbicide to these species.

For a Eurasian water milfoil treatment on Pigeon Lake, a likely treatment scenario include the assumption of a specific area treated, yet whole-lake dispersal of the herbicide assumed. The cost of a single treatment would be roughly $10,000, not including professional monitoring of the native and non-native plant species, project logistics, reporting, etc. It is believed that this approach would be more effective than spot treatments, which would be only slightly cheaper and provide seasonal control.

Researchers through the University of Wisconsin have found that often, overabundance of invasive species is not the case. In fact, in most cases invasives exist in moderate to low numbers, sometimes mixing in within native species and often in similar abundances to native species (Hansen et al, 2013). The study suggests that on a large scale, it is in a minority of cases that invasives increase their abundance greatly and impose ecological threat to native ecosystems. This circumstance has been documented in Wisconsin lakes with respect to curly-leaf pondweed and Eurasian water milfoil. Essentially, managers are finding that sometimes these species, though non-native, do not always act as “invasive”. Given the right conditions, it is possible for non-native and native species to co-exist. This observation provides further testimony to the PLMC’s current approach to managing their Eurasian water milfoil population of monitoring the population until it reaches a point in which a herbicide control action is warranted. The strategy that the PLMC will employ is further described below.

Eurasian water milfoil monitoring and control strategy

The PLMC have elected to continue professionally monitoring Eurasian water milfoil in Pigeon Lake. During 2014-2017, an assessment of the Eurasian water milfoil colonies would occur during the late summer, using a similar qualitative survey method to the one utilized in the 2013 survey. In 2017, or sooner if deemed appropriate, a point-intercept survey would be completed to gather data on native and non-native plant abundance in the lake prior to a whole-lake treatment. Determination of need for a whole-lake treatment would be met through the data collected as well as conversations between the PLMC, WDNR and Onterra staff. If the colonies have expanded little or have changed in density very little during these years, the PLMC may elect to continue monitoring and forgo an herbicide treatment until the presence of the species in this lake warrant a treatment. If expansion or density increases are observed, the PLMC may elect to proceed with herbicide treatments on Eurasian water milfoil. This herbicide treatment would occur using the methodology outlined below.

Pre-treatment Survey
In April/May, professional ecologists would visit areas marked through previous surveys to verify the growth of Eurasian water milfoil. This survey provide confirmation on the plant's growth and would be utilized to determine final treatment areas. Herbicide treatments would then be conducted in late May/early June by a certified applicator.

Post-treatment Survey
Eurasian water milfoil peak-biomass surveys would be conducted in August/September following herbicide treatments. During this survey, data would be collected to determine the treatment's effectiveness as well as map remaining and new areas of infestation. Following a whole-lake treatment, a whole-lake point-intercept survey would be conducted. Comparison of data prior to and following the whole-lake treatment would allow for a quantitative comparison of the native and non-native aquatic plant communities before and after treatment.

Herbicide Concentration Monitoring
If invited to participate within a WDNR's herbicide monitoring program, trained PLMC volunteers would collect water samples from treatment areas at set intervals to understand the nature of herbicide concentration in these areas. Following collection, properly preserved samples will then be sent to a laboratory for analysis. The information obtained from this monitoring will tell the PLMC if target concentrations were reached, how long the herbicide resided in the water column, how long it took to diffuse, etc. In short, this information would be useful for future decision making.

Control Project Applicable Funding
In December of 2014, the PLMC would submit a WDNR Aquatic Invasive Species Education, Prevention and Planning grant to fund 2015-2017 monitoring and reporting. Should an herbicide treatment program be the outcome of these surveys, an Established Population Control grant would be applied for to fund a multi-year project, including treatments and further monitoring.

Action Steps:

1. Board of directors retain consultant to conduct 2014 monitoring studies.
2. Board of directors submit an AIS-EPP grant application to the WDNR by December 10, 2014 to prepare for 2015-2017 studies.
3. At the completion of 2017 studies, prepare AIS-EPC grant application if herbicide treatments are warranted.

Management Goal 3: Strengthen Association Relationships, Effectiveness, and Lake Managing Capacity

Management Action: Increase PLMCA membership and volunteerism.

Timeframe: Continuation of existing efforts

Facilitator: Board of Directors

Even through lake associations consist of individuals who are passionate about the lake they reside upon, it is often difficult to recruit new members or volunteers to join a lake association. Lake residents with a "summer cottage" may visit their lake property only several times a year, or only during weekends. Volunteering or joining an organization may be difficult for them because of the limited involvement they have with the lake community. Finding additional volunteers may be difficult for this reason as well. Additionally, some lake association members may be elderly and retired, so labor intensive volunteer jobs could be difficult to perform. Other lake residents have cut back on volunteering because of recent economic downturns, have concerns over the time commitment involved with various volunteer tasks, while others may simply have not been asked to lend their services.

It will take the combined efforts of many lake residents to ensure that the ecological condition of Pigeon Lake and its recreational potential is preserved for future generations. Realizing this, the PLMC has set their sights on a goal of 100% lake resident membership within their association. Additionally, they wish to increase the current level of volunteer involvement for lake management and PLMC social activities. At Planning Meeting II, the planning committee and Onterra staff identified several opportunities to assist in reaching this goal:

1. A spring membership drive, where the PLMC would identify non-renewing members and people who have never joined. Contact would be made with these individuals annually to discuss membership with the PLMC.
2. Creation of a brochure that describes the PLMC and current/ongoing lake management activities.

To increase volunteerism, PLMC follow the steps below, which are synthesized from various volunteer recruitment organizations:

1. Appoint a volunteer coordinator. The coordinator's duties are to recruit, train, supervise and recognize volunteers. Building and maintaining a volunteer database with names, contact information, tasks, hours completed, etc. will be necessary.

2. Recruit new volunteers through personal invitation, not telephone, email or newsletter notification. Engaging a person in a friendly atmosphere through a personal invitation is more likely to result in a successful recruitment than through impersonal contact.

3. Coordinator will have duties outlined prior to recruiting volunteers. A volunteer's time should not be wasted! Work descriptions, timeframes and other specifics should be known by each worker prior to their shift.

4. Coordinator will be flexible in allowing volunteers to contribute towards project designs and implementation. Recruiting new leaders through delegating tasks will empower volunteers and give them reason to continue volunteering.

5. The board of directors will recognize volunteers through incentives and appreciation. Snacks, beverages, public acknowledgement and other means of expressing appreciation are encouraged.

Action Steps:

1. Board of directors appoints personnel to oversee spring membership drive, PLMC brochure creation and volunteer coordinator.
2. Volunteer coordinator develops volunteer database and designs structure to retain volunteer assistance as outlined by steps above.

<u>Management Action:</u> Facilitate efficient dialogue with other management entities.

Timeframe: Initiate 2014/2015

Facilitator: Board of Directors

The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while other organizations are similar to the PLMC in that they rely on voluntary participation.

It is important that the PLMC actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. The primary management units regarding Pigeon Lake include governmental units such as the WDNR, but also include entities such as the Manitowoc County Lakes Association and Manitowoc County Aquatic Invasive Species Coordinator. Each entity is specifically addressed below.

Action Steps:

1. See table guidelines on next page.

Table 5.0-1. Pigeon Lake management partner contact list.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Manitowoc County Lakes Association	President (Gene Weyer – 920.758.2897)	Protects Manitowoc County waters through facilitating discussion and education.	Once a year or as needed.	Become aware of training or education opportunities, partner in special projects, or networking on other topics pertaining to Manitowoc County lakes.
Manitowoc County Aquatic Invasives Coordinator	AIS Coordinator (Tom Ward – 920.588.0047)	Oversees AIS monitoring and prevention activities locally.	Twice a year or more as issues arise.	Spring: AIS training and ID, AIS monitoring techniques Summer: Report activities to Mr. Ward.
Manitowoc County Park & Highway Office	Superintendent (Adam Backus – 920-683-4189)	Oversees development & operation of county parks	As needed.	Oversees public access park, can be contacted for support with projects involving Manitowoc County Lakes.
Town of Liberty	Town Chairman (Bill Pitz – 920.901.9737)	Oversees ordinances and other items pertaining to town.	As needed.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Wisconsin Department of Natural Resources	Fisheries Biologist (Steve Hogler – 920.662.5480)	Manages the fishery of Pigeon Lake.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Mary Gansberg– 920.662.5489)	Oversees management plans, grants, all lake activities.	As needed.	Information on lake management plans, WDNR permits, AIS management or to seek advice on other lake issues.
	Warden (Byron Goetsch – 920.662.5128)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity on the lake, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandra Wickman – 715.365.8951)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	PLMC members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Goal 4: Increase PLMC's Capacity to Educate and Communicate with Lake Stakeholders

<u>Management Action:</u> Support an Education and Communication Committee to promote lake health, public safety, and quality of life on Pigeon Lake.

Timeframe: Enhancement of existing efforts

Facilitator: Board of Directors

Description: Education represents an effective tool to address issues that impact water quality such as lake shore development, lawn fertilization, and other issues such as air quality, noise pollution, and boating safety. An Education Committee will be created to promote lake protection through a variety of educational efforts.

Currently, the PLMC has several educational initiatives in place for Pigeon Lake stakeholders. The association distributes Pigeon Lake updates through e-mail which conveys important information regarding Pigeon Lake management, upcoming association events, and other pertinent information. The association does not currently distribute a newsletter, but does host several social events through the year, which aid in spreading information about lake happenings as well as forming a sense of community amongst riparian property owners.

By forming an Education Committee, the PLMC will be have a group of stakeholders dedicated to coming up with new and innovative ways of educating Pigeon Lake stakeholders on the ecology of their lake, rules and regulations regarding activities on the lake, and what they may do to protect or restore Pigeon Lake. Example topics include:

- Aquatic invasive species monitoring updates
- Boating safety and ordinances
- Catch and release fishing
- Noise, air, and light pollution
- Shoreland restoration and protection
- Fishing Rules
- Other topics

The committee will be responsible for reaching out to state or local affiliates which can provide them with educational pamphlets, other materials or ideas. These partners may be some of those included in the table found under Management Goal 3.

Action Steps:

1. Board of directors appoints an Education and Communication Committee.
2. Committee creates educational materials based upon subject matter specified in text above, with additional topics added as needed.
3. Committee distributes educational material.

Management Goal 5: Protect and Enhance Fisheries of Pigeon Lake

Management Action: Work with WDNR fisheries biologist to implement coarse woody habitat project.

Timeframe: Initiate 2015

Facilitator: Board of Directors

Description: As a result of the coarse woody habitat survey, it was discovered minimal coarse woody habitat were observed along the Pigeon Lake shoreline. In fact, roughly 36 pieces of coarse woody habitat were mapped along 1.7 miles of shoreline on Pigeon Lake's shoreline. In contrast, some undeveloped lakes may have several hundred pieces of coarse woody habitat per mile of lake shoreland. The benefits of coarse woody habitat are well researched, and have implications for many organisms in the aquatic food web, including algae, insects, amphibians and fish.

In order to improve fishery habitat on Pigeon Lakes, the PLMC wishes to create coarse woody habitat in appropriate areas of the lake. Projects would likely include tree drops extending from shorelands into the lake – see Section 3.0, Shoreland Research, for more details on this type of habitat. This would be a coordinated effort between the PLMC, private landowners, WDNR fisheries biologists and lakes coordinator. The Manitowoc County Fish and Game Protective Association would be an additional management entity to partner with.

Action Steps:

1. PLMC representative discusses potential project with WDNR fisheries biologist Steve Hogler to determine feasibility.
2. PLMC representative discusses grant funding opportunities with Manitowoc County Land and Water Conservation Department and WDNR lakes coordinator Mary Gansberg to determine applicability.
3. PLMC solicits interest from lake residents through conversation or association meetings. WDNR fisheries biologist must determine potential sites are suitable for introduction of coarse woody habitat structure.

Management Action: Work with fisheries managers to understand and enhance fishery while communicating aspects of fishery studies to PLMC members.

Timeframe: Continuation of current effort

Facilitator: Board of Directors

Description: Fishing, a hobby that is no stranger to Wisconsin residents, is an important activity for Pigeon Lake stakeholders. In order to maintain the fishery of Pigeon Lake, a good understanding of its ecological condition and human's impact on it is required. Further, it is important that Pigeon Lake stakeholders have a realistic expectation about what type of fishery the lake is capable of supporting.

The PLMC has a good relationship with WDNR fisheries biologists, and would like to continue to strengthen this relationship. A representative of the board of directors will be appointed to contact WDNR biologist Steve Hogler on an annual basis. The purpose of the contact would be to go over any surveys that are occurring that particular year, obtaining results from previous surveys, etc. The PLMC volunteer may ask for a WDNR representative to come to a PLMC meeting and deliver a short presentation on the fishery status of Pigeon Lake following completed lake surveys. Additionally, the PLMC may discuss options for improving the fishery in Pigeon Lake, which may include changes in angling regulations, habitat enhancements, or private stocking.

Biologist Steve Hogler has a comprehensive fisheries survey scheduled for 2014. The PLMC is anxious to hear information the survey produces about the condition and composition of the Pigeon Lake fish community. As Mr. Hogler will likely recommend certain actions to improve the fishery, this provides an opportunity for the PLMC to be the force behind initiation of these recommendations.

Action Steps:

1. See above description.

6.0 METHODS

Watershed Analysis

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

Aquatic Vegetation

Early Season AIS Survey

Surveys of AIS were completed on Pigeon Lake during a June 2013 field visit, in order to correspond with the anticipated peak growth of curly-leaf pondweed and pale yellow iris. Eurasian water milfoil was also mapped during this time, but would be revisited during a late summer Peak Biomass Survey. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Pigeon Lake to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study by the WDNR in 2012.

Community Mapping

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

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

Eurasian Water Milfoil Peak Biomass Survey

A survey was conducted in August of 2013 to assess Eurasian water milfoil at its peak growth. Data collected during the Early Season AIS Survey was verified during this survey, using sub-meter GPS technology to map point locations and polygons (colonies).

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