Pickerel Chain of Lakes

Oconto County, Wisconsin

Comprehensive Management Plan

November 2016

DRAFT

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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:

Pickerel Chain of Lakes Planning Committee

The Planning Committee was comprised of several riparian property owners from each of the chain lakes.

Drew Zelle
Dennis Van Handel
Jan Gonnering
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1.0 INTRODUCTION

The Pickerel Chain of Lakes includes three waterbodies (Map 1); the 28-acre Little Pickerel Lake with a maximum depth of 26 feet, and the 51-acre Smoke Lake, with a maximum depth of 8 feet, flow into Pickerel Lake, which at 185 acres is the largest in the chain and has a maximum depth of 14 feet. Pickerel Lake flows out to Pickerel Creek, which eventually meets the North Branch Oconto River. Smoke and Little Pickerel Lakes are considered spring lakes, while Pickerel Lake is considered a drainage lake. None of the three lakes are listed by the Wisconsin Department of Natural Resources (WDNR) as being impaired. The chain can be accessed through a town-owned launch supporting 12 vehicle-trailer stalls, restrooms, ADA (Americans with Disabilities Act) docking, a public beach, and picnic area. A carry-in access owned by the Pickerel Chain Lake Association is located at the end of Little Pickerel Lane on Little Pickerel Lake. The Nicolet Trail passes within 1,000 feet of the chain and the Chequamegon-Nicolet Forest abuts Pickerel Lake along two shorelines.

The chain lakes are held at an artificially higher water elevation due to a dam located at the northern-most point of Pickerel Lake on Pickerel Creek (Map 1). The original dam was built in 1961 to hold water for recreational purposes, the dam is owned by the Town of Townsend and the dam structure, excluding the earthen dike were rebuilt during 2012-2014. The dam has a total structural height of 10.3 feet and a hydraulic height of 5.3 feet. The dam typically stores roughly 517 acre-feet of water, but is built to maintain a maximum storage of 1,750 acre-feet.

The Pickerel Chain Lakes Association (PCLA) is the primary management group for the chain. The group is active in fish-stocking and other management activities and was the sponsor of this management planning project. During the project, PCLA volunteers served integral roles in monitoring the lakes' water quality, serving on various committees, reviewing documents and providing input and numerous project meetings.

Lake at a Glance - The Pickerel Chain Lakes

		Pickerel Lake	Little Pickerel Lake	Smoke Lake
Morphology	**Acreage**	185	28	51
	Max. Depth (ft)	14	26	9
	Volume (Acre-ft)	1,287	212	315
	Mean Depth (ft)	6.5	7.5	6.1
Vegetation	**Curly-leaf Survey Date**	6/3/15	6/3/15	6/3/15
	Comprehensive Survey Date	7/13/15-7/14/15	7/13/15-7/14/15	7/13/15-7/14/15
	Number of Native Species	47	27	21
	Non-Native Species	1	0	0
	Threatened/Special Concern Species	0	0	0
Water Quality	**Trophic State**	Mesotrophic	Mesotrophic	Mesotrophic
	Limiting Nutrient	Phosphorus	Phosphorus	Phosphorus
	pH	8.1	8.2	8.3
	Sensitivity to Acid Rain	Not sensitive	Not sensitive	Not sensitive
	Watershed to Lake Area Ratio	4:1	5:1	2:1

2.0 STAKEHOLDER PARTICIPATION

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

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

Project Planning Process

Kick-off Meeting

On July 25, 2015, Onterra ecologist Dan Cibulka attended the PCLA's annual meeting to deliver a presentation which described the management planning project. All of the project's components were discussed, as well as a general timeline for activities and opportunities for public participation. Following the presentation, Mr. Cibulka answered many questions on general lake ecology and then met with a group of 10-12 lake residents that volunteered to serve on the Pickerel Chain Lakes Planning Committee. The tasks the planning committee were to undertake, including reviewing project documents and participating in 2016 planning meetings, were discussed with this group at that time.

Planning Committee Meetings

Two planning meetings were held with the Pickerel Chain of Lakes Association Planning Committee during the summer of 2016. The first meeting, held on June 6, 2016 and facilitated by Tim Hoyman, Onterra, LLC, lasted a bit over 3 hours and covered all of the data collected and compiled by Onterra over the past 16 months. The goal of the meeting was to inform the committee members about the Pickerel Chain of Lakes, answer any questions they had, and discuss the findings. To better foster their understanding and bring about a more active discussion, the draft report sections contained below were supplied to the group a week prior to the meeting.

The second planning meeting was held on August 8, 2016 was facilitated by Tim Hoyman and included a brainstorming exercise to bring out positive and negative challenges the PCLA faces in management the chain. These challenges were then refined and converted to goal statements. Discussion was then held to determine actions the association could implement to meet those goals. The implementation plan frame created during this meeting was used to develop the expanded implementation plan found below.

Wrap-up Meeting
Scheduled for May 20, 2017. At this meeting, the results of the planning project studies will be highlighted and the approved management plan will be detailed. The objective of the meeting is to bring about a better understanding of the Pickerel Chain of Lakes among the association members and to inform them of how the management plan will guide them in the protection and enhancement of the chain.

Management Plan Review and Adoption Process
The first draft of this management plan was provided to the PCLA Planning Committee for their review in October 2016. The committee's comments (Appendix A) were integrated within the second draft of the plan, as applicable, and that version was provided to the PCLA membership, Oconto County, and WDNR in November 2016. Electronic copies were provided to the current PCLA email list and hardcopies were placed in the Townsend Town Hall and Library. Members were given until December 20, 2016 to provide comments. Several members provided comments to the PCLA Planning Committee Chairperson (Appendix A) and those comments were integrated into version 3 of the plan as applicable. Information provided by WDNR Fisheries Biologist, Chip Long, was also integrated. Draft 3 of the Pickerel Chain of Lakes Management Plan was provided to the association board of directors in early January 2017 and on January 14, 2017, the board approved and accepted the management plan.

Stakeholder Survey

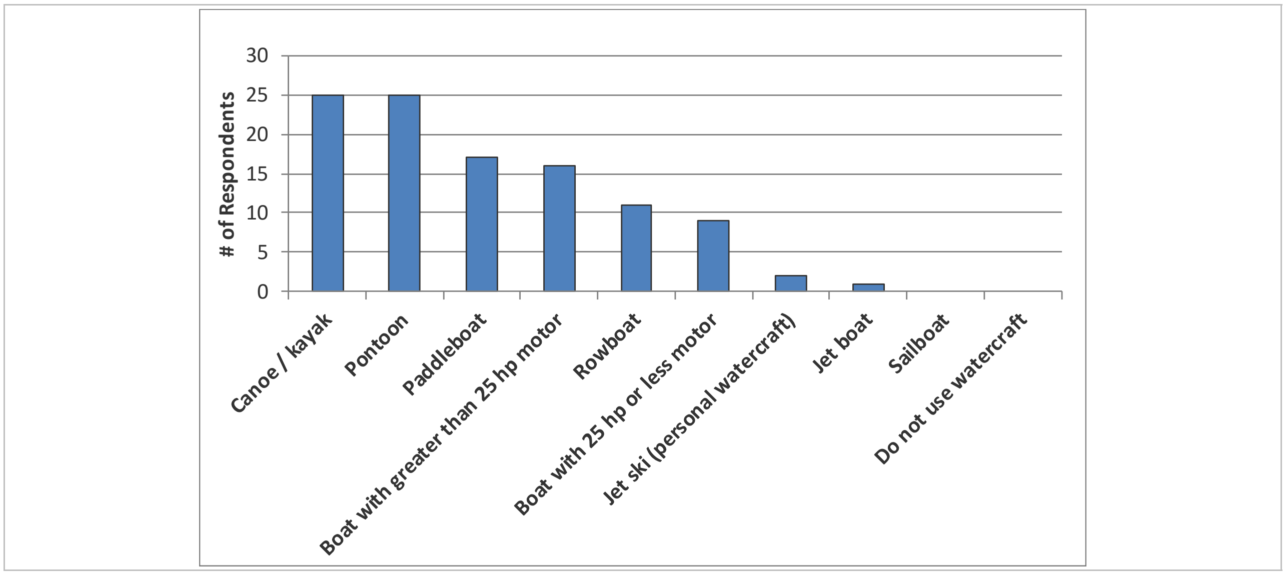
As a part of this project, a stakeholder survey was distributed to PCLA members and non-member riparian property owners. This survey was designed by Onterra staff and the PCLA planning committee during the summer of 2015. The draft survey was sent to a WDNR social scientist for review in October of 2015. During November 2015, the eight-page, 37-question survey posted online through Survey Monkey for property owners to answer electronically. If requested, a hardcopy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a PCLA volunteer for analysis. Forty-five percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. While the level of return does not meet the 60% threshold, the data is still useful in the planning process. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for the Pickerel Chain of Lakes. Thirty-eight percent of stakeholders visit on weekends throughout the year, while 27% are year-round residents and 19% are seasonal residents (Appendix B – Question #3). Sixty-two percent of stakeholders have owned their property for over 15 years with 38% of those owning their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. More than half of survey respondents indicate that they use a canoe/kayak or a pontoon on the chain (Question

#15). Motorboats of various sizes, paddleboats, and rowboats were also popular choices on this question. As seen on Question #17, fishing is the most important activity for property owners on the Pickerel Chain. The majority of respondents find relaxing and enjoying the nature around their property more important than recreational motorized watercraft use. Onterra, with the help of a social scientist from the WDNR, created more in-depth questions about fishing and the fish kills on the Pickerel Chain. These questions will be further covered in the fisheries section.

Question #15: What types of watercraft do you currently use on the lake?



Question #17: Please rank up to three activities that are important reasons for owning your property on or near the lake.

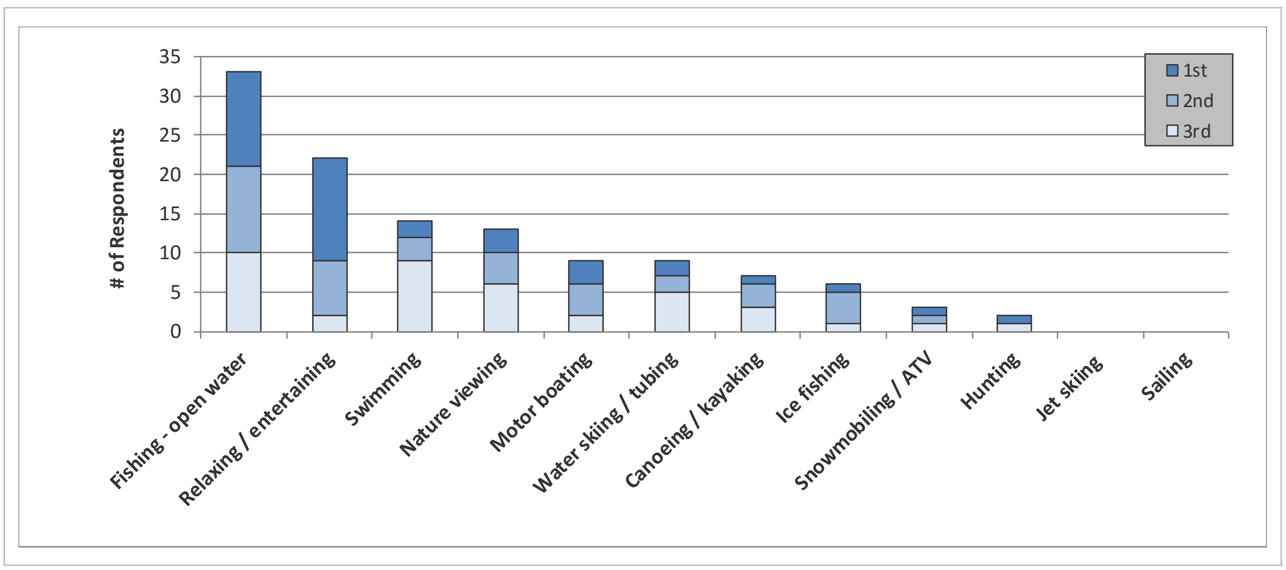
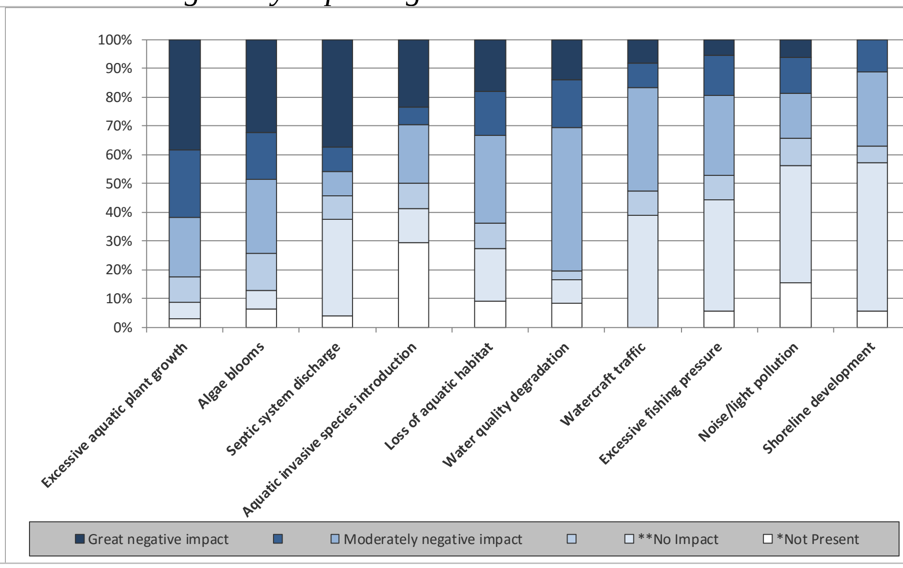


Figure 2.0-1. Select survey responses from the Pickerel Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Pickerel Chain stakeholders indicated that excessive plant growth is the biggest problem negatively impacting the Pickerel Chain Lakes (Question #26). The Pickerel Chain stakeholders also list excessive plant growth and water quality degradation as their top two concerns within the chain. (Question #27). Comments were recorded regarding these issues on the Pickerel Chain (Appendix B – Written Comments).

Several concerns noted throughout the stakeholder survey include excessive plants and loss of fish over the winter as described above and within the written comments portion of Appendix B, concern over aquatic invasive species detection and control, and water levels on the Pickerel Chain. Winter fish kills are summarized within the Fisheries Data Integration Section and excessive plant growth is detailed within the Aquatic Plants Section.

Question #26: To what level do you believe each of the following factors may currently be negatively impacting the Pickerel Chain Lakes.



Question #27: Please rank your top three concerns regarding the Pickerel Chain of Lakes, with the 1st being your top concern.

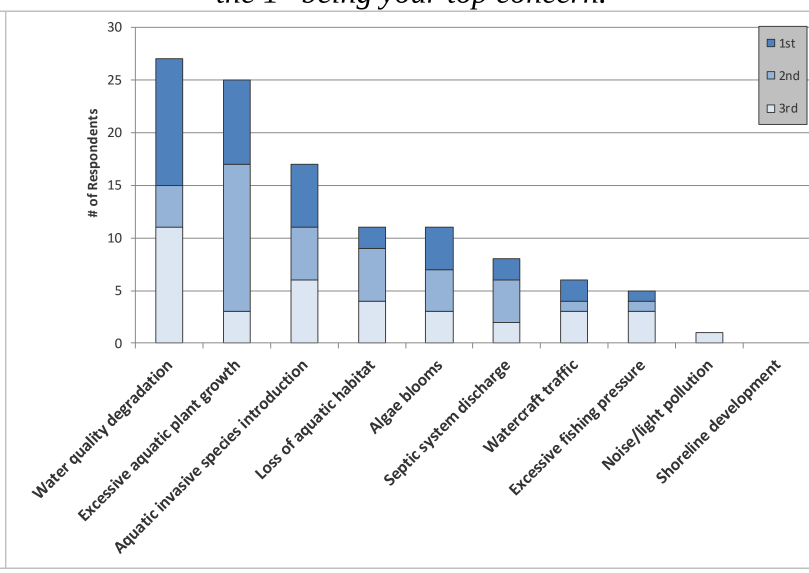


Figure 2.0-2. Select survey responses from the Pickerel Chain Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on the Pickerel Chain Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three water quality parameters are focused upon in the lake water quality analysis:

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

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

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) typically do not.

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

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

Internal Nutrient Loading

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can 'pump' phosphorus from the sediments to the water column throughout the growing season. In lakes that mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algae blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add large loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013) 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 the Pickerel Chain Lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by Lathrop and Lillie (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, Smoke Lake and Pickerel Lake are classified as a shallow, headwater drainage lakes (category 2 on Figure 3.1-1) while Little Pickerel Lake is classified as a deep, headwater drainage lake (category 3).

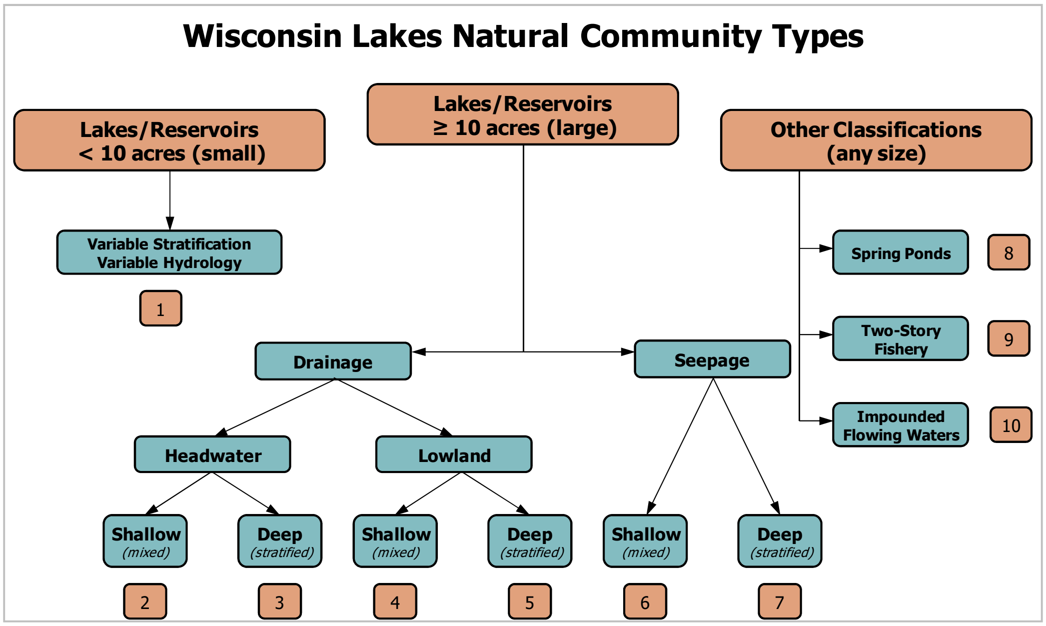


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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. The Pickerel Chain Lakes are within the Northern Lakes and Forests ecoregion.

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

These data along with data corresponding to statewide natural lake means, historic, current, and average data from the Pickerel Chain Lakes is displayed in Figures 3.1-3 - 3.1-7. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Pickerel Chain of Lakes Water Quality Analysis

Pickerel Chain of Lakes Nutrient Content and Clarity

The amount of historical water quality data existing for the Pickerel Chain varies by lake. Pickerel Lake has had some early data collected on it as a part of the first EPA National Lakes Assessment completed in the late 1970s and WDNR basin study completed in the Oconto County area in the late 1990s. Little Pickerel and Smoke lakes have no historical data to compare against the data that were collected as a part of this project. The importance of consistent, reliable data cannot be stressed enough; just as a person continuously monitors their weight or other health parameters, the water quality of a lake should be monitored in order to understand the system clearly and make sound management decisions.

Onterra staff collected water quality samples and monitored Secchi disk clarity on each Pickerel Chain lake during the course of this project. Monitoring occurred during the spring, summer, fall and following winter. Volunteers also sampled biweekly on Little Pickerel Lake for a more in depth picture of the lake's water quality. Please note that on the following figures comparisons are best made across lakes of similar classification (shallow, lowland drainage lakes in light blue and deep, lowland drainage lakes in dark blue). Unless otherwise indicated, parameters represent samples collected from the sub-surface of each lake.

Total phosphorus values ranged largely between 18.4 and 28.7 µg/L (Figure 3.1-3). All Pickerel Chain lakes are near or even below the median value for their respective lake class (shallow or deep lowland drainage lakes) for this parameter. These levels are normal and considered healthy for Wisconsin Lakes.

Average summer chlorophyll-*a* concentrations vary little within the Pickerel Chain of Lakes (Figure 3.1-4). All three lakes support average chlorophyll-*a* values that are considered healthy for the ecosystem.

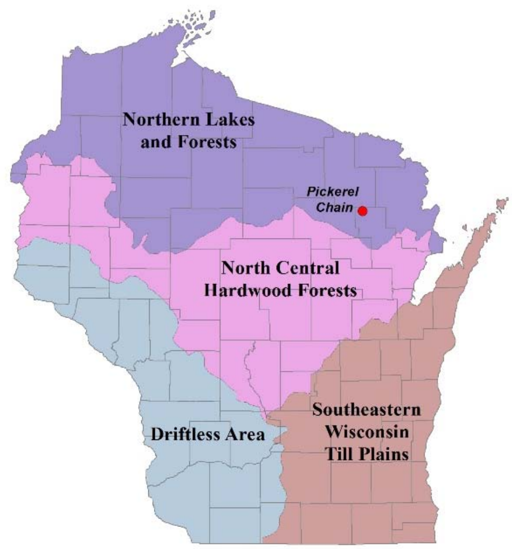


Figure 3.1-2. Location of the Pickerel Chain Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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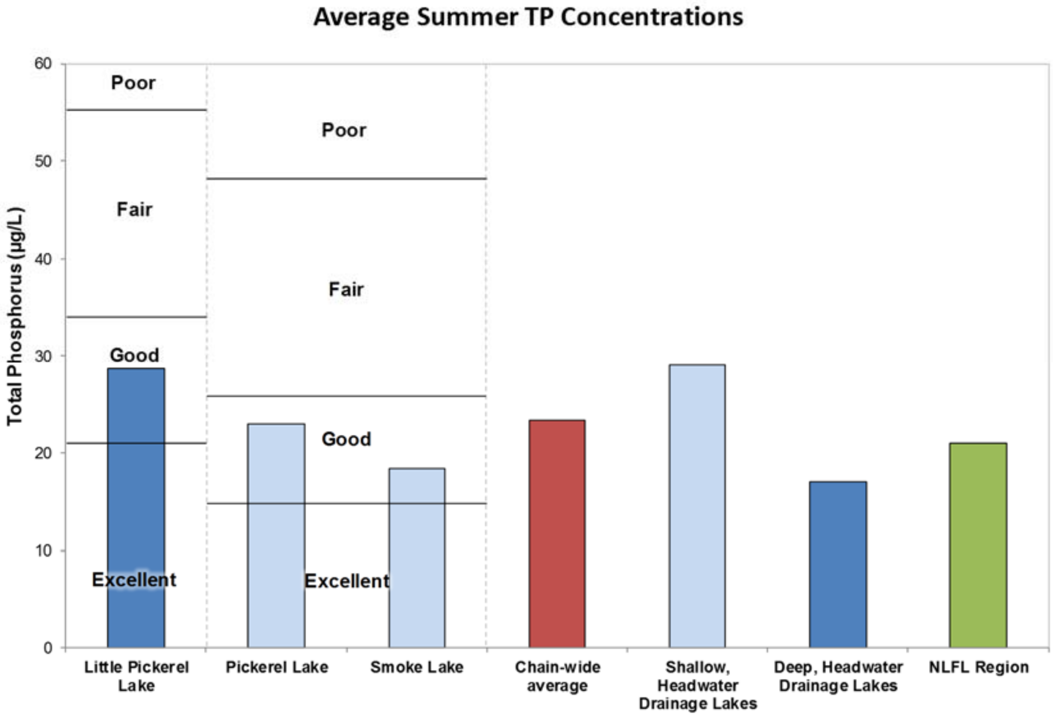

Figure 3.1-3. Pickerel Chain and comparable lakes total phosphorus concentrations. Comparables include Class 3 (light blue) and Class 4 (dark blue) lakes and Northern Lakes and Forests ecoregion median values. Values calculated with summer month surface sample data and methodology using WDNR 2012A.

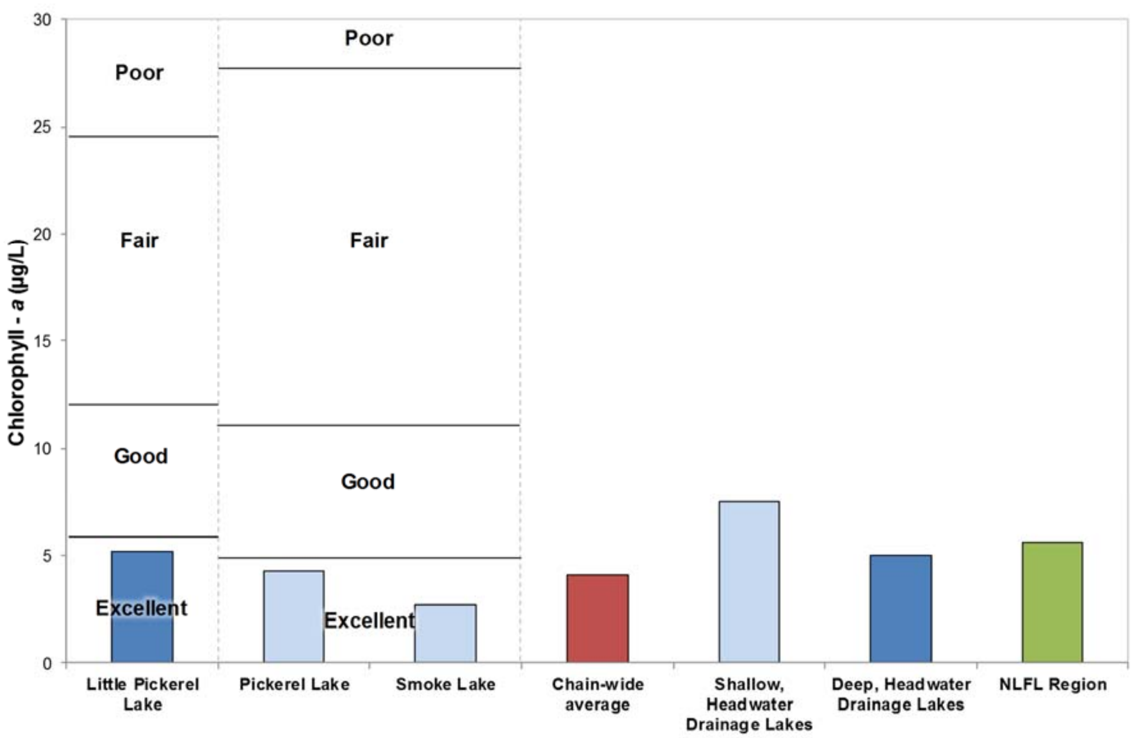

Figure 3.1-4. Pickerel Chain and comparable lakes chlorophyll-*a* concentrations. Comparables include Class 3 (light blue) and Class 4 (dark blue) lakes and Northern Lakes and Forests ecoregion median values. Values calculated with summer month surface sample data and methodology using WDNR 2012A.

Average summer Secchi disk clarity ranged from 8.0 feet deep to 9.7 feet deep in the Pickerel Chain lakes (Figure 3.1-5). Every Secchi disk sample taken in Smoke Lake in 2015 hit the bottom so clarity was quite good throughout the project. Data supplied by the PCLA in summer of 2016, the Secchi disk did not reach bottom and the average was 7.2 feet, which is still considered excellent as seen in Figure 3.1-5.

True color is a measurement of the dissolved organic and minerals in water after filtration removes suspended particles. Water samples collected in April and July 2015 were measured for this parameter, and were found to be at 10 Platinum-cobalt units (Pt-co units, or PCU) and 15 PCU in Little Pickerel Lake. During these same time periods, true color was measured at 20 PCU and 10 PCU in Pickerel Lake and 10 PCU for both samples in Smoke Lake. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color. This helps to explain the clear water of the Pickerel Chain, as this parameter indicates the lower level of dissolved organics acids that are naturally found in many lakes with highly forested watersheds.

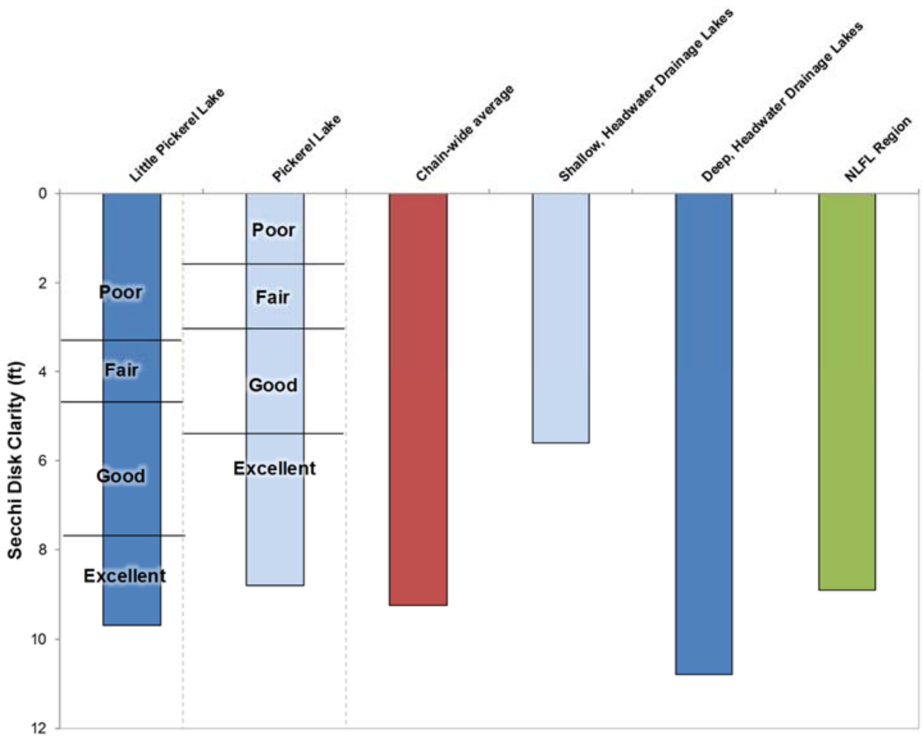

Figure 3.1-5. Pickerel Chain and comparable lakes Secchi disk clarity values. Comparables include Class 3 (light blue) and Class 4 (dark blue) lakes and Northern Lakes and Forests ecoregion median values. Values calculated with summer month surface sample data and methodology using WDNR 2012A.

Limiting Plant Nutrient of Pickerel Chain of Lakes

Using average nitrogen and phosphorus concentrations from all lakes included in the Pickerel Chain of Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.1-1). In all lakes, the ratio weighed heavily in favor of nitrogen, rather than phosphorus. This finding indicates that all of the lakes of the Pickerel Chain of Lakes are indeed phosphorus limited as are the vast majority of Wisconsin lakes.

Table 3.1-1. Pickerel Chain nitrogen and phosphorus values and N:P ratios. Ratios calculated from sub-surface samples taken in summer from each lake.

Lake Name	Avg. Summer Nitrogen (µg/L)	Avg. Summer Phosphorus (µg/L)	N:P Ratio
Pickerel Lake	541	23	22:1
Little Pickerel Lake	688	28.7	21.9:1
Smoke Lake	606	18.4	28:1

Pickerel Chain of Lakes Trophic State

Figure 3.1-6 contain the Trophic State Index (TSI) values for Pickerel Chain of Lakes. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to lower eutrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters. All three of the lakes within the chain fall within the range of mesotrophic – characterized mid-range phosphorus and chlorophyll-*a* content.

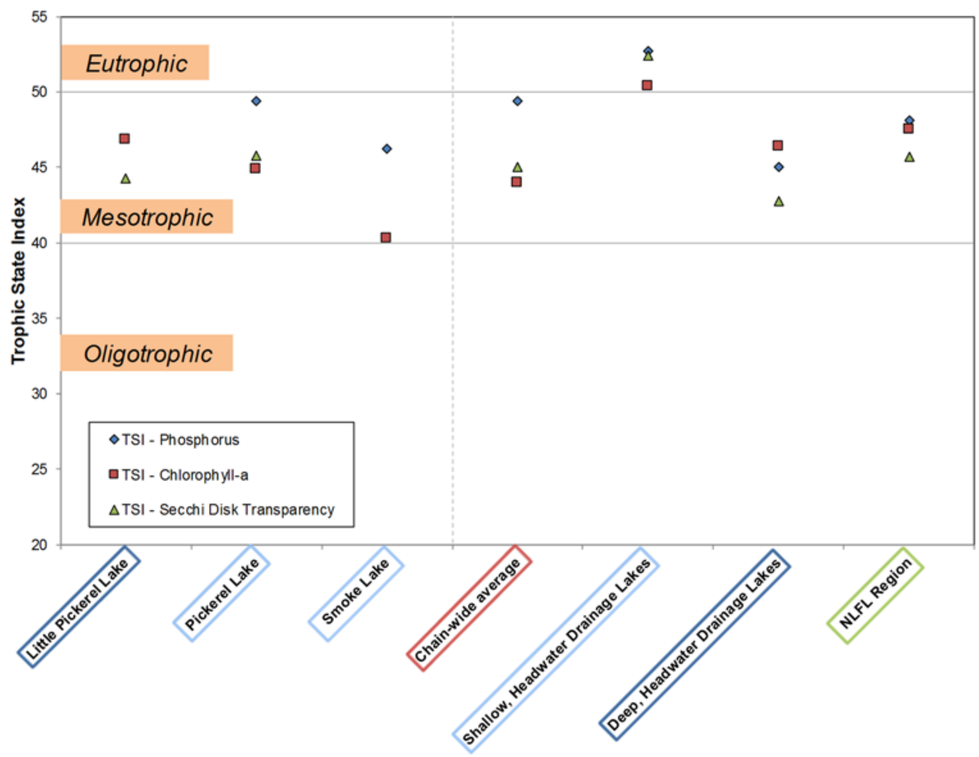

Figure 3.1-6. Pickerel Chain and comparable lakes Trophic State Index values. Comparables include Class 3 (light blue) and Class 4 (dark blue) lakes and Northern Lakes and Forests ecoregion median values. Values calculated with summer month surface sample data and methodology using WDNR 2012A.

Additional Water Quality Data Collected on the Pickerel Chain of Lakes

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

The pH scale ranges from 0 to 14.0 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7.0 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7.0 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7.0 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology near the lake and within its surface and underground watersheds. On a smaller scale within a lake or between similar lakes, photosynthesis by plants can impact pH because the process uses dissolved carbon dioxide, which acts as a carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Within the Pickerel Chain, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Figure 3.1-7). The values seen within the chain lakes are slightly above neutral and are normal for Wisconsin lakes.

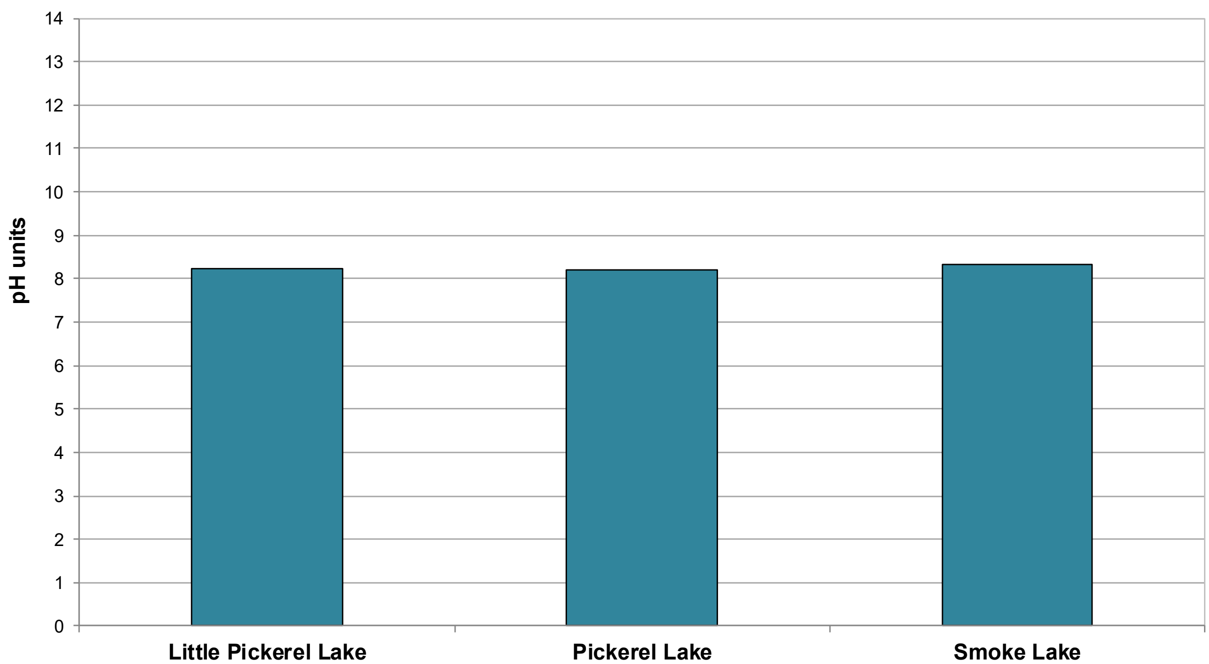

Figure 3.1-7. Pickerel Chain pH values. Data collected from summer month surface samples.

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity it contains. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. Alkalinity is similar between the Pickerel Chain of Lakes, but still within expected ranges for northern Wisconsin lakes (Figure 3.1-8). Alkalinity determines the sensitivity of a lake to acid rain. Values between 2.0 and 10.0 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10.0 to 25.0 mg/L as $CaCO_3$ are considered to have low sensitivity, and lakes above 25.0 mg/L as $CaCO_3$ are non-sensitive.

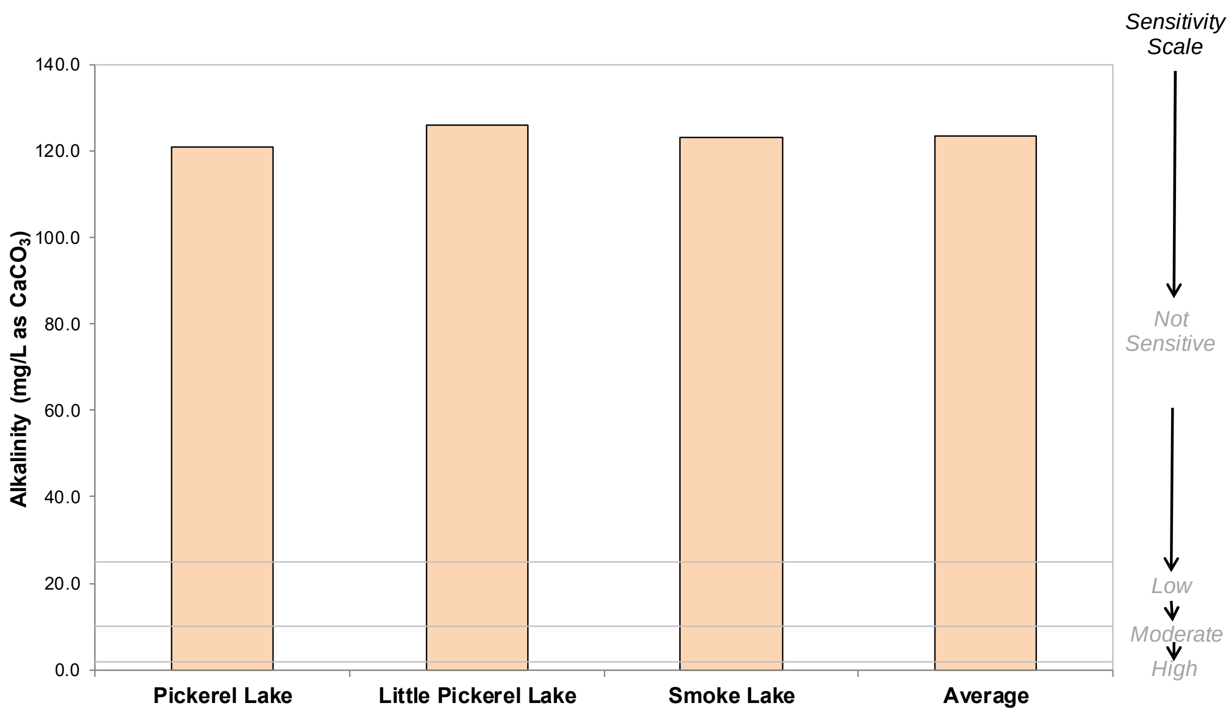

Figure 3.1-8. Pickerel Chain alkalinity values and acid rain sensitivity ranges. Data collected from summer surface samples.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, calcium concentration has been used to determine what lakes can support zebra mussel populations if they are introduced. These studies, conducted by researchers at the University of Wisconsin-Madison, have led to a suitability model called Smart Prevention (Vander Zanden and Olden 2008). This model relies on measured or estimated dissolved calcium concentration to indicate whether a given lake in Wisconsin is suitable, borderline suitable, or unsuitable for sustaining zebra mussels. Within this model, suitability was estimated for approximately 13,000 Wisconsin waterbodies and is displayed as an interactive mapping tool (www.aissmartprevention.wisc.edu).

All the lakes within the Pickerel Chain are suitable for zebra mussel establishment based upon pH. As indicated on Figure 3.1-9, the calcium concentrations within the chain lakes are at the very high end for zebra mussel suitability. Overall, the Pickerel Chain of Lakes is capable of supporting zebra mussels, should they be introduced.

During the summer of 2015, Onterra staff completed net tows to collect plankton samples for examination by a WDNR expert for the presence of zebra mussel veligers, which are a free-swimming zebra mussel larva. Samples for all three lakes came back as negative.

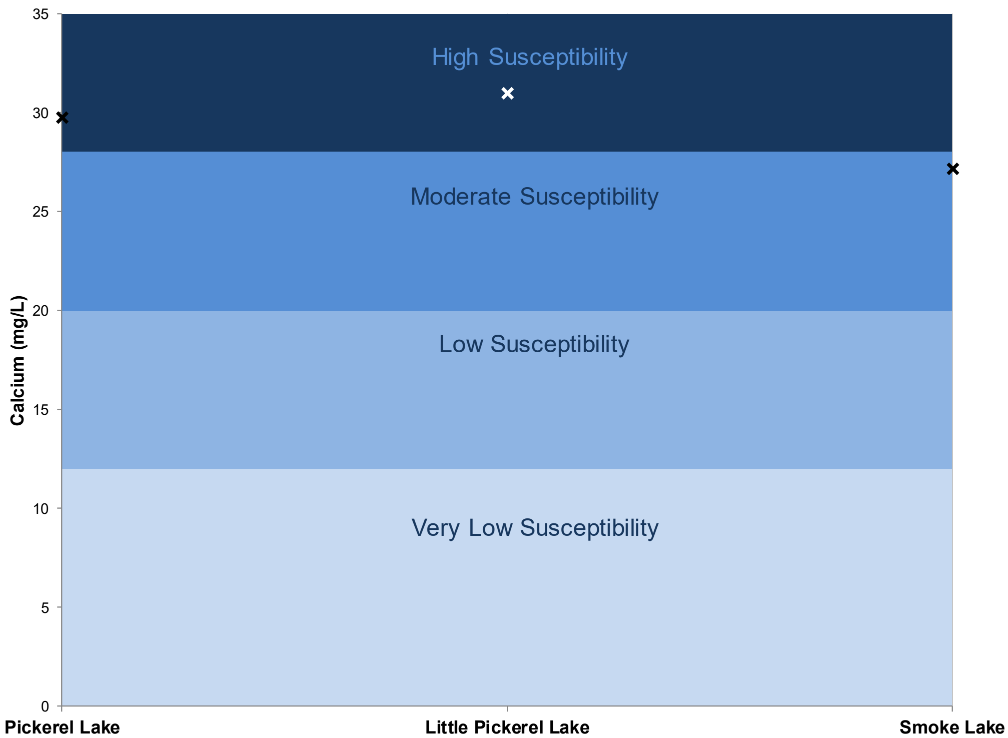

Figure 3.1-9. Pickerel Chain zebra mussel susceptibility analysis, based upon calcium concentration. Created from lake surface calcium values. Calcium susceptibility range adapted from Whittier et al. 2008.

3.2 Watershed Assessment

Watershed Modeling

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.

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.

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

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

In systems with high WS:LA ratios, like those 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 (high residence time, i.e., years), there may be a buildup of phosphorus in the sediments that may reach sufficient levels over time that internal nutrient loading may become a problem. On the contrary, a lake with a higher flushing rate (low residence time, i.e., days or weeks) may be more productive early on, but the constant flushing of its waters may prevent a buildup of phosphorus and internal nutrient loading may never reach significant levels.

A reliable and cost-efficient method of creating a general picture of a watershed's affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS – Panuska, 2003). 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.

As discussed above, the size of the watershed in relation to the size of the lake can have a considerable impact on the lake's water quality. There is a relatively small amount of land draining to each of the Pickerel Chain lakes (Map 2). The watershed to lake area ratios of the Pickerel Chain lakes are all very small. Little Pickerel has a 5:1 watershed:lake ratio while Pickerel Lake and Smoke Lake have a 2:1 ratio. Approximately 972 acres of land drains to the Pickerel Chain lakes, the majority (31% or 292 acres) of which is classified as forest (Figure 3.2-1). The Pickerel Chain Lakes surface account for the second largest land cover type in the watershed (30% or 285 acres) while wetlands are the third largest cover type at 27% (257 acres). Pasture/grass (7%) and row crops (4%) are found within the watershed to a lesser extent, while insignificant amounts of rural residential and urban areas exist as well.

In the individual lake sections found below, the watershed of each lake is discussed in more detail, including how the land cover types found in the respective lake's watershed impacts that lake's nutrient budget. Overall, each of the three lakes receives very low phosphorus inputs from their watersheds.

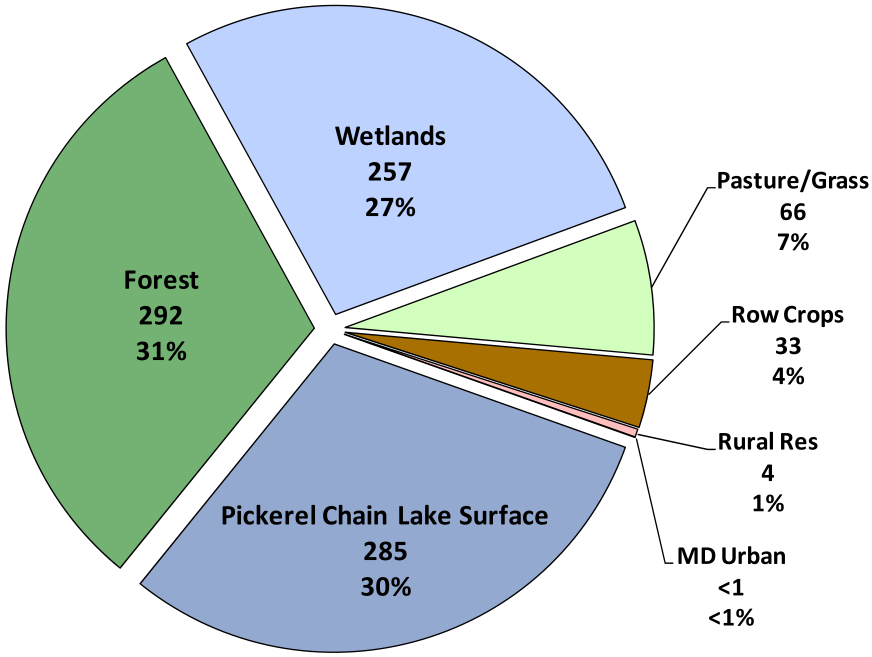

Figure 3.2-1. Pickerel Chain watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

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) affects 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 swimmer's itch. Developments such as rip rap, masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails. This is not desirable for lakes that experience problems with swimmer's itch, because 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. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

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

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

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

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

Wisconsin Act 31

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

Shoreland Research

Studies conducted on nutrient runoff from Wisconsin lake shorelands have produced interesting results. For example, a USGS study on several Northwoods Wisconsin lakes was conducted to determine the impact of shoreland development on nutrient (phosphorus and nitrogen) export to these lakes (Graczyk et al. 2003). During the study period, water samples were collected from surface runoff and ground water and analyzed for nutrients. These studies were conducted on several developed (lawn-covered) and undeveloped (undisturbed forest) areas on each lake. The study found that nutrient yields were greater from lawns than from forested catchments, but also that runoff water volumes were the most important factor in determining whether lawns or wooded catchments contributed more nutrients to the lake. 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 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 was 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 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 not 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 land conservation 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.
- 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.

Pickerel Chain of Lakes Shoreland Zone Condition

Shoreland Development

The lakes within the Pickerel Chain were surveyed as a part of this project to determine the extent of their degree of development. Lakes were visited during each appropriate phase, generally during the late summer to conduct this survey. A lake's shoreland zone can be classified based upon the amount of human disturbance (vegetation removal, construction of rip-rap or seawalls, etc.). 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 each of Pickerel Chain of Lakes, the development stage of the entire shoreline was surveyed during field studies using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

The Pickerel Chain of Lakes has stretches of shoreland that fit all of the five shoreland assessment categories. In all, the Pickerel Chain lakes contain approximately about 7.5 miles of natural/undeveloped and developed-natural shoreline (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. A little over 0.6 miles of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each lake's shoreland condition, while each individual lake section discusses the shoreline condition further. Maps of each lake and the location of these categorized shorelands are included within each individual lake section as well.

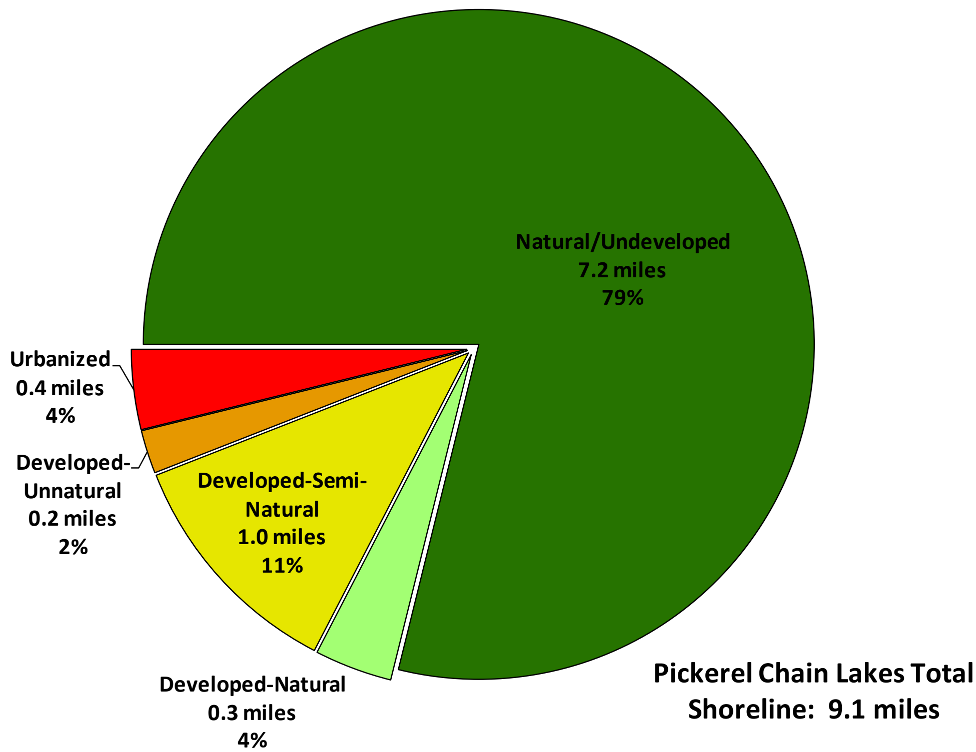

Figure 3.3-2. Pickerel Chain Lakes total shoreland classification. Based upon field surveys conducted in late summer 2015.

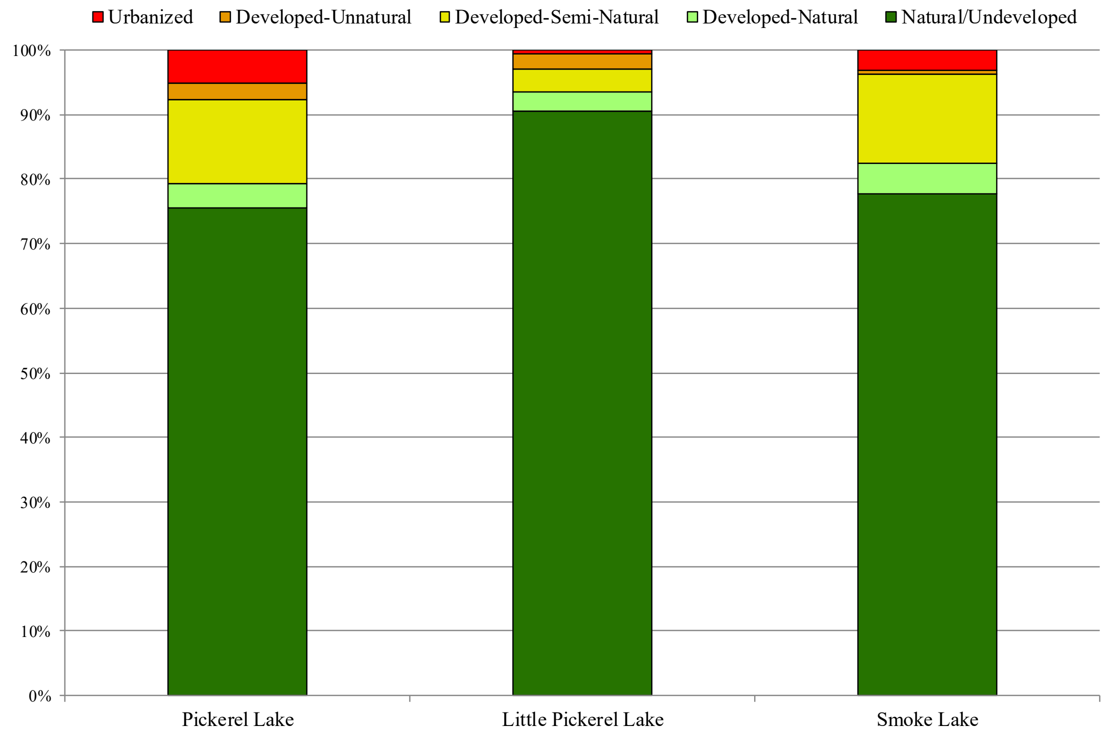

Figure 3.3-3. Pickerel Chain Lakes shoreland condition breakdown. Based upon late summer 2015 field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

While producing a completely natural shoreline is ideal for a lake ecosystem, it is not practical for most lakes, especially considering our natural draw to be near water. 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.

One factor that influences the diversity and species richness of the aquatic plant community of a lake is the "development factor" of the shoreline. 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 shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline 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 shoreline 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 shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind. The shoreline complexity value for each lake within the Pickerel Chain is reported within its respective individual lake section.

Coarse Woody Habitat

The Pickerel Chain Lakes were surveyed in 2015 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, a total of 497 pieces of coarse woody habitat were observed along 9.1 miles of shoreline, which gives the Pickerel Chain Lakes a coarse woody habitat to shoreline mile ratio of 55:1. 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). Trees falling into the lake are natural and are an important component of lake ecology, providing valuable structural habitat for fish and other wildlife. Fallen trees should be left in place unless they impact access to the lake or recreational safety. Locations of the coarse woody habitat can be found on maps within each individual lake section.

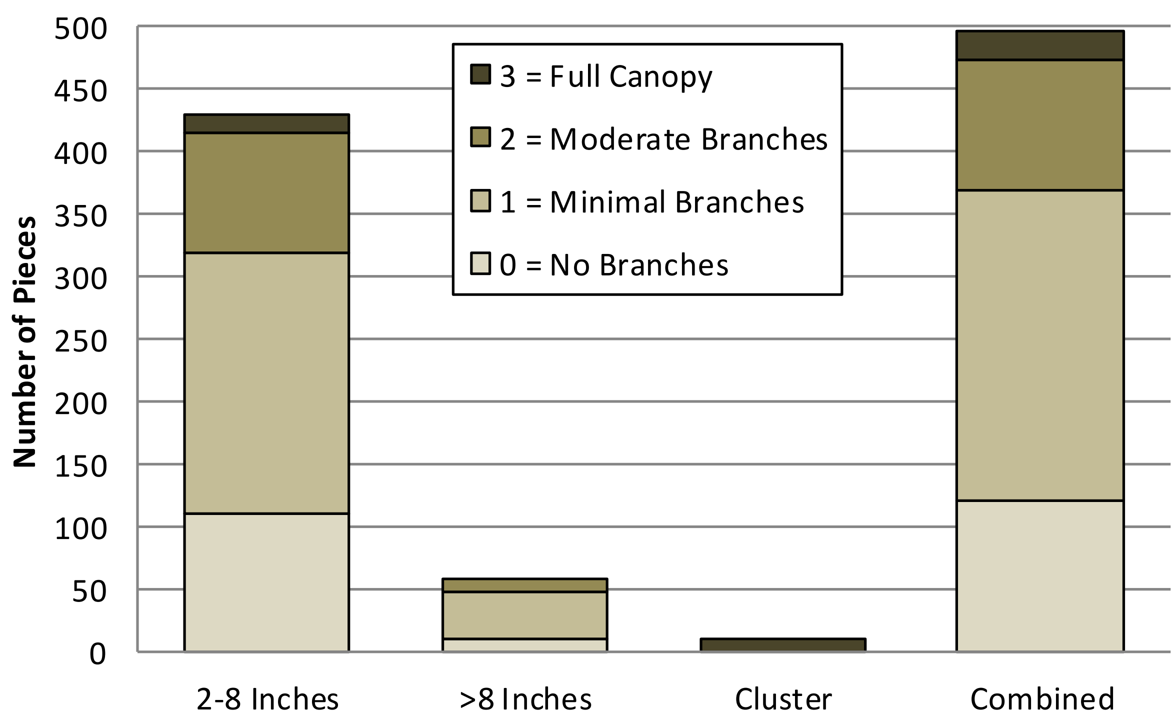

Figure 3.3-4. Pickerel Chain Lakes coarse woody habitat survey results. Based upon a Fall 2015 survey. Locations of Pickerel Chain Lakes coarse woody habitat can be found on within each individual lake section.

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.

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

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

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

Aquatic Plant Management and Protection

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

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

Permits

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

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

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 the use of bottom screens may require a mechanical harvesting permit to be issued by the WDNR.

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 (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*). • Permitting process may require an environmental assessment that may take months to prepare. • Unselective.

Mechanical Harvesting

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

Costs

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

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

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, trageted 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 emergents or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Pickerel Chain of Lakes; 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 Pickerel Chain of Lakes, 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

> A box plot or box-and-whisker diagram graphically shows data through five-number summaries: minimum, lower quartile, median, upper quartile, and maximum. Just as the median divides the data into upper and lower halves, quartiles further divide the data by calculating the median of each half of the dataset.

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 Pickerel Chain of Lakes. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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 Pickerel Chain of Lakes 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.

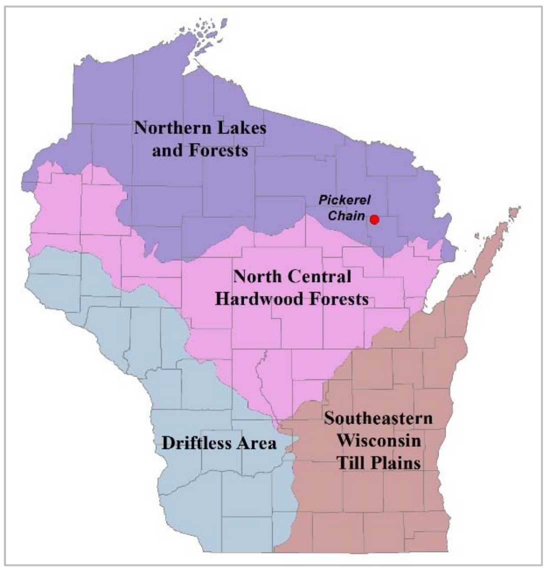

Figure 3.4-1. Location of the Pickerel Chain within the ecoregions of Wisconsin. After Nichols 1999.

Community Mapping

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

Exotic Plants

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

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). 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.

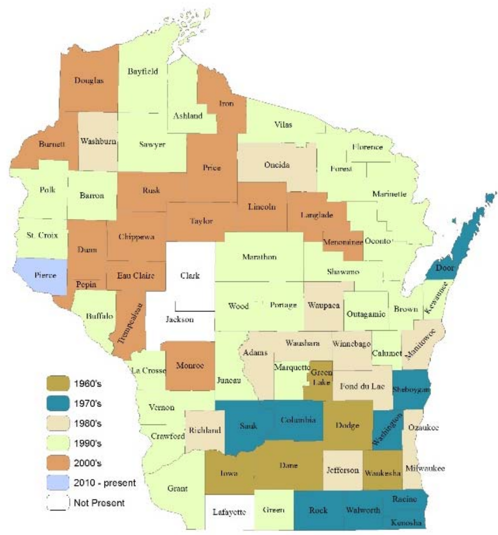

Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

Numerous plant surveys were completed as a part of this project. In June, early-season aquatic invasive species surveys were completed on each project lake. This meander-based survey is done early in the summer to coincide with the peak-growth period of curly-leaf pondweed. Additionally, during this time of year Eurasian water milfoil is taller in the water column than native plants so it may be easier to pick out should it be present. This meander-based survey did not locate any occurrences of curly-leaf pondweed within any of the project lakes. It is believed that this aquatic invasive species either does not occur in Pickerel Chain of Lakes or exists at an undetectable level. Curly-leaf pondweed does exist to the west in Rollingstone Lake, northern Langlade County and to the east in Caldron Falls Reservoir and High Falls Reservoir, both in northern Marinette County.

The point intercept surveys were conducted on the Pickerel Chain of Lakes during July 2015 by Onterra. Additional surveys were completed during this time by Onterra to create the aquatic plant community maps (See "Aquatic Plant Community Map" after each individual lake section). Aquatic plant point-intercept survey data may be viewed in Appendix F.

A total of 56 different plant species were identified from the lakes involved with this project (Table 3.4-1). Seven submergent species were found within all three of these lakes. Six emergent or floating-leaf species were found within all three lakes as well. Many species were found only occasionally; 21 species were found within only one of the three lakes. This adds testament to the individuality of each of the lakes, even though they are all part of the same chain of lakes. Only one of the species found during the plant surveys is considered non-native, invasive species: Purple loosestrife was located only on Pickerel Lake.

The Pickerel Chain of Lakes vary somewhat in their physical, biological and chemical attributes. Even though all of the lakes are connected, there is some variance in substrate, nutrient concentrations, algae concentrations, pH, clarity, alkalinity and watershed/shoreland characteristics. The substrate and water chemical composition of a lake influences aquatic plant species composition and abundance, and has the ability to create completely different plant communities among lakes that may be located across the street from each other. Generally speaking, lakes can be divided into two main groups based upon their plant community composition: 1) lakes that are dominated by plants of the isoetid growth form, and 2) lakes dominated by plants of the elodeid growth form.

Plant species of the isoetid growth form are small, slow growing, inconspicuous submerged plants that have evergreen leaves located in a rosette and are usually found growing in sandy soils within the near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000). Some isoetid species found in the Pickerel Chain of Lakes include pipewort, brown-fruited rush and needle spikerush. Conversely, submerged species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column. The elodeid growth form includes plants such as common waterweed, coontail and many varieties of pondweeds and milfoils.

Alkalinity is the primary water chemistry factor determining whether a lake is dominated by plant species of the isoetid or elodeid growth form (Vestergaard and Sand-Jensen 2000). As mentioned in the Water Quality Section, alkalinity measures the concentration of calcium carbonate ($CaCO_3$) in the lake water and is a close descriptor of the amount of bicarbonate present. Isoetids, unable to use bicarbonate as source of carbon for photosynthesis, are typically found in lakes of lower alkalinity as they are adapted to grow in areas where carbon is limited. Through an extensive, permeable root system, isoetids are able to release oxygen into the sediment. This stimulates microbial decomposition while decreasing sediment pH (Urban et al. 2006). In turn, the decomposition process increases sediment carbon, which is not useable by plants of the elodeid growth form.

In lakes with higher alkalinity, elodeids grow in abundance as they are able to utilize the bicarbonate as a carbon source. In lakes with moderate alkalinity levels, both elodeids and isoetids may be found. While some of the project lakes displayed these alkalinity levels, most lakes were overwhelmingly dominated by elodeid plants, with instances of isoetid plants being found occasionally. While isoetid species are physically able to grow in lakes with higher alkalinity, their short stature makes them susceptible to shading from the much taller, leafy elodeid species which often restricts their growth to shallow, wave-exposed sites with course sediments (Vestergaard and Sand-Jensen 2000). Floating-leaf species, such as spatterdock and white water lily, obtain most of their carbon from the atmosphere, allowing them to be prevalent in most Wisconsin lakes.

Increases in alkalinity and sedimentation from residential development around a lake may result in creating a more suitable habitat for the taller elodeids, displacing isoetid species. As a result, many of the isoetid species have higher conservatism values as they are intolerant of disturbance and are indicators of high quality lake environments. Isoetid dominated lakes tend to be lower in species richness than elodeid dominated lakes. In general, the lakes within the Pickerel Chain may be described as elodeid dominated lakes.

In the Pickerel Chain of Lakes, the number of species observed per lake varied from 21 species in Smoke Lake to 44 native species in Pickerel Lake (Figure 3.4-3). Please note that Figure 3.4-3 displays the number of plants found within the point-intercept survey (on the rake), as well as the additional species found incidentally. The total number of species is a combination of these two; however, in comparing to ecoregion and state medians and computing conservatism values (see discussion below) only the plants located during the point-intercept survey are considered. Two of the three lakes met or exceeded the Northern Lakes Ecoregion median for species richness. Smoke Lake, with 12 native species located on the rake, fell just short of this standard comparison level. This is likely due to the types of plants found in the lake, its shallowness, and low nutrient levels. Over half of the species located in Smoke Lake were emergent or floating-leaf species, which typically do not show up on the rake during the point-intercept survey.

Table 3.4-1. Aquatic plant species located in the Pickerel Chain Lakes during Onterra 2015 aquatic plant surveys

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	Pickerel	Little Pickerel	Smoke
Emergent	*Calla palustris*	Water arum	9	I		
	Carex comosa	Bristly sedge	5	I		
	Carex hystericina	Porcupine sedge	3	I		
	Carex lacustris	Lake sedge	6			I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9	I		I
	Carex utriculata	Common yellow lake sedge	7		I	
	Cladium mariscoides	Smooth sawgrass	10	I		
	Decodon verticillatus	Water-willow	7			I
	Dulichium arundinaceum	Three-way sedge	9	X		I
	Eleocharis erythropoda	Bald spikerush	3	I		
	Eleocharis palustris	Creeping spikerush	6	I	I	
	Iris sp. (sterile)	Iris sp. (sterile)	5	I		
	Lythrum salicaria	Purple loosestrife	Exotic	I		
	Phragmites australis subsp. *americanus*	Common reed	5			I
	Sagittaria latifolia	Common arrowhead	3	I	I	I
	Sagittaria rigida	Stiff arrowhead	8	I		
	Schoenoplectus acutus	Hardstem bulrush	5	X	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I		
	Typha spp.	Cattail spp.	1	X	I	I
FL	*Brasenia schreberi*	Watershield	7	X	X	X
	Nuphar variegata	Spatterdock	6	X	X	X
	Nymphaea odorata	White water lily	6	X	X	I
	Persicaria amphibia	Water smartweed	5	X	I	I
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I	I	
	Sparganium sp.	Bur-reed sp.	N/A		X	
Submersed	*Ceratophyllum demersum*	Coontail	3	X	X	
	Chara spp.	Muskgrasses	7	X	X	X
	Elodea canadensis	Common waterweed	3	X	X	
	Myriophyllum sibiricum	Northern water milfoil	7		X	
	Myriophyllum verticillatum	Whorled water milfoil	8	X		
	Najas flexilis	Slender naiad	6	X	X	X
	Najas guadalupensis	Southern naiad	7	X		
	Nitella spp.	Stoneworts	7	X		
	Potamogeton amplifolius X *P. praelongus*	Large-leaf X white-stem pondweed	N/A	I		
	Potamogeton friesii	Fries' pondweed	8	X	X	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X		X
	Potamogeton illinoensis	Illinois pondweed	6	X	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X	X
	Potamogeton praelongus	White-stem pondweed	8	X		
	Potamogeton spirillus	Spiral-fruited pondweed	8	X		
	Potamogeton strictifolius	Stiff pondweed	8	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	
	Stuckenia pectinata	Sago pondweed	3	X	X	
	Utricularia gibba	Creeping bladderwort	9	X	X	
	Utricularia intermedia	Flat-leaf bladderwort	9	X	X	
	Utricularia minor	Small bladderwort	10	X		
	Utricularia vulgaris	Common bladderwort	7	X	X	
	Vallisneria americana	Wild celery	6	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X		
	Sagittaria cuneata	Arum-leaved arrowhead	7	I		
	Schoenoplectus subterminalis	Water bulrush	9	X	X	X
	Sparganium natans	Little bur-reed	9	I		
FF	*Lemna trisulca*	Forked duckweed	6	I		
	Lemna turionifera	Turion duckweed	2	X		

FL = Floating-leaf; FL/E = Floating-leaf & Emergent; S/E = Submersed & Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidentally located

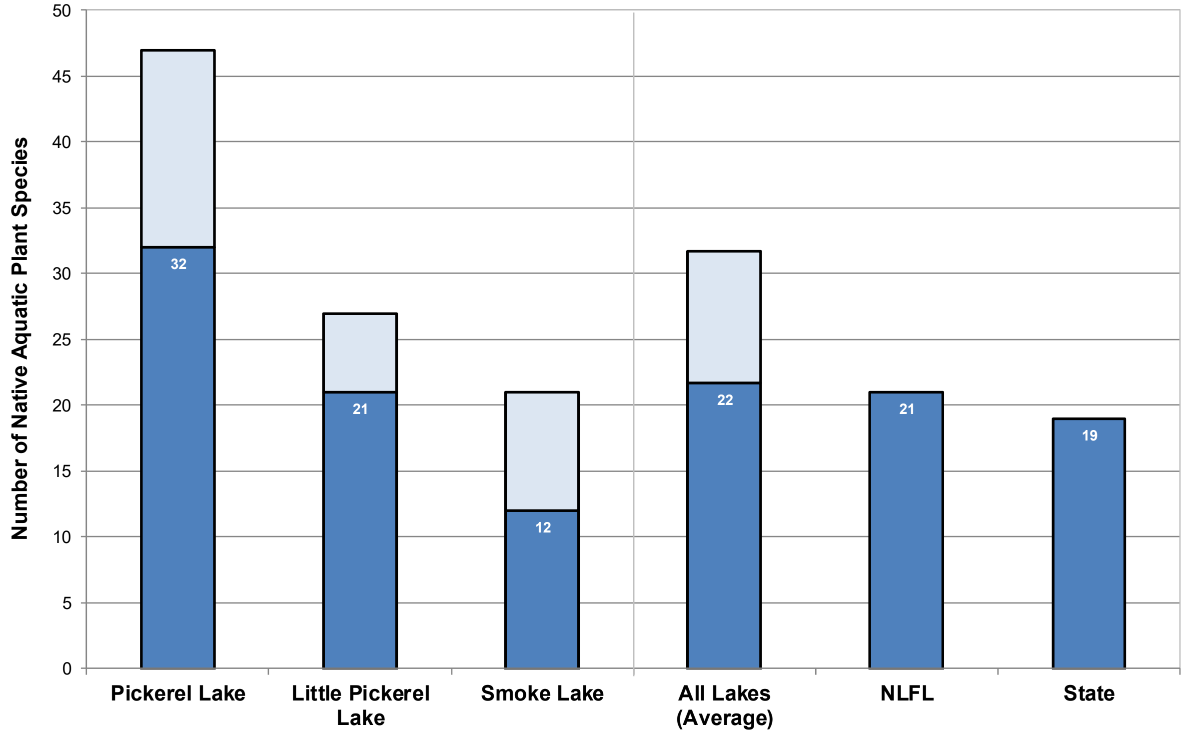

Figure 3.4-3 Pickerel Chain native species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

Like species richness, the Pickerel Chain of Lakes had a wide range of plant species diversity (Figure 3.4-4). As discussed earlier, how evenly the species are distributed throughout the system and species richness together influence species diversity. In other words, a lake with many species is not necessarily diverse, and a lake with few species is not necessarily lacking diversity. Simpson's diversity index (1-D) is used to make this distinction.

Species diversity ranged from 0.78 to 0.88 in the Pickerel Chain of Lakes (Figure 3.4-4). Smoke Lake was found to have the lowest species diversity which coincides with also having the lowest species richness.
While a method of characterizing diversity values as "Fair" or "Poor", etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Pickerel Chain of lakes' scores compare with other lakes. Using data obtained from WDNR Science Services, median values and upper/lower quartiles were calculated for 109 lakes within the Northern Lakes and Forests ecoregion (Figure 3.4-4). One of the lakes rank above the median for the ecoregion, one lake is within the lower quartile and one lake is below the ecoregion quartiles. The three Pickerel Chain lakes all have high alkalinity values as discussed in the water quality section. High alkalinity lakes often support high levels of Chara species as they typically do well in calcium-rich environments. All three lakes are dominated by Chara species, leading to the moderate species diversity values in them.

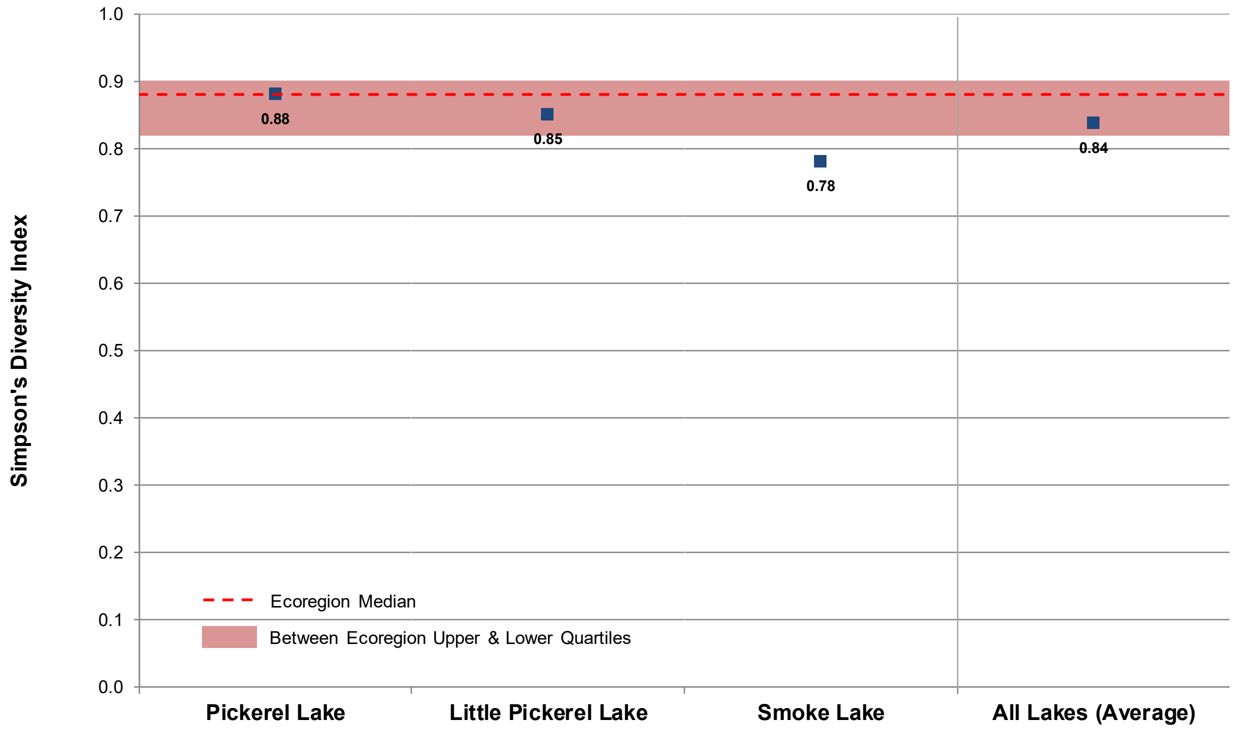

Figure 3.4-4 Pickerel Chain species diversity index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Data collected from the point-intercept surveys indicates that Pickerel and Little Pickerel lakes have slightly lower than median values for the Northern Lakes Ecoregion coefficient of conservatism values and that Smoke falls exactly on the median (Figure 3.4-5). Pickerel and Little Pickerel lakes are above and at the state median values; however. When compared to lakes within the Northern Lakes Ecoregion, the Pickerel Chain lakes are on the lower end of lakes containing high quality species that only exist in less disturbed systems. The watershed and shorelands of the chain are disturbed and a dam is used to maintain water levels, so these values are not unexpected.

Combining the species richness and average conservatism values for each chain lake to produce the Floristic Quality Index (FQI) resulted in a range of values from 23.1 to 36.2, with an average of 29.4 (equation shown below) (Figure 3.4-6). Only Pickerel Lake exceeded the state and ecoregion median FQI value while Little Pickerel Lake was found to be above the state median and Smoke Lake fell below both the state and ecoregion median. As mentioned above, Smoke Lake's size and depth plays an important role in its plant community. Further, all three lakes being dominated by low-growing *Chara* species, which can minimize the occurrence of some plant species.

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

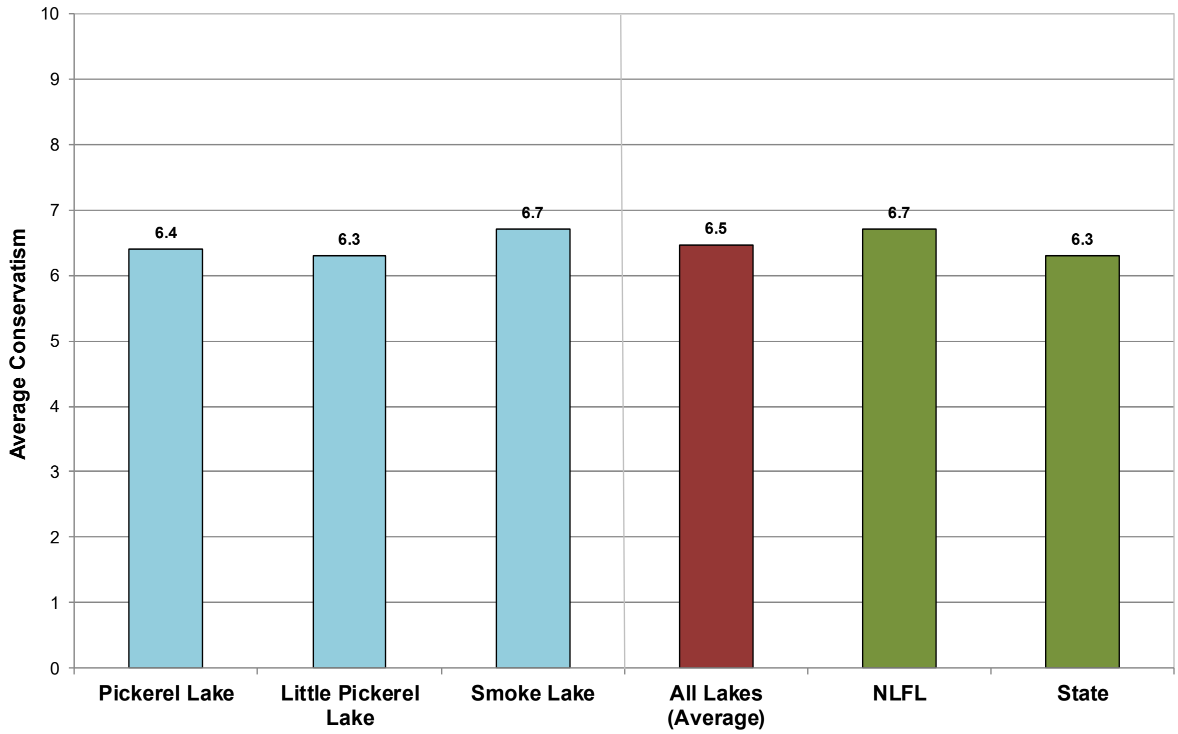

Figure 3.4-5 Pickerel Chain average native species' coefficients of conservatism. Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

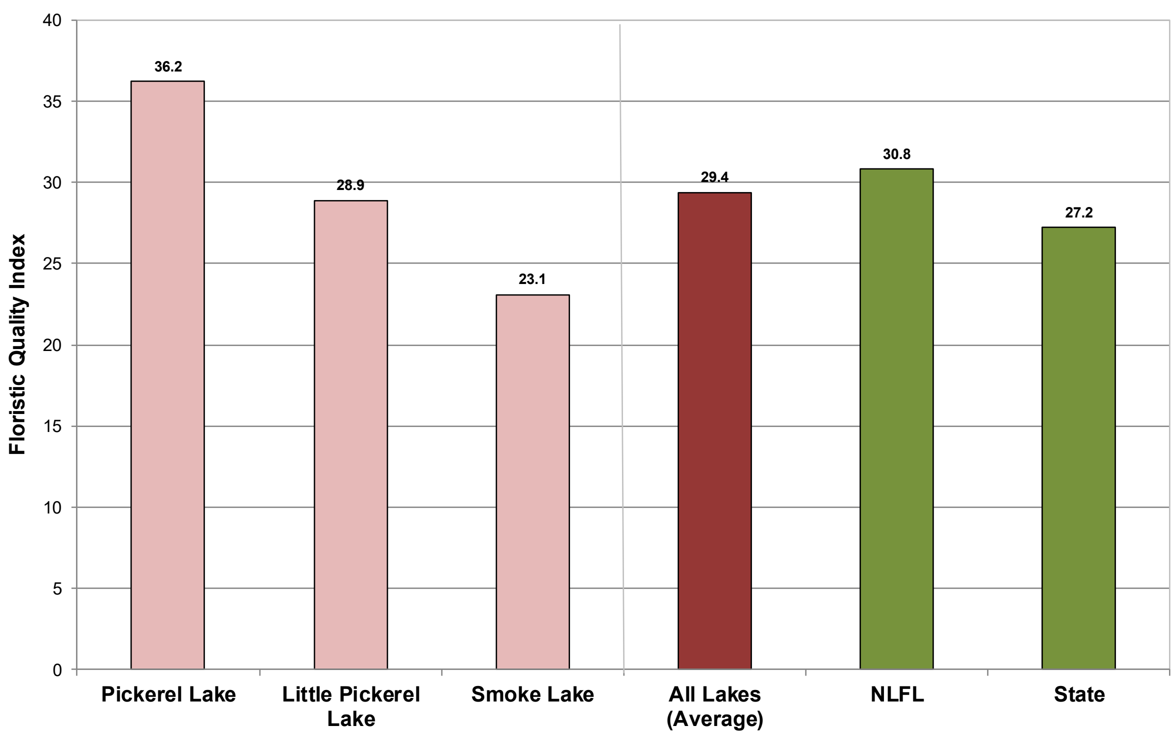

Figure 3.4-6. Pickerel Chain Floristic Quality Assessment. Created using data from summer point-intercept surveys. Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

As discussed in the analyses above, the plant communities within the Pickerel Chain are generally of good quality and indicate a healthy ecosystem. One of the biggest advantages of having a healthy plant community in a lake is the habitat value it provides. Areas of emergent and floating-leaf plant communities provide valuable fish and wildlife habitat important to the ecosystem both inside and outside of the lake. These areas are utilized by adult fish for spawning, by juvenile fish as a nursery, and by forage fish for protection from predators. Wading birds can be found in these areas hunting fish and insects, and escaping dangerous predators. Finally, these communities protect shorelines from eroding, as they temper the energy on the waves approaching the shoreline from the interior of the lake.

All of the Pickerel Chain lakes contain large areas of these plant communities. Figure 3.4-7 displays the percent of lake acreage occupied by either emergent, floating-leaf, or a combined emergent and floating-leaf plant communities.

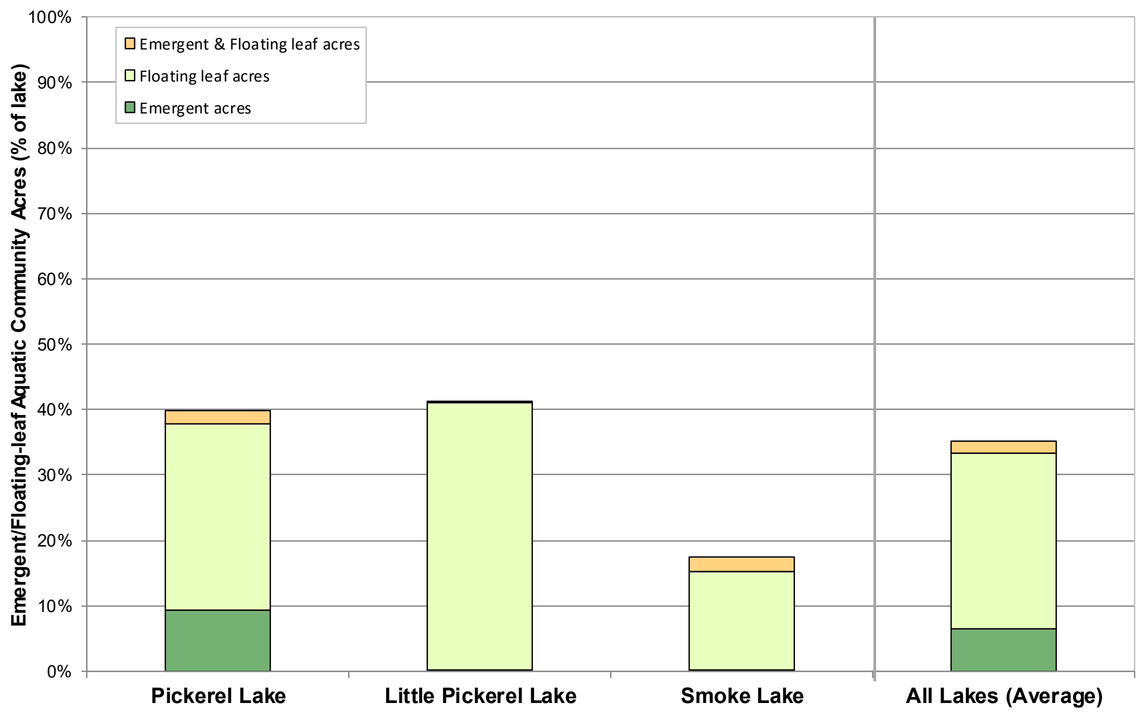

Figure 3.4-7. Pickerel Chain emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

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, as those aspects are currently being conducted by WDNR biologists overseeing the Pickerel Chain of Lakes. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2016B & GLIFWC 2016A and 2016B). Please note that as discussed in more detail below, the Pickerel Chain of Lakes is located in ceded territory under the Treaty of 1842. There is no indication that tribal spearing has recently occurred on any of the chain lakes. The section below discussing tribal spearing is included strictly for informational purposes.

Pickerel Chain of Lakes Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the highest ranked important or enjoyable activity on the Pickerel Chain of Lakes (Question #17). Approximately 74% of these same respondents believed that the quality of fishing on the lake is good or excellent (Question #12). Based upon the fact that the lake had what was believed to be a complete fish kill in 2012-2013, this good or excellent fishing likely refers to pre-fish kill status.

When examining the fishery of a lake, it is important to remember what "drives" that fishery, or what is responsible for determining its mass and composition. The gamefish in Pickerel Chain of Lakes 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 piscovores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

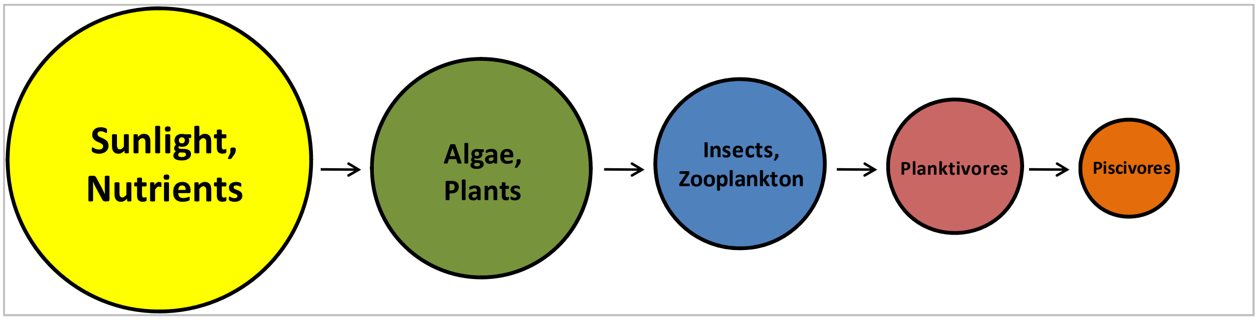

Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, the Pickerel Chain of Lakes is a mesotrophic system, meaning it has fairly high nutrient content and thus relatively high primary productivity. Simply put, this means the Pickerel Chain of Lakes should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Table 3.5-1. Gamefish present in the Pickerel Chain Lakes with biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
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

Pickerel Chain Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). The Pickerel Chain of Lakes falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems.

While within the ceded territory, none of the lakes within the Pickerel chain have experienced a spearfishing harvest, likely due to the fact that walleye or muskellunge are not a significant part of the fishery in the lakes.

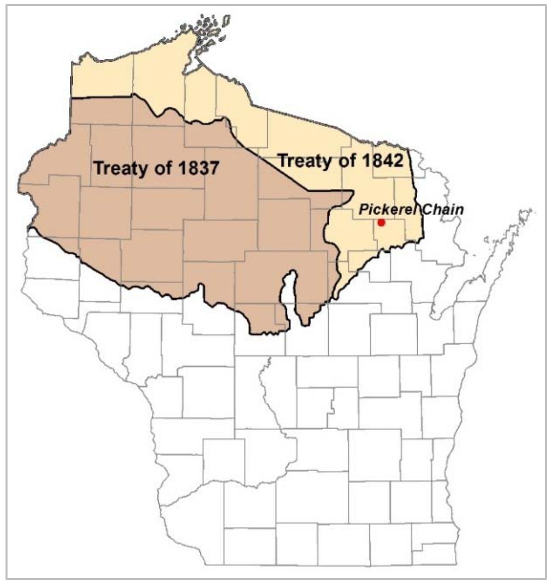

Figure 3.5-2. Location of the Pickerel Chain within the Native American Ceded Territory (GLIFWC 2016A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Pickerel Chain of Lakes Fishing Regulations

State Highway 64 in Oconto County separates the northern and southern bass management zones in Wisconsin. The Pickerel Chain of Lakes falls into the northern bass zone. Smallmouth bass are catch and release only from May 7, 2016 through June 17 and from June 18 to March 5, 2017, the daily limit is 5 fish per day in combination with largemouth bass. The daily limit for largemouth bass is 5 fish per day in combination with smallmouth bass from May 7, 2016 to March 5, 2017 and the minimum length requirement for largemouth bass is 14 inches. The Pickerel Chain of Lakes is in the northern management zone for muskellunge and northern pike. No minimum length limit exists for northern pike and five pike may be kept in a single day. Statewide regulations apply for all other fish species. Wisconsin species regulations are provided in each annual WDNR fishing regulations publication. Anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Pickerel Chain of Lakes Fish Stocking

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

The Pickerel Chain is stocked with largemouth bass and northern pike as well as bluegill and black crappie. A recent stocking summary for the Pickerel Chain of Lakes is displayed in Table 3.5-2.

Pickerel Chain of Lakes Fisheries Management

The Pickerel Chain has experienced periodic fish kills over winter caused by a lack of dissolved oxygen in the water. Anoxic conditions can develop during the winter months when dissolved oxygen is depleted from biological processes in which oxygen is consumed. Fish kills are reported to have occurred during the 1960's as well as in 1986, 1996, 2008, and most recently during the winter of 2012-2013 (per. Comm Chip Long, WDNR). It is unclear if the fish populations in the Pickerel Chain naturally recovered following the earlier fish kill events or if additional stocking occurred to restore the fish populations. Following the 2012-2013 winter kill, a goal of re-stocking gamefish including largemouth bass, northern pike, bluegill and black crappie to a self-sustaining population has been undertaken. No recent WDNR fish studies have been conducted on the Pickerel Chain to evaluate the current populations of gamefish in the system.

Table 3.5-2. Recent Stocking History on the Pickerel Chain of Lakes.

Pickerel Lake Recent Stocking History						
Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)	Source
2013	Northern Pike	Mud Lake - Madison Chain of Lakes	Small fingerling	998	4.80	DNR Hatchery
2013	Bluegill	Unspecified	Small fingerling	899	3.00	Private Hatchery
2013	Black Crappie	Unspecified	Small fingerling	900	3.00	Private Hatchery
2014	Largemouth Bass	Unspecified	Large fingerling	4,325	3.20	DNR Ponds
2014	Northern Pike	Mud Lake - Madison Chain of Lakes	Small fingerling	8,740	2.52	DNR Hatchery
2014	Bluegill	Unspecified	Large fingerling	12,319	1.00	Federal Hatchery
2014	Black Crappie	Unspecified	Large fingerling	20,800	1.50	Federal Hatchery
2015	Largemouth Bass	Unspecified	Large fingerling	8,734	1.90	DNR Ponds
2015	Northern Pike	Mud Lake - Madison Chain of Lakes	Small fingerling	8,781	3.00	DNR Hatchery
2016	Largemouth Bass	Unspecified	Large fingerling	4,990	2.20	DNR Ponds
2016	Northern Pike	Mud Lake - Madison Chain of Lakes	Small fingerling	8,910	4.10	DNR Hatchery
2016	Bluegill	Unspecified	Small fingerling	1,000	5.00	Private Hatchery
2016	Black Crappie	Unspecified	Large fingerling	31,871	2.00	Federal Hatchery

During 2014, the PCLA began working with the WDNR to install an aeration system in Pickerel Lake to maintain sufficient dissolved oxygen levels to avoid further fish kills. Aeration is a process where air is circulated through an aquatic system for the purpose of re-oxygenating the water. To address winter oxygen depletion, aeration is a common technique. Many believe that the aeration process itself re-oxygenates a lake by providing an air source to the water. While some oxygen may be provided to the lake in this manner, the greatest oxygen accumulation actually occurs through the creation of open water during the winter months, allowing for atmospheric exchange of oxygen with the open water. The overarching goal of winter aeration is to open an area of ice for this oxygen exchange, essentially creating a refuge for fish to last through the winter months. Therefore, it is not necessary to aerate large areas of a lake. Commonly, fish biologists refer to >1 to several acres of aerated area as a "refuge" where fish can overwinter.

In general, aeration systems are best suited in waters greater than five feet of depth within several hundred feet of shoreline. Because aeration units are power operated, an electrical source must be located near the unit. The aerator must be situated on public land or on private land with the landowner's permission. Usually for an aeration system to be installed off of a private landowner's property, the landowner must obtain a water regulations permit and become liable for the system, in accordance with Wisconsin Statute 167.26. The PCLA plans on obtaining an easement which will relieve the land owners of some to all liability for the aeration system while still following Wisconsin Statue 167.26.

One of the most critical responsibilities of the liable party is the erection and maintaining of a barricade. Wisconsin Statute 167.26 outlines the requirements of the barricade, including height of barricade rope off the ice, spacing around the aerated area, reflective tape / ribbon requirements, etc. When a proper barricade is made and maintained, Wisconsin Statute 167.26 specifies that the responsible party for the aeration system is exempt from liability for injury or death of any person entering the ice opening. Setting up the barricade after the onset of ice and initiation of the aeration unit does not meet the standards of Wisconsin Statute 167.26; the barricade must be initiated prior to active aeration.

The PCLA is considering the installation of additional aerating systems in Little Pickerel and/or Smoke Lakes. It is believed that fish migrate freely during the winter months between Little Pickerel, Smoke and Pickerel lakes and are able to seek out areas with sufficient dissolved oxygen if anoxic conditions occur within other areas of the chain. During the winter of 2015-2016, extensive dissolved oxygen monitoring at six locations in the chain was undertaken largely by members of the PCLA. The goal of the winter dissolved oxygen monitoring was to understand the development of anoxic conditions during the winter months and to identify possible locations to prioritize for consideration of installing aeration systems.

Map 3 displays the dissolved oxygen monitoring locations visited by PCLA volunteers during the winter of 2016. The map also includes the results of the monitoring at each site. Pickerel Lake, which had an aeration system in place and running during the study period, experienced sufficient dissolved oxygen levels throughout. Smoke Lake, the shallowest of the three chain lakes, was able to hold oxygen levels throughout the winter with no anoxia and only a single reading below 2 mg/L being collected in late February at a depth of 7 feet. Little Pickerel Lake, on the other hand, experienced high levels of anoxia through the study period.

The results for Little Pickerel Lake are not surprising as the WDNR and PCLA have voiced concern regarding anoxia in the lake for many years. The anoxia is brought about under winter ice as oxygen is utilized by bacterial decomposition of the lake's abundant plant population.

Smoke Lake's results are surprising due to the lake's shallowness and abundant plant population. The combination of several factors may have lead to these results; including the specific composition of plants within the respective lakes, higher levels of algae in Little Pickerel Lake as discussed in the lake's individual section, a 50% greater volume of water in Smoke Lake compared to Little Pickerel, and the fact that the system as a whole experienced an unusually late ice-in date during late 2015. It is impossible to tease out the actual reason or reasons with a single season's worth of data.

While Smoke Lake did not experience anoxia during winter 2016, it certainly did during February 2014 when staff from Lake and Pond Solutions Company visited the chain to collect dissolved oxygen reading through the ice on all three lakes. During their visit, 47 sets of readings were taken throughout the chain when ice was over 18 inches thick and there was approximately a foot of snow cover. Nearly all mid-depth readings were below 2.0 mg/L dissolved oxygen and all near-bottom readings were well below 0.6 mg/L.

Pickerel Chain of Lakes Substrate Type

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 are a fish that does not provide parental care to its eggs (Becker 1983). 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. 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.

According to the point-intercept survey conducted by Onterra, the lakes within the Pickerel Chain do not vary much in terms of their substrate type. The lakes contained mostly a soft, mucky bottom with small areas of sand (Table 3.5-3).

Table 3.5-3. Substrate types for the Pickerel Chain Lakes. Data collected during point intercept surveys by Onterra (2015).

Lake	% Muck	% Sand	% Rock
Pickerel Lake	91	9	1
Little Pickerel Lake	99	0	1
Smoke Lake	94	6	0

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 Pickerel Chain of Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within each lake, if any were found.
3) Collect sociological information from Pickerel Chain of Lakes stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The data collected and compiled as a part of this project indicate that overall, the Pickerel Chain of Lakes is a healthy ecosystem. Analysis of the system's water quality, watershed, and aquatic plant community all indicate the exceptional health of the system and as a result, the primary focus of the chain management plan is protection and continued monitoring. The implementation plan contained in the next section was developed by the PCLA and is based upon the association's realistic goals for the chain and the operation of the association itself. Completing the actions within the implementation plan will allow the PCLA to maintain the health of the Pickerel Chain of Lakes so future generations can enjoy the them as current generations do now.

While little historical data exist, currently, all three lakes have very good water quality exhibited by low nutrient levels and clear water. Both Little Pickerel and Pickerel Lakes experience occasional algae blooms that have been documented to contain many types of algae, including cyanobacteria (blue-green algae). Whether or not the cyanobacteria were producing toxins is unknown. Understanding algae dynamics in lakes is complicated because so many factors control growth rates of algae, such as light availability, nutrient levels, water temperatures, zooplankton populations, and interactions between algal species themselves. The complexity is compounded in low-nutrient systems like the Pickerel Chain. While most stakeholders would like a simple answer with a single reason as to why these blooms occur, that answer does not exist. Studies are being conducted all over the world to understand algal dynamics within lakes and while our general understanding is very good, detailing why blooms of certain species or a group of species occur within a lake is often impossible because so many factors come into play. Understanding the algal fluctuations in the Pickerel Chain of Lakes will begin with the determination of what species are causing the blooms. From there we can begin understanding what conditions in the lakes bring the blooms about and possibly determine corrective actions.

The water flowing through the Pickerel Chain of Lakes originates from three sources: groundwater through springs and seepage, surface flow from the chain's watershed (drainage basin), and precipitation falling directly on the lakes. Precipitation entering a lake directly without flowing off the land and groundwater typically do not carry significant amounts of pollutants, like nutrients and sediment. Normally, those pollutants enter a lake via surface flows and the amount of those pollutants depends on how big the watershed is and how the land in that watershed is used. Fortunately, the watershed that drains to the Pickerel Chain of Lakes is relatively small and the land use within it is primarily made up of cover types, like forests and wetlands, that export very small loads of pollutants to lakes. The makeup and the size of the

Pickerel Chain of Lakes watershed is the primary reason that the lakes have such good water quality.

The level and extent of shoreland development on the chain also has a lot to do with the quality of the lakes water. Studies completed by the EPA in partnership with every state in the country, have shown that shoreland development is the greatest factor leading to the deterioration of our nation's lakes – from their water quality to the fish assemblages. Development on lake shores leads to decreased habitat for terrestrial and aquatic wildlife and increased pollutant loads due to reduced buffering capacity of the shoreland zone. The Pickerel Chain supports only a moderate amount of development and in those areas that are developed, much of the shoreline is not completely devoid of habitat and buffer areas. Maintaining the shorelands or even bettering their condition from the present state is key in protecting the health of the chain.

While the aquatic plant studies completed on the chain did not indicate that the lakes' plant populations are overly diverse, the analysis did show that the community is indicative of a healthy lake ecosystem. All three of the Pickerel Chain lakes are considered mesotrophic, or moderately productive; therefore, an incredibly diverse plant population is not necessarily expected. In addition, much of the lake area is shallow, so the plant community is dominated by species that do well in those conditions. The key is that the plants within the chain provide very important ecological benefits to the system. The benefits extend to all aspects of the chain, including the fishery, its water quality, and wildlife in general.

The amount of aquatic plant biomass found in the Pickerel Chain of Lakes is there naturally and not solely because of some human action; therefore, combating the plant growth to increase navigability will be nearly impossible and at a minimum be very expensive. Raising water levels will not drown-out the plants, but will likely lead to greater shoreland erosion.

Navigability in portions of the chain is limited due to water depths and aquatic plant growth. Often lake users believe that dredging would relieve these problems. However, dredging is incredibly expensive and can lead to other, more problematic issues, such as release of buried nutrients and exposure of fresh lake sediments for rapid colonization by pioneering exotic species like Eurasian water milfoil and curly-leaf pondweed. As an example, dredging 1 acre of lake bottom, 3 feet deeper would mean that 130,680 cu.ft. of sediment would need to be removed (43,560 sq.ft. x 3 ft.) or 4,840 cu.yd. At an average cost of $15/cu.yd. of sediment removed via hydraulic dredging, that means the project would cost roughly $72,600.

In conclusion, the Pickerel Chain of Lakes is a healthy, relatively shallow chain. Because the chain is moderately productive, aquatic plants do well in its shallow waters. The aquatic plants in some areas do create an impediment to navigation and on a chain-wide scale, lead to low dissolved oxygen levels under winter ice as they decompose; however, the benefits they bring to the chain in terms of fish and wild life habitat far out way the negative issues they present. Maintenance of the existing Pickerel Lake aeration system and installation of systems in Smoke and Little Pickerel Lakes will alleviate the fish kill potential in all three lakes. Those actions are called for within the implementation plan below.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the Pickerel Chain of Lakes Association Planning Committee, Onterra ecologists, Oconto County staff, and WDNR staff. It represents the path the PCLA 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 Pickerel Chain of Lakes stakeholders as portrayed by the members of the Planning Committee and the 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 chain, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Protect and Enhance the Fishery of the Pickerel Chain of Lakes

Management Action:	Maintain Pickerel Lake aeration system and install/maintain proper aeration systems in Little Pickerel and Smoke Lakes.
Timeframe:	Pickerel Lake – Current Little Pickerel Lake – 2017 Smoke Lake - 2018
Facilitator:	Aeration Committee
Grant:	Lake Management Protection Grant in Plan Implementation Category
Description:	As described in the Fishery Section, the Pickerel Chain of Lakes has suffered several winter fishkills due to depleted oxygen levels; including the years of 1986, 1996, 2008, and most recently during the winter of 2012-2013. Volunteer dissolved oxygen monitoring completed during the winter of 2016 (Map 3) found sufficient levels of oxygen at all 4 Pickerel Lake sites during the 5 sampling periods between late-January and early-March, as expected because the aeration system was running. Smoke Lake's single site held oxygen the entire sampling period as well. Little Pickerel Lake was anoxic below 3 feet for the entire period. Although Smoke Lake was oxic during the 2016 monitoring, readings taken during February 2014 showed significant anoxia in the lake's deep hole. In fact, all three lakes showed troublesome anoxia during that sampling. With the guidance of Chip Long, WDNR Fishery Biologist, the PCLA self-funded and installed an aeration system in Pickerel Lake during 2014. The PCLA will operate and maintain that system to assure sufficient oxygen during ice-on periods on Pickerel Lake. In 2017, the PCLA will request WDNR Lake Protection funds to assist with the costs of purchasing and installing a compressor and diffuser type aeration system in Little Pickerel Lake (Maps 5) prior to winter 2017/2018. This system is supported by local WDNR fisheries staff

and designed by the PCLA Aeration Committee based on WDNR guidelines. Equipment and supply costs will be included within the grant application and the unit will provide for +/- 1 acre of open water or +/- 2% of lake area.

The PCLA is also investigating the applicability of utilizing an aspirator-style aerator on Smoke Lake. This style of system is more appropriate for shallower lakes such as Smoke Lake. During spring 2016, several PCLA members traveled to western Wisconsin to discuss installation, operation, maintenance, and advantages with local fisheries biologists. Based upon that information PCLA Aeration Committee has created a preliminary design displayed in Maps 4-6.

Action Steps:

1. Finalize design and cost estimate for Little Pickerel Lake aeration system
2. Apply for Lake Protection Grant funding in February 2017 for Little Pickerel Lake aeration system.
3. Install Little Pickerel Lake aeration system during summer 2017.
4. Finalize design and cost estimate for Smoke Lake aspirator-based aeration system.
5. Apply for Lake Protection Grant funding for Smoke Lake aeration system.
6. Install a Smoke Lake system in fall 2018

Management Action: Support WDNR in stocking of Pickerel Chain of Lakes with appropriate fish species.

Timeframe: Initiate 2017

Facilitator: Fishery Committee

Description: As described in the fishery sections, the Pickerel Chain of Lakes has experienced several winter fish kills, most recently during the winter of 2012-2013. Fish have been recently stocked in the Pickerel Chain following the last fish kill and the PCLA will continue to work with the WDNR to manage its fishery through monitoring and stocking. The PCLA will maintain good communications with Chip Long, WDNR Fisheries Biologist for Oconto County.

Action Steps: See above

Management Action: Monitor winter dissolved oxygen levels in Pickerel Chain lakes.

Timeframe: Continuation of current effort

Facilitator: CLMN volunteers

Description: Continued monitoring of dissolved oxygen levels in all three Pickerel Chain lakes is necessary to document the need for aeration in these lakes and the successful operation of the aeration units once they are installed. Monitoring is important during the operation of the units to verify efficient placement of the units. Monitoring effort would be decreased over time as successful operation of the units is documented and the association becomes confident.

Dissolved oxygen would be monitored bi-weekly at multiple sites in lakes that currently do not have an aeration system installed and in lakes where the system is operating for the first year or the lake's system has been substantially modified.

During the second year of a system's operation, and beyond, dissolved oxygen would be monitored monthly at several sites in the lake.

Action Steps:

1. Recruit volunteers for monitoring
2. Train volunteers on use of association-owned YSI dissolved oxygen probe and meter.
3. Monitor lakes as described above.
4. Enter data into SWIMS and report to the association annually.
5. Maintain/calibrate dissolved oxygen probe and meter per manufacturer's instructions.

Management Goal 2: Enhance Water Quality of Pickerel Chain of Lakes

Management Action: Continue monitoring of the Pickerel Chain of Lakes' water quality through WDNR Citizens Lake Monitoring Network.

Timeframe: Continuation of current effort

Facilitator: CLMN volunteers

Description: Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason as of why the trend is developing. Or conversely, the detection of positive trends may indicate that remediation actions are working.

The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the PCLA have been collecting water quality data from each lake of the chain since 2015. The PCLA realizes the importance of continuing this effort, which will supply them with valuable data about their lake. When a change in the collection volunteer occurs, Brenda Nordin, or the appropriate WDNR/UW-Extension staff, will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. CLMN volunteers, recruited as needed..
2. Volunteer contacts Brenda Nordin (920.360.3167) as needed.
3. Enter data into SWIMS and coordinator reports results and PCLA members during annual meeting.

Management Action:	Investigate occasional algae blooms on Pickerel and Little Pickerel Lakes
Timeframe:	2018?
Facilitator:	Board of Directors
Potential Grant:	Lake Management Planning or Lake Management Protection

Description: Residents on Pickerel Lake of the Pickerel Chain of Lakes, have documented high levels of algae growth in spot locations during the growing seasons of 2013-2016. Blooms have also been documented on Little Pickerel Lake during some summers as recently as 2014. Some of these algae were confirmed as cyanobacteria (blue-green algae) by WDNR algae experts; however, a determination if algal toxins were present was not performed.

Determining the causes of algal blooms, especially in moderately productive lakes like the Pickerel Chain, are always difficult and at times impossible. Nutrient levels and sunlight availability, while important in all cases, are not the only factors controlling the growth rates of algae. Temperature, inter-species competition, iron availability, lake stratification, and many other factors can cumulate to produce conditions allowing one or more algae types to proliferate and create a bloom. In clear systems like the Pickerel Chain, a low-level bloom can create concern among lake residence.

Specific types of algae respond to different conditions; therefore, understanding the types of algae found in the blooms is the first step in understanding the blooms. This action would initiate a study that would document the types of algae found in Pickerel Lake during the growing season and determine approximate relative abundances. It would also track nutrient concentrations, water clarity, temperature, dissolved oxygen, and chlorophyll levels over the same time period. With these data, a clearer understanding of the conditions causing the algae blooms would be possible and a determination of actions to reduce their frequency could be made.

Action Steps:

1. Finalize study design.

2. Discuss appropriate grant category with WDNR.
3. Recruit and train volunteers for water quality and algae sampling.
4. Share results with PCLA and WDNR to determine next steps.

Management Action:	Inform Pickerel Chain of Lakes stakeholders on potential risks of blue-green algae.
Timeframe:	Initiate 2017
Facilitator:	Board of Directors
Description:	As discussed within the Water Quality Section, the Pickerel Chain of Lakes has experienced blue-green algae blooms on an occasional basis. Some species of blue-green algae can produce toxins which can be hazardous to human and animal health through ingestion or direct contact. Toxins are not always produced during these blooms and the conditions that lead to toxin production are not well understood. Therefore, because toxin production cannot be predicted, water use warnings are issued when there are high concentrations of blue-green algae present. The PCLA will include information on blue-green algae blooms within their newsletter informing people to avoid contact with the water, including their pets, if it resembles "pea-soup." Individuals who want to report blue-green algae should contact the PCLA who will then take proper actions. Information supplied to the PCLA by the WDNR, during the summer of 2016 would be used as a basis for the information provided to the association members.
Action Steps:	See above.

Management Goal 3: Enhance the Capacity of the Pickerel Chain of Lakes Association to Manage the Pickerel Chain of Lakes through Increased Membership, Volunteerism, and Information

Management Action:	Create Membership & Volunteerism standing committee of PCLA.
Timeframe:	Initiate 2017
Facilitator:	Board of Directors
Potential Grant:	Small-scale Planning Grant could include some aspects of initial set-up, such as training and printing.
Description:	Sustaining membership and volunteerism in any organization is difficult, especially in an organization that represents a population that is not consistently in the area and is there primarily to recreate and relax. Many lake associations struggle with this issue because member and volunteer recruiting is completed sporadically and on an as-needed or urgent basis.

Without good management, volunteers may become underutilized. Some may have been turned off by an impersonal, tense or cold atmosphere. Volunteers want to feel good about themselves for helping out, so every effort must be made by volunteer managers to see to it that the volunteer crews enjoy their tasks and their co-volunteers.

To increase and sustain association membership and volunteerism effectively and efficiently, the PCLA will create a standing committee of the association aimed at completing these tasks consistently.

Committee, and other association members, should consider attending all or a portion of the Wisconsin Lakes Partnership Convention held each spring. A wealth of knowledge regarding lake group function is available each year through presentations, workshops, and networking opportunities.

This committee would work closely with the Education & Communication Committee as each committee's goals overlap considerably.

Action Steps:

1. Recruit first committee member to act as chairperson.
2. Investigate if WDNR Small-Scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. Establish reasonable, but flexible annual budget.
4. Chairperson recruits additional members with board assistance.
5. Chairperson reports activities and results to board and membership.

Management Action: Create Education & Communication standing committee of PCLA.

Timeframe: Initiate 2017

Facilitator: Board of Directors

Potential Grant: Small-Scale Planning Grant could include some aspects of initial set-up, such as training and printing.

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 PCLA utilizes 4 newsletters per year, its Facebook page, and annual meetings to convey information to its members. By forming an Education Committee, the PCLA will have a group of stakeholders dedicated to creating new and innovative ways of educating chain stakeholders on the ecology of the system, rules and regulations regarding activities on the lakes, and what they may do to protect or restore the chain. Example educational topics include:

- Aquatic invasive species monitoring updates
- Boating safety and ordinances (slow-no-wake zones and hours)
- Catch and release fishing
- Littering
- Noise, air, and light pollution
- Shoreland restoration and protection
- Septic system maintenance
- Fishing Rules
- Issues concerning the dam

The committee will be responsible for reaching out to state or local affiliates which can provide them with educational pamphlets, other materials or ideas, such as the UW-Extension Lakes Program. These partners may be some of those included in the table found under Management Goal 4 below.

Committee members should consider attending all or a portion of the Wisconsin Lakes Partnership Convention held each spring. A wealth of knowledge regarding lake group function is available each year through presentations, workshops, and networking opportunities.

This committee would work closely with the Membership & Volunteerism Committee as each committee's goals overlap considerably.

Action Steps:

1. Recruit first committee member to act as chairperson.
2. Investigate if WDNR Small-Scale Lake Planning Grant would be appropriate to cover initial setup costs.
3. Establish reasonable, but flexible annual budget.
4. Chairperson recruits additional members with board assistance.
5. Chairperson reports activities and results to board and membership.

Management Goal 4: Facilitate Partnerships with Other Management Entities and Stakeholders

Management Action: Enhance PCLA's involvement with other entities that have a hand in managing (management units) or otherwise utilizing the Pickerel Chain of Lakes.

Timeframe: Initiate 2017

Facilitator: Board of Directors to appoint PCLA representatives.

Description: It is important that the PCLA engage with all management entities to enhance the association's understanding of common management goals and to participate in development of those goals. This also familiarizes all management entities with actions that others are taking to reduce the duplication of efforts. The primary management units regarding the Pickerel Chain of Lakes include governmental units such as the WDNR, or the Town of Townsend, but also include groups similar to the PCLA such as the Oconto County Lakes and Waterways Association. Each entity is specifically addressed below.

Action Steps:

1. See table guidelines below.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (Chip Long – 715.582.5017)	Manages the fishery of the Pickerel Chain.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Brenda Nordin – 920.360.3167)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants or to seek advice on other lake issues.
	Conservation Warden (Paul Hartrick – 920.373.4179)	Oversees regulations handed down by the state.	As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also.	Suspected violations pertaining to recreational activity, including fishing, boating safety, ordinance violations, etc.
	CLMN Director (Sandra Wickman – 715.365.8951)	Training and assistance on CLMN activities.	Twice a year or more as needed.	Contact to arrange for training as needed, in addition to planning out monitoring and reporting of data.
Oconto County	County Conservationist (Ken Dolata – 920.834.7152)	Provide technical assistance and education.	Twice a year or more as issues arise.	Contact to report new occurrences of AIS.
Timberland Invasives Partnership	Coordinator (Chris Arrowood – 715-799-5710 x3)	Facilitates education on AIS.	As needed	Provides AIS education, ID, and training. Contact to report new occurrences of AIS.
Town of Townsend	Chairperson (Bruce Karow - 715.276.1515)	Supports PCLA, assists in lake management.	As needed. Visit website (www.townoftownsend.com) often.	Contact regarding grant applications, projects such as CBCW, town events, etc.
Lakewood Area Chamber of Commerce (includes Townsed)	President (Chip Maule – (715.276.6500)	Coordinates recreational and town-wide events, partner in managing lakes	As needed.	Management project results may be shared, or displayed at public events, etc. Informative packets available at chamber of commerce.
Oconto County Lakes & Waterways Association	Secretary (Judie Gowaski – 920.826.5358 or 920.672.8063)	Protects Oconto Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partnering in special projects, or networking on other topics pertaining to Oconto Co. waterways.
UW-Extension	Program Coordinator (Erin McFarlane – 715.346.4978)	Clean Boats Clean Waters Program	As needed.	May be contacted to set up CBCW training sessions, report data, etc.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on lake issues.	As needed. May check website (www.wisconsinlakes.org) often for updates.	May attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, training, habitat enhancement techniques, etc.

Management Goal 5: **Increase Boater Safety and Reduce Boating Impact on Pickerel Chain of Lakes**

Management Action:	Inform resident and transient boaters regarding slow-no-wake areas and times on Pickerel Chain of Lakes to protect habitat and assure watercraft safety.
Timeframe:	Initiate 2017
Facilitator:	Education & Communication Committee
Description:	Several slow-no-wake (SNW) areas exist on the Pickerel Chain of Lakes, including the waterways that connect them. These SNW areas exist to protect aquatic habitat, reduce resuspension of bottom sediments in shallow areas, and provide for watercraft safety in near-shore and narrow channels. A Town of Townsend ordinance also sets SNW hours for the entire chain from 5:00pm to 10:00am. Of the people who responded to the stakeholder survey, 85.2% believe that the SNW hours are reasonable as they are set currently. Little support for extending the time (10%) or shortening the time (7.5%) was indicated by responses (Appendix B – Question 16). Expecting local law enforcement to patrol the Pickerel Chain of Lakes to enforce these rules is not realistic; therefore, PCLA will work to inform Pickerel Chain residents and visitors to the chain about these rules within their newsletters, at their association meetings, and on the PCLA Facebook page.
Action Steps:	See description above.

Management Action:	Place association-owned buoys to mark slow-no-wake zones on the Pickerel Chain of Lakes.
Timeframe:	2017
Facilitator:	Board of Directors
Potential Grant:	Sign and buoy costs may be applicable to Lake Protection Grant
Description:	Slow-no-wake (SNW) areas exist within the channels between the individual waterbodies of the Pickerel Chain of Lakes. The SNW areas are set by state law and exist to protect shallow water and near shore habitat and to assure boater safety in narrow channels. The PCLA will purchase buoys for placement at channel entrances at the beginning of each boating season. The association will also remove the buoys at the end of the season. Information regarding the buoys, their location, and their meaning will be provided to chain residents and transient boaters via the PCLA newsletter, Facebook page, and at kiosks located at the Pickerel Lake boat landing..

Action Steps:

1. Review WDNR guidelines available for local boating ordinances and waterway

markers at: http://dnr.wi.gov/files/PDF/pubs/le/LE0317.pdf

2. Submit Waterway Marker Application and Permit to WDNR (Form 8700-058, http://dnr.wi.gov/topic/Waterways/permit_apps/Waterway_Marker_Application_Permit_Form_8700-058.pdf)
3. Purchase buoys and place according to map included in permit.

Management Goal 6: Maintain Current Healthy Pickerel Chain of Lakes Watershed

Management Action:	Establish and maintain contact with key watershed property owners.
Timeframe:	Initiate 2017
Facilitator:	Education & Communication Committee
Description:	The Pickerel Chain of Lakes watershed, as discussed in the Watershed Section (3.2), is in very good condition with much of it being in forest or wetland cover. Only 33 acres or roughly 4% of the total watershed is in agriculture; however, these areas are close to Little Pickerel and Smoke Lakes. The modeling completed as a part of this project indicates that these areas are not currently impacting the chain significantly, but major changes, such as frequent spreading of manure, over use of fertilizers, or expansion, may negatively affect the lakes. The Education & Planning Committee will establish contact with these key watershed property owners and maintain that contact by including the owners in the association newsletter distribution. Opening this line of communication prior to the development of issues will lead to easier resolution if issues arise.
Action Steps:	See description above.

Management Action:	Inform Pickerel Chain of Lakes Property Owners about the Importance of Healthy Shorelands.
Timeframe:	Initiate 2017
Facilitator:	Education & Communication Committee
Potential Grant:	Small-Scale Lake Planning Grant could pay a portion of printing costs.
Description:	As discussed in the Shoreland Condition Section (3.3), the shoreland zone of a lake is highly important to the ecology of the system. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. In 2015, the shoreland assessment survey indicated that only 0.6 miles, or 6% of the chain's roughly 9.2-mile shoreline, consisted of *urbanized* or *developed-*

unnatural areas (See Individual Lake sections); therefore, the restoration of these areas is not imperative at this time to improve water quality; however, informing chain residents about shoreland restoration and protection is important in preventing the degradation of properties around the lakes. Also, information should be provided to those property owners whose shorelands are in the urbanized or developed-unnatural category in the even they would like to restore it.

The Education & Communication Committee will assemble information from available resources, such as the Oconto County Lakes & Waterways Association, Oconto County, and UW-Extension Lakes Program and provide that information via the association newsletter, Facebook Page, and at association meetings. The information will include topics such as:

- Importance of natural or near-natural shorelands in buffering runoff and providing terrestrial and aquatic habitat.
- Cost share programs available from Oconto County (Ken Dolata – 920.834.7152) and WDNR Healthy Lakes Initiative (http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/healthylakes/default.aspx).
- Benefits of natural shorelands for deterring Canada goose loafing on lake properties.

If interest is sufficient, the PCLA would work with property owners, and possibly the Town of Townsend, to complete shoreland restoration demonstration sites on the Pickerel Chain of Lakes. Oughton Park may be a good location for one of these demonstrations. Oconto County would be available to assist with designs and possible funding as discussed above.

Action Steps: See description above.

Management Goal 7: Prevent Introduction of Additional AIS and Control Current AIS in Pickerel Chain of Lakes

Management Action: Create AIS standing committee of PCLA.

Timeframe: Initiate 2017

Facilitator: Board of Directors

Potential Grant: Small-Scale AIS-Education, Prevention, and Planning Grant would cover a portion of start-up, training, and printing costs.

Description: Three aquatic plant surveys were completed on the Pickerel Chain of Lakes as a part of this management planning project and the only exotic plant species located in the lake was purple loosestrife. Further, plankton tows completed in 2015 were found to be free of zebra mussel veligers. Other known AIS included banded and Chinese mystery snails. The absence of exotic species, such as Eurasian water milfoil and curly-leaf pondweed, both found in nearby lakes, is an incredible positive attribute of the Pickerel Chain of Lakes. Protecting that positive attribute is important in protecting the health of the chain.

To facilitate consistent AIS protection and control measures on the Pickerel Chain of Lakes, the PCLA will form an AIS Committee to oversee association AIS programs.

Action Steps:

1. Recruit first committee member to act as chairperson.
2. Investigate if WDNR Small-Scale AIS-Education, Prevention, and Planning Grant would be appropriate to cover initial setup costs.
3. Establish reasonable, but flexible annual budget.
4. Chairperson recruits additional members with board assistance.
5. Chairperson reports activities and results to board and membership.

Management Action: Initiate Clean Boats Clean Waters inspections at public landing.

Timeframe: Initiate 2017

Facilitator: AIS Committee

Potential Grant: WDNR Clean Boats Clean Waters Grant

Description: The Pickerel Chain of Lake is currently believed to be free of common AIS such as Eurasian water milfoil, curly-leaf pondweed, and zebra mussels. These AIS, and most others, are primarily transferred between lakes through their public and private access sites. The WDNR Clean Boats Clean Waters (CBCW) Program has shown to slow the spread of AIS between lakes in Wisconsin primarily by educating boaters about AIS and their role in potentially spreading it.

The program relies on volunteers to inspect boats at public landings prior to launch and when they are being taken out of the lake. Volunteers are trained and provided materials produced by the WDNR. Inspection activities are logged on the WDNR Surface Water Integrated Monitoring System (SWIMS) database. Funding is available through the WDNR CBCW Grant Program (http://dnr.wi.gov/lakes/cbcw/).

The focus of the Pickerel Chain of Lakes CBCW program will be to cover the landing at Oughton Park during the busiest weekends of the year, such as opening day for the fishing season, Memorial Day weekend, Independence Day weekend, and Labor Day weekend.

Action Steps:

1. Recruit association members for CBCW training.

2. Contact Brenda Nordin, WDNR (920.360.3167) to arrange training session.
3. Conduct watercraft inspections.
4. Report inspection data to WDNR via SWIMS and PCLA via Education & Communication Committee.

Management Action:	Complete volunteer-based AIS monitoring on Pickerel Chain of Lakes
Timeframe:	Initiate 2017
Facilitator:	AIS Committee
Potential Grant:	Small-Scale AIS-Education, Prevention, and Planning Grant
Description:	Currently, the Pickerel Chain of Lakes is believed to be free of Eurasian water milfoil and curly-leaf pondweed, two of the most common and potentially troublesome AIS in the Midwest. With proper training, volunteers are able to monitor their lake for these species and others with the primary goal of early detection. WDNR or UW-Extension staff provide the training at no cost to the lake group. The lake group is responsible for organizing and completing the surveys. Suspicious findings can be verified by county or WDNR staff.
Action Steps:	

1. AIS Committee recruits volunteers from each lake in the chain.
2. AIS Committee arranges training date with WDNR or UW-Extension staff (see Goal 4 above for contact information).
3. Trained volunteers monitor specified lakes and/or areas of a lake.
4. Report monitoring results to PCLA and WDNR.

Management Action:	Control purple loosestrife on Pickerel Chain of Lakes
Timeframe:	Initiate 2017
Facilitator:	AIS Committee
Potential Grant:	Small-Scale AIS-Education, Prevention, and Planning Grant
Description:	Surveys completed in 2015 located a scattered population of purple loosestrife in the northern portion of Pickerel Lake (Pickerel Lake Map 3). Purple loosestrife is an aggressive wetland emergent capable of taking over large areas of wetland and nearshore emergent communities very quickly. The PCLA will work with the WDNR, UW-Extension, and Timberwood Invasive Partnership to inspect the area and determine the best method of control for this invasive species. Once that method is determined, the PCLA will use volunteers or professionals, as appropriate, to complete the control action.
Action Steps:	See description above.

Management Goal 8: Increase Stakeholder Understanding of Dam Operation and Water Levels on Pickerel Chain of Lakes

Management Action: Install staff gauge at town-owned dam and report periodic readings to WDNR and PCLA members.

Timeframe: Initiate 2017

Facilitator: Board of Directors

Description: The Pickerel Lake Dam, owned by the Town of Townsend was reconstructed in 2015 to include a hydraulic height of 5.2 feet. Water levels are controlled by stop logs being placed in a 5-foot weir that flows into a whistle tube which outfalls to Pickerel Creek. While water levels can be manipulated through the addition and removal of stop logs, the town leaves the stop logs in place with a constant crest at 1308.91 feet above Mean Sea Level resulting. No dam operating order exists to determine operating levels; however, a minimum flow to Pickerel Creek must be maintained. The natural flow from the Pickerel Chain sufficiently feeds Pickerel Creek above minimum required by state law.

Developing a long-term water level dataset for the Pickerel Lake Dam will lead to a better understanding of dam operations and the actual impact the dam has on the water levels of the Pickerel Chain of Lakes. While over half of the respondents believe that water levels are adequate in the chain roughly 1/3 of the respondents believe that water levels are too low making navigation difficult and degrading water quality. Understanding how the dam operates and having access to accurate data would ease some of these concerns and bring about realistic expectations on the chain.

Oconto County Conservationist, Ken Dolata (920.834.7152) has offered to install the gauge and train a volunteer on how to record data and supply it to the WDNR for listing on the department's Surface Water Integrated Monitoring System (SWIMS) database.

Action Steps:

1. Contact Ken Dolata regarding gauge purchase and installation.
2. Train volunteers for periodic reading and data entry.
3. Make data available to membership by suppling URL to SWIMS database.
4. Report on data collection and results at annual meetings.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied in 2015 to assist in identifying potential water quality problems in the Pickerel Chain lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in each lake that would most accurately depict the conditions of the lake (Map 1). Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B). Sampling occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following standard protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included the following:

Parameter	Spring		June		July		August		Fall		Winter	
	S	B	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Dissolved Phosphorus	●	●			●	●					●	●
Chlorophyll <u>a</u>	●		●		●				●			
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Total Suspended Solids	●	●			●	●			●	●		
Calcium	●				●							

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was completed using a Hydrolab DataSonde 5.

Watershed Analysis

The watershed analysis began with an accurate delineation of the Pickerel Chain of Lakes drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. Watershed delineations were determined for each project lake. 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

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on the Pickerel Chain of Lakes during mid to late June in order to correspond with the anticipated peak growth of the plant. Please refer to each individual lake section for the exact date in which each survey was conducted. 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 the system to characterize the existing communities within each lake and included 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 (Hauxwell 2010) was used to complete the studies. Based upon advice from the WDNR, the following point spacing and resulting number of points comprised the surveys:

Community Mapping

During the species inventory work, the aquatic vegetation community types within each 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 each of the lakes.

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8.0 INDIVIDUAL LAKE REPORTS

Note: Methodology, explanation of analysis and scientific background on Pickerel Lake studies are contained within the Pickerel Chain-wide Management Plan document.

8.1 Pickerel Lake

An Introduction to Pickerel Lake

Pickerel Lake, Oconto County, is a drainage lake with a maximum depth of 14 feet and a surface area of 185 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Pickerel Lake contains 44 native plant species, of which muskgrass was the most common plant.

Field Survey Notes

Northern section of the lake leading up to the dam is largely undeveloped. Coarse woody habitat in the form of downed trees, logs and stumps are prevalent in the area and provide excellent habitat for fish and wildlife inhabiting the lake.

Photo 8.1 Pickerel Lake, Oconto County

Lake at a Glance* – Pickerel Lake

Morphology	
Acreage	185
Maximum Depth (ft)	14
Mean Depth (ft)	6.5
Volume (acre-feet)	1287
Shoreline Complexity	8.9
Vegetation	
Curly-leaf Survey Date	June 3, 2015
Comprehensive Survey Date	July 13th and 14th, 2015
Number of Native Species	47
Threatened/Special Concern Species	N/A
Exotic Plant Species	Purple loosestrife (*Lythrum salicaria)*
Simpson's Diversity	0.88
Average Conservatism	6.3
Water Quality	
Wisconsin Lake Classification	Shallow, lowland drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	4:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.1.1 Pickerel Lake Water Quality

Water quality data was collected from Pickerel Lake on six occasions in 2015/2016. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

Unfortunately, very limited data exists for the three water quality parameters of interest – Secchi disk, total phosphorus and chlorophyll-*a* concentrations. Total phosphorus values are available from only four years on Pickerel Lake (Figure 8.1.1-1) making long-term trend analysis impossible. All values are considered excellent and are close to or below ecoregion and state values. While the chart shows a slight upward trend in values from 1979 to 2015, this would be a gross misinterpretation because no data exist between 1979-1993 and 1993-2013. Most lakes see fluctuations in water quality annually and seasonally, which cannot be seen with these large gaps in phosphorus data.

Like total phosphorus, very little chlorophyll-*a* data are available for analysis (Figure 8.1.1-2); however, those that exist match well with the phosphorus data and are lower than median values for lakes within the ecoregion and state. Secchi disk clarity is influenced by many factors, including plankton production, as measured by chlorophyll-*a*, as well as other suspended particles and the color of the water., which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. As shown in Figure (8.1.1-3) clarity values for Pickerel Lake fall within the "Excellent" category and often exceed ecoregion values.

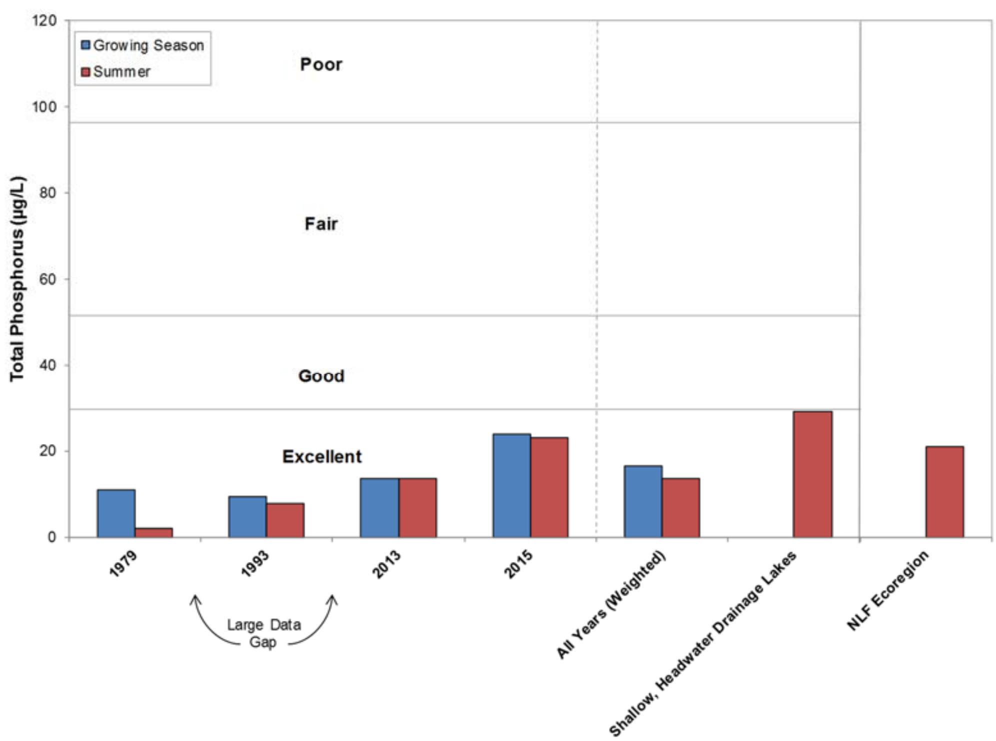

Figure 8.1.1-1. Pickerel Lake, state-wide shallow, headwater drainage lakes, and regional total phosphorus values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

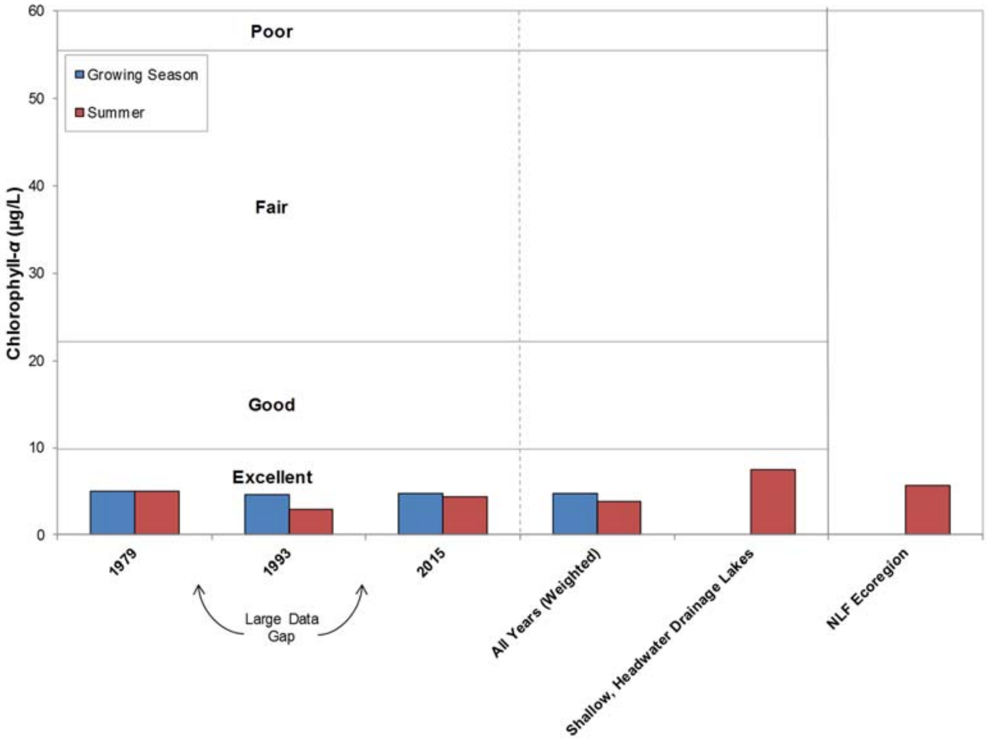

Figure 8.1.1-2. Pickerel Lake, state-wide shallow, headwater drainage lakes, and regional chlorophyll-α values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

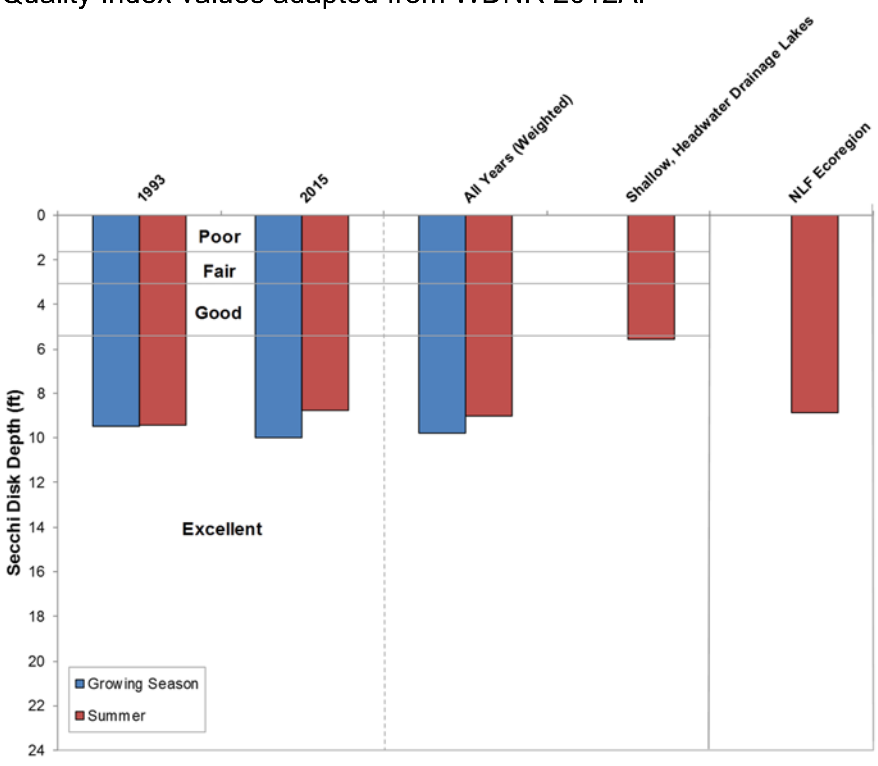

Figure 8.1.1-3. Pickerel Lake, state-wide shallow, headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

Pickerel Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper oligotrophic to upper mesotrophic (Figure 8.1.1-4). 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 Pickerel Lake is moderately productive and in a mesotrophic state.

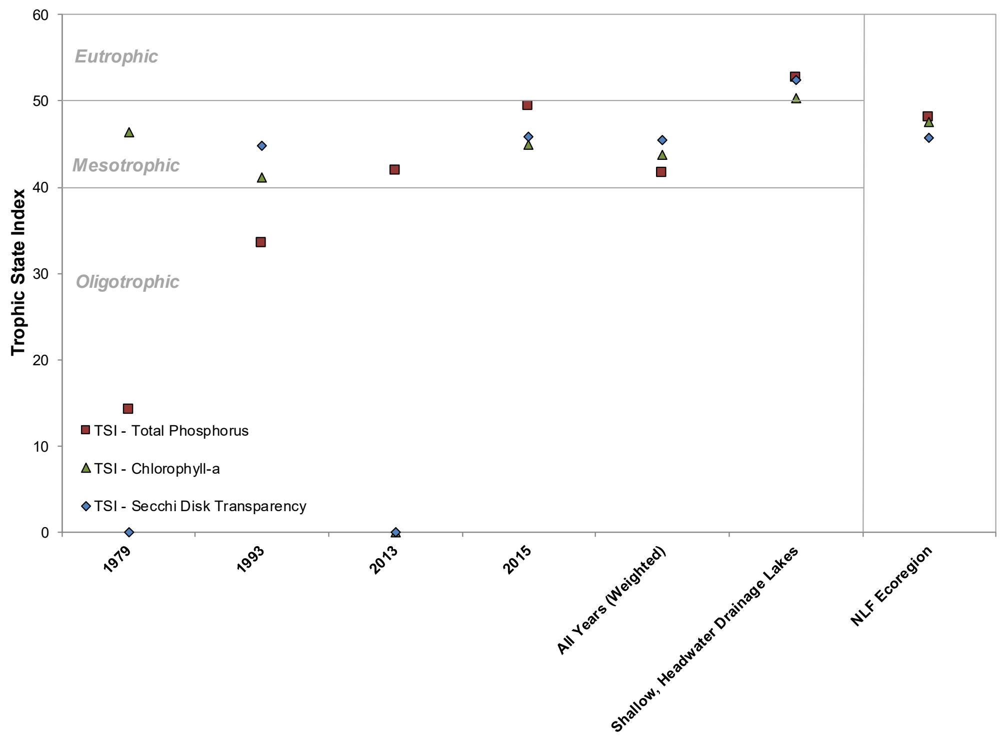

Figure 8.1.1-4. Pickerel Lake, state-wide shallow, headwater drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Pickerel Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Pickerel Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-5 for all sampling events.

Pickerel Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, Pickerel Lake stays mixed due to its shallow depth. Dissolved oxygen values were high during the entire study period. Additional dissolved oxygen data were collected by PCLA volunteers during the winter of 2016 and are discussed in the chain-wide section of this document.

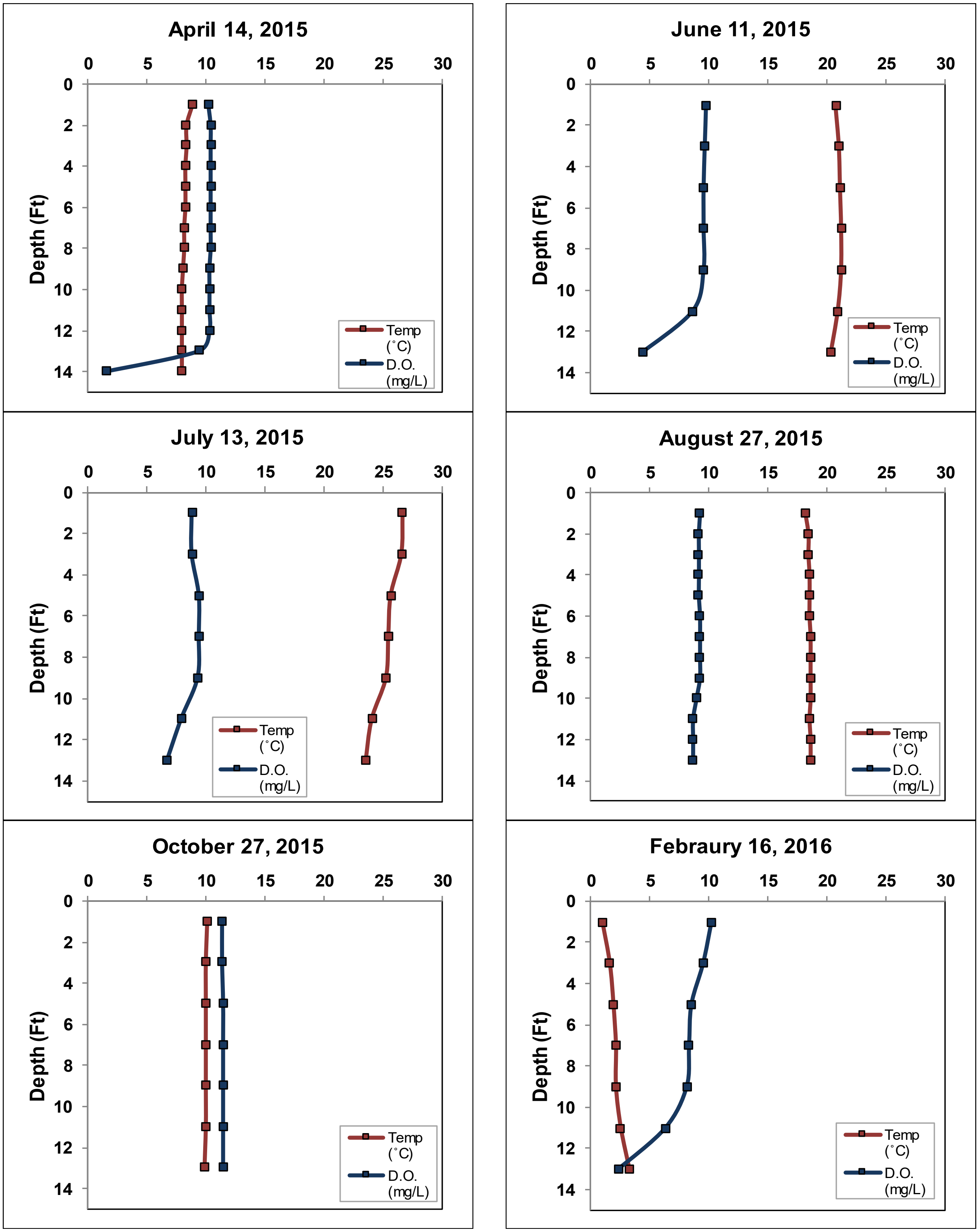

Figure 8.1.1-5. Pickerel Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Pickerel Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Pickerel Lake's surface water pH was measured at roughly 8.2 during summer 2015. This value is slightly above neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Pickerel Lake was measured at 121 mg/L as $CaCO_3$, indicating that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Pickerel Lake during the summer of 2015. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Pickerel Lake's pH of 8.0 - 8.2 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Pickerel Lake was found to be 29.8 mg/L, which is outside of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2015 and these samples were processed by the WDNR for larval zebra mussels. No veligers (zebra mussels in the larval form) were found within these samples.

8.1.2 Pickerel Lake Watershed Assessment

Pickerel Lake's watershed is 972 acres in size. Compared to Pickerel Lake's size of 197 acres, this makes for small watershed to lake area ratio of 4:1. As mentioned in the chain-wide section above, lakes with small watershed to lake area rations typically have less nutrients being delivered to them. Little Pickerel Lake and Smoke Lake's watersheds are subwatersheds of Pickerel Lake (Figure 8.1.2-1); therefore the analysis must include the impacts that Smoke and Little Pickerel lakes have on the water passing through them from their watersheds and into Pickerel Lake. The Little Pickerel and Smoke subwatersheds make up nearly 40% of the Pickerel Lake watershed. Forests occupy 17%, while wetlands and Pickerel Lake itself cover 20% each. Pastures and rural residential areas occur in 4% and less than 1%, respectively.

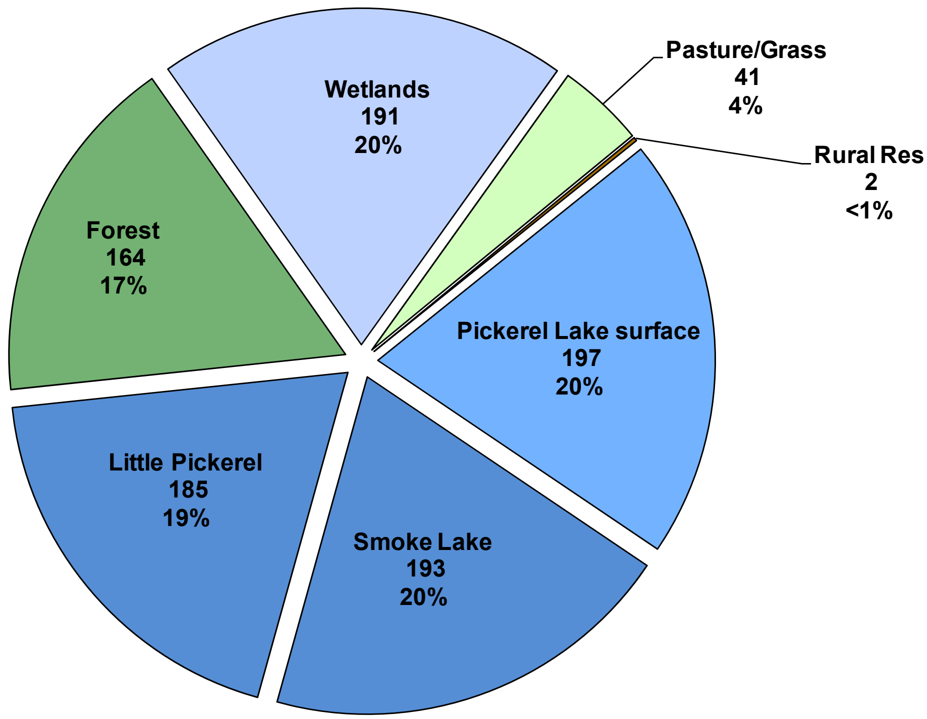

Figure 8.1.2-1. Pickerel Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011). Specifics concerning Smoke and Little Pickerel lakes subwatersheds can be found in their respective individual lake sections below.

Figure 8.1.2-2 displays the breakdown of phosphorus contributions to Pickerel Lake by each land cover type and the Little Pickerel and Smoke subwatersheds. Overall, an estimated 116 lbs of phosphorus enters Pickerel Lake from its watershed. This would be considered a very small amount of loading, but is not surprising considering the size of the watershed and the high quality of the land cover within it. Of the total load, 46% arrives to the Pickerel Lake surface via atmospheric fallout – basically dust landing on the lake's surface or being added to the lake directly as precipitation. Contributions from the Smoke and Little Pickerel subwatersheds make up approximately 15% of the total. . Forest areas, wetlands, and pasture/grasslands contribute 11%, 15%, and 9%, respectively.

It should be noted that both Smoke and Little Pickerel lakes act as sedimentation basins for Pickerel Lake by settling out phosphorus entering them before sending the water downstream to Pickerel. Smoke Lake's watershed contributes about 46 lbs of phosphorus to the lake each year, yet the lake only releases approximately 5 lbs to Pickerel Lake. Little Pickerel Lake's annual phosphorus load is approximately 36 lbs and it exports approximately 11 lbs to Pickerel Lake.

The WiLMS analysis for Pickerel Lake also included an estimate for septic system inputs to the lake based upon data collected through the stakeholder survey. The estimate takes into account the types of septic systems utilized around the lake and how much they are used. The estimate indicates that approximately 5 lbs of phosphorus may enter the lake from septic systems, which would be considered very low.

Using standard predictive equations, an estimated in-lake, growing season average phosphorus concentration can be determined for Pickerel Lake based upon its morphology and typical precipitation levels for Oconto County. The Pickerel Lake modeling indicated a predicted average concentration of 24 mg/L phosphorus, which is higher than the actual average concentration of 16.6 mg/L. This indicates that the modeling effort slightly over-estimated the amount of phosphorus entering the lake, further evidencing the healthy nature of the Pickerel Lake watershed. It also indicates that unknown sources of phosphorus, like internal nutrient loading and/or excessive inputs from shoreland properties or septic systems are not impacting the lake.

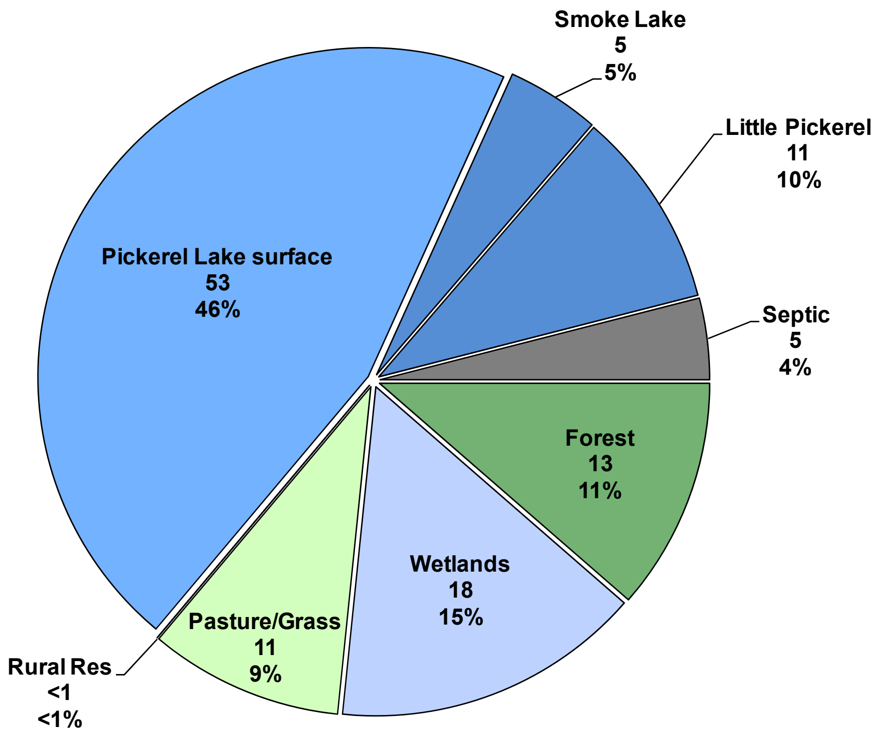

Figure 8.1.2-2 Pickerel Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates. Specifics concerning Smoke and Little Pickerel lakes subwatersheds can be found in their respective individual lake sections below.

8.1.3 Pickerel Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff and is also a critical area for wildlife habitat. In late summer of 2015, Pickerel Lake's immediate shoreline was assessed in terms of its development. Pickerel Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.4 miles (80% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural/near-natural state if at all possible. During the survey, 0.4 miles of urbanized and developed–unnatural shoreline (7% of the total shoreline) was observed. If restoration of the Pickerel Lake shoreline 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. Pickerel Lake Map 1 displays the location of these shoreline lengths around the entire lake.

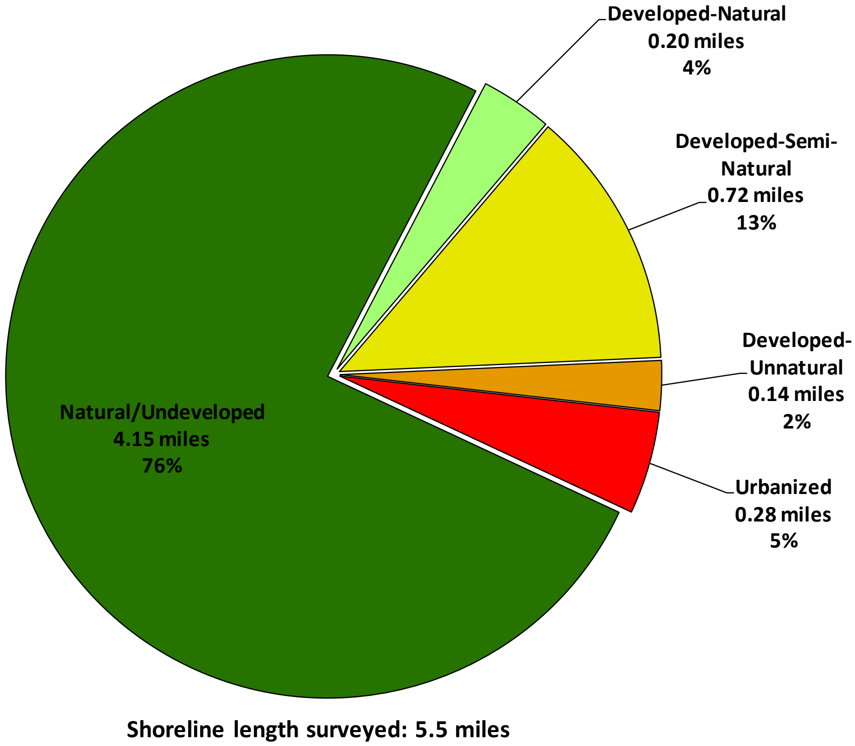

Figure 8.1.3-1. Pickerel Lake shoreland categories and total lengths. Based upon a late summer 2015 survey. Locations of these categorized shorelands can be found on Pickerel Lake Map 1.

Coarse Woody Habitat

Pickerel Lake was also surveyed in the fall of 2015 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 320 total pieces of coarse woody habitat were observed along 5.5 miles of shoreline, which gives Pickerel Lake a coarse woody habitat to shoreline mile ratio of 58:1. Locations of coarse woody habitat are displayed on Pickerel Lake Map 2. 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).

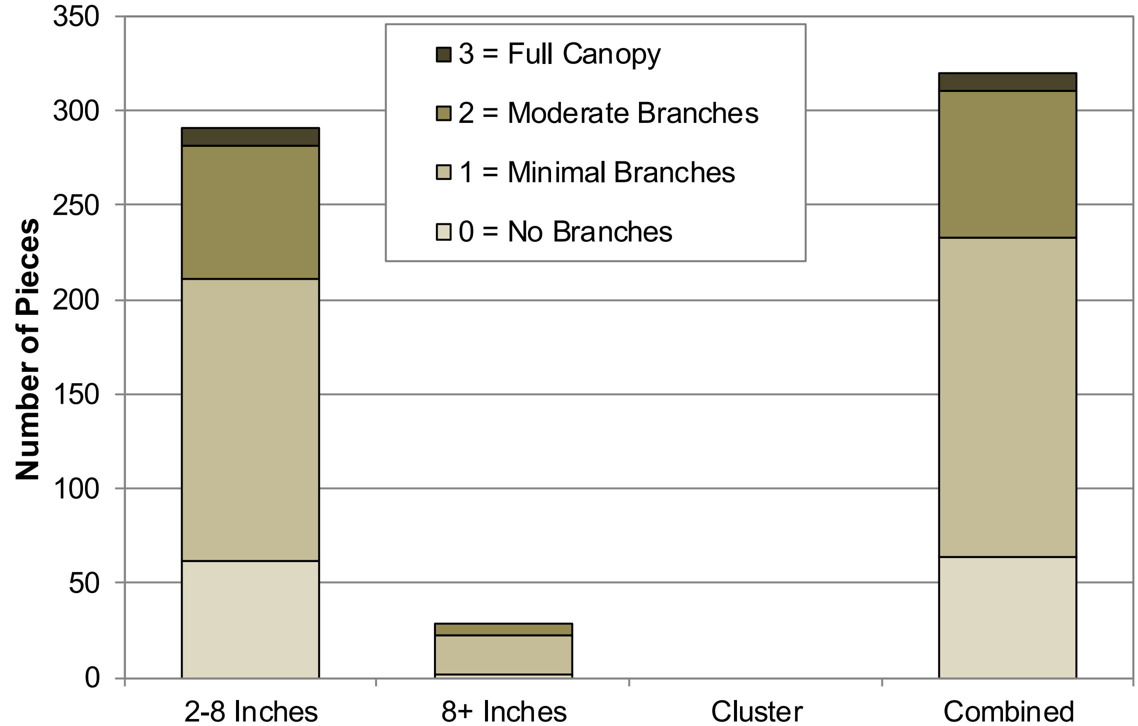

Figure 8.1.3-2. Pickerel Lake coarse woody habitat survey results. Based upon a fall 2015 survey. Locations of Pickerel Lake coarse woody habitat can be found on Pickerel Lake Map 2

8.1.4 Pickerel Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Pickerel Lake on June 3, 2015. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Pickerel Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Pickerel Lake on July 13 & 14, 2015 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on August 14 & 15, 2015 to create the aquatic plant community map (Pickerel Lake Map 3) during this time. During all surveys, 44 species of native aquatic plants were located in Pickerel Lake (Table 8.1.4-1). Thirty-two of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 14 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare.

Of the 399 point-intercept locations sampled within the littoral zone, approximately 95% contained aquatic vegetation. Pickerel Lake Map 4 depicts the total rake fullness of the 399 sampled locations. Approximately 8% of the point-intercept sampling locations where sediment data was collected were sand, 91% consisted of a fine, organic substrate (muck) and 1% were determined to be rocky.

Table 8.1.4-1. Aquatic plant species located in the Pickerel Lake during the 2015 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2015 (Onterra)
Emergent	*Calla palustris*	Water arum	9	I
	Carex comosa	Bristly sedge	5	I
	Carex hystericina	Porcupine sedge	3	I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9	I
	Cladium mariscoides	Smooth sawgrass	10	I
	Dulichium arundinaceum	Three-way sedge	9	X
	Eleocharis erythropoda	Bald spikerush	3	I
	Eleocharis palustris	Creeping spikerush	6	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Sagittaria rigida	Stiff arrowhead	8	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
FL	*Brasenia schreberi*	Watershield	7	X
	Nymphaea odorata	White water lily	6	X
	Nuphar variegata	Spatterdock	6	X
	Persicaria amphibia	Water smartweed	5	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Najas guadalupensis	Southern naiad	7	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia minor	Small bladderwort	10	X
	Utricularia gibba	Creeping bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	I
	Schoenoplectus subterminalis	Water bulrush	9	X
	Sparganium natans	Little bur-reed	9	I
FF	*Lemna trisulca*	Forked duckweed	6	I
	Lemna turionifera	Turion duckweed	2	X

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

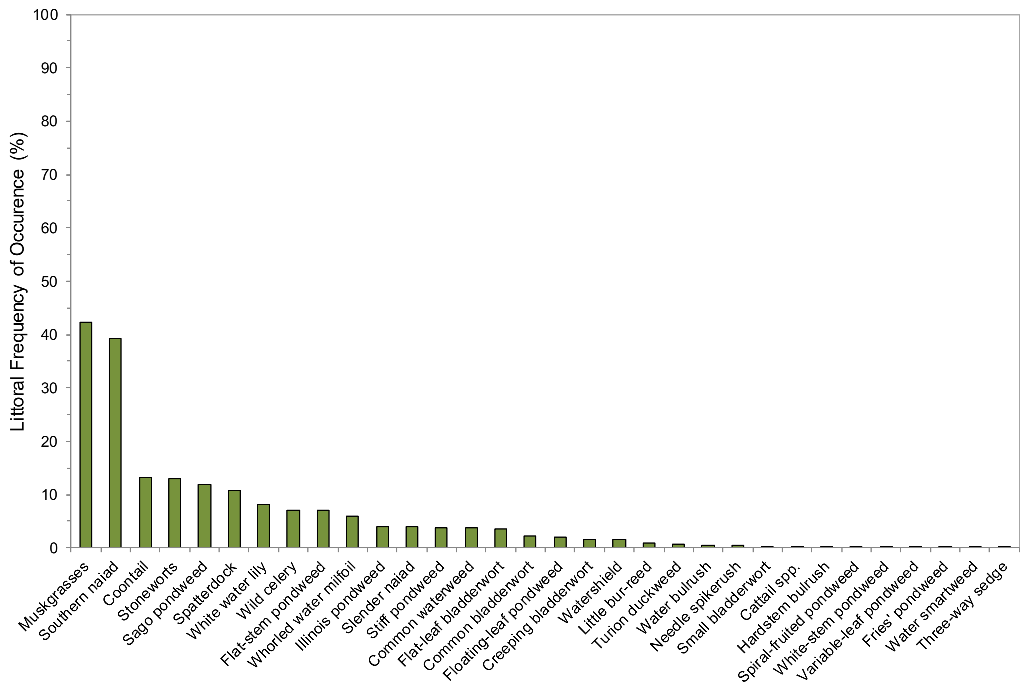

Figure 8.1.4-1 Pickerel Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence. Created using data from a 2015 point-intercept survey.

Figure 8.1.4-1 (above) shows that muskgrasses, southern naiad and coontail were the most frequently encountered plants within Pickerel Lake. Muskgrasses were found to the most encountered plant with a littoral frequency of occurrence of 42.4%. Members of the muskgrasses, while similar to many submersed aquatic plants, are actually marcroalgae. In calcium-rich lakes, like the Pickerel Chain, muskgrasses have a competitive advantage over most other plants. Muskgrasses also help stabilize bottom sediments while working as a phosphorus sink. Southern naiad was the second most frequently encountered plant with a littoral frequency of occurrence of 39.3%. Southern naiad is an annual, growing back from seeds each year. Emerging research is indicating that hybrids between southern naiad subspecies exist and are often observed acting aggressively and growing to levels which may interfere with recreation (Les et al. 2010). Southern naiad was not observed matting on the surface on Pickerel Lake during the Onterra surveys. It is not clear why some southern naiad populations act aggressively, but the population in Pickerel Lake does not appear to be hindering recreational areas. Coontail is found throughout lakes in Wisconsin and North American, often being a dominant plant. It provides valuable aquatic habitat while its ability to derive nutrients directly from the water improves water quality.

An incredible 44 species of native aquatic plants (including incidentals) were found in Pickerel Lake, along with one non-native plant. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Pickerel Lake's plant community (0.88) lies just above the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds high diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants are 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 southern naiad was found at 41% of the sampling locations, its relative frequency of occurrence is 21%. Explained another way, if 100 plants were randomly sampled from Pickerel Lake, 21 of them would be southern naiad. This distribution can be observed in Figure 8.1.4-2, where together six species account for 69% of the population of plants within Pickerel Lake, while the other 26 species account for the remaining 31%. Twelve additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.1.4-1 as incidentals.

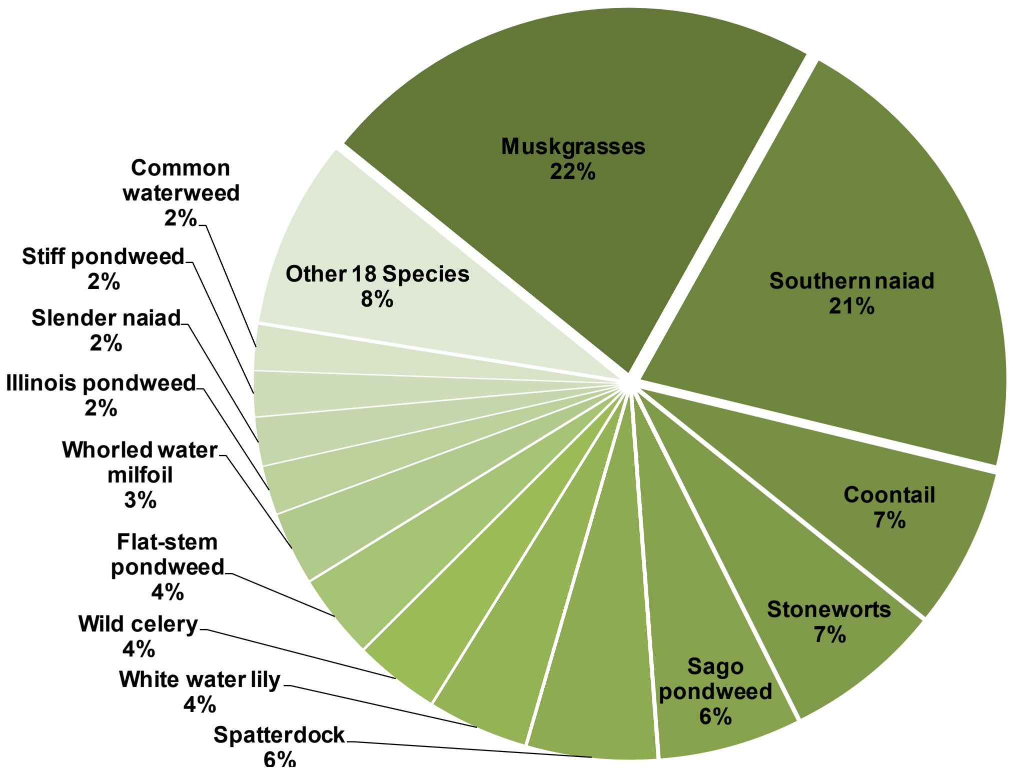

Figure 8.1.4-2 Pickerel Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2015 point-intercept survey.

Pickerel Lake's average conservatism value (6.4) is higher than the state (6.3) and lower than the ecoregion (6.7) median. This indicates that the plant community of Pickerel Lake is indicative of an undisturbed system. This is not surprising considering Pickerel Lake's plant community has great diversity and high species richness. Combining Pickerel Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 36.2 which is well above the median values of the ecoregion and state.

The quality of Pickerel Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2015 community map indicates that approximately 78.1 acres of the lake contains these types of plant communities (Pickerel Lake

Map 3, Table 8.1.4-2). Thirteen floating-leaf and emergent species were located on Pickerel Lake (Table 8.1.4-1), all of which provide valuable wildlife habitat.

Table 8.1.4-2. Pickerel Lake acres of emergent and floating-leaf plant communities from the 2015 community mapping survey.

Plant Community	Acres
Emergent	18.2
Floating-leaf	56.0
Mixed Floating-leaf and Emergent	4.0
Total	78.1

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Pickerel 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 shorelines when compared to undeveloped shorelines 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 shorelines.

Aquatic Invasive Species in Pickerel Lake

During the 2015 point-intercept and community mapping surveys, several shoreland areas containing purple loosestrife were located on Pickerel Lake. These were the only incidence of exotic plant species located on the Pickerel Chain of Lakes.

Note: Methodology, explanation of analysis and scientific background on Little Pickerel Lake studies are contained within the Pickerel Chain-wide Management Plan document.

8.2 Little Pickerel Lake

An Introduction to Little Pickerel Lake

Little Pickerel Lake, Oconto County, is a spring lake with a maximum depth of 26 feet and a surface area of 28 acres. This mesotrophic lake has a relatively small watershed when compared to the size of the lake. Little Pickerel Lake contains 27 native plant species, of which muskgrass is the most common plant. No exotic plants were observed during the 2015 lake surveys.

Field Survey Notes

Lake accessed through a unique river channel that cuts through a wetland area. Much of the lake shoreland is undeveloped with a mix of hardwood forest and wetlands surrounding the lake.

Photo 8.2.1 Little Pickerel Lake, Oconto County

Lake at a Glance* – Little Pickerel Lake

Morphology	
Acreage	28
Maximum Depth (ft)	26
Mean Depth (ft)	7.5
Volume (acre-feet)	212
Shoreline Complexity	5.1
Vegetation	
Curly-leaf Survey Date	June 3, 2015
Comprehensive Survey Date	July 14, 2015
Number of Native Species	27
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.85
Average Conservatism	6.0
Water Quality	
Wisconsin Lake Classification	Deep, headwater drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	5:1

**These parameters/surveys are discussed within the Chain-wide portion of the management plan.*

8.2.1 Little Pickerel Lake Water Quality

During 2015/2016, water quality data was collected from Little Pickerel Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

There was no previous monitoring on Little Pickerel Lake before the 2015/2016 session. Consistent monitoring efforts provide reliable data on which a comparable database may be built. Monitoring beyond 2016 should be continued in order to understand trends in the water quality of Little Pickerel Lake in the years to come.

During this study period, summer average total phosphorus concentrations ranged between 21.5 and 33.6 μg/L. Some of these concentrations rank within the category of *Good*, with most ranking as *Excellent.* The 2015 average is only slightly higher than the median for deep, headwater drainage lakes in the State of Wisconsin (Figure 8.2.1-1). Summer chlorophyll-*a* concentrations also ranked within the *Good* category, with the bulk in the *Excellent* category. The Little Pickerel Lake summer average is slightly higher than the median concentration for similar lakes across the state and slightly lower than other lakes in the ecoregion (Figure 8.2.1-2).

Measurements of Secchi disk clarity ranged from 7.5 feet to 12.6 feet. Summer averages lie completely within the *Excellent* category (Figure 8.2.1-3). The summer average clarity is about one foot deeper than the median concentration for similar lakes across the state.

Overall, the water quality of Little Pickerel Lake would be consider very good to excellent. Still, during the development of this project design, association members voiced concerns over occasional "blue-green algae blooms" that plague the lake. In an effort to document such a bloom and possibly the conditions leading to it, PCLA volunteers collected water quality samples each week during July-September 2015. The results of these collections are contained in the descriptions above and in Figures 8.2.1-1 through 8.2.1-3. Further analyses are elaborated on below.

Blue-green algae, also known as Cyanobacteria, are a type of bacteria that can photosynthesize. Typically they appear in lakes with very high levels of nutrients (phosphorus and nitrogen). Some types of blue-green algae release toxins and if the bloom is severe can create a health hazard for humans and other animals. Numerous factors come into play to spur an excessive blue-green algae bloom; including nutrient dynamics, competition with other types of algae, water temperatures, and the availability of other elements required for their growth. Often, a bloom is brought on by high levels of phosphorus and nitrogen during warm water temperatures. While these conditions spur the accelerated growth of most types of algae, blue-greens have a specific competitive edge that allows their growth to exceed other algal types considerably.

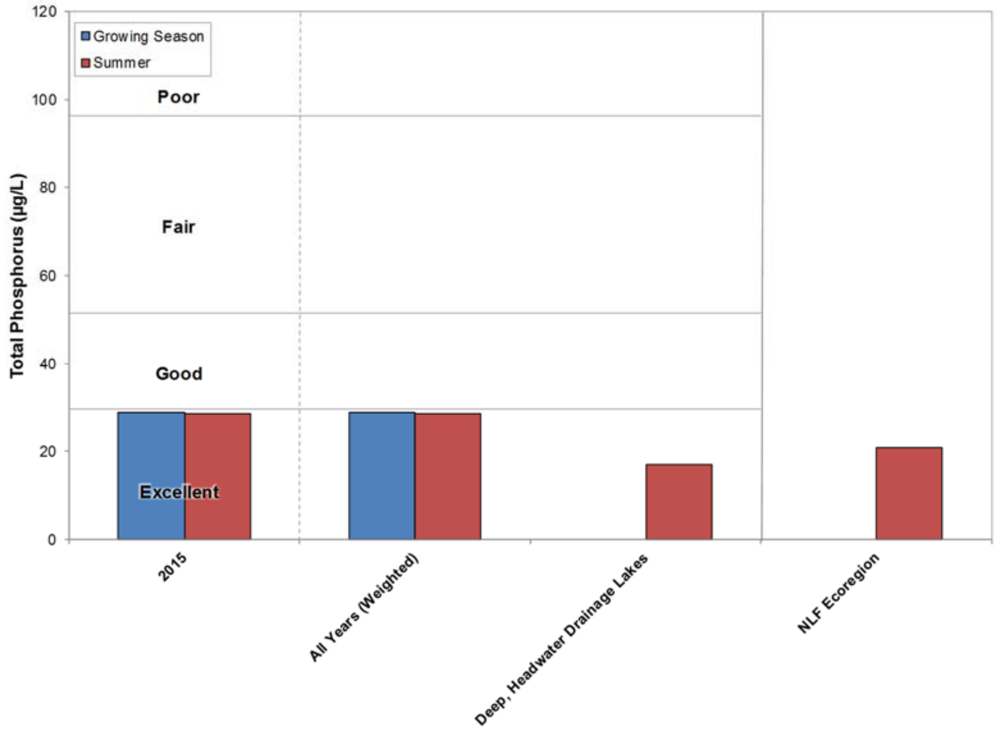

Figure 8.2.1-1. Little Pickerel Lake, state-wide deep, headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

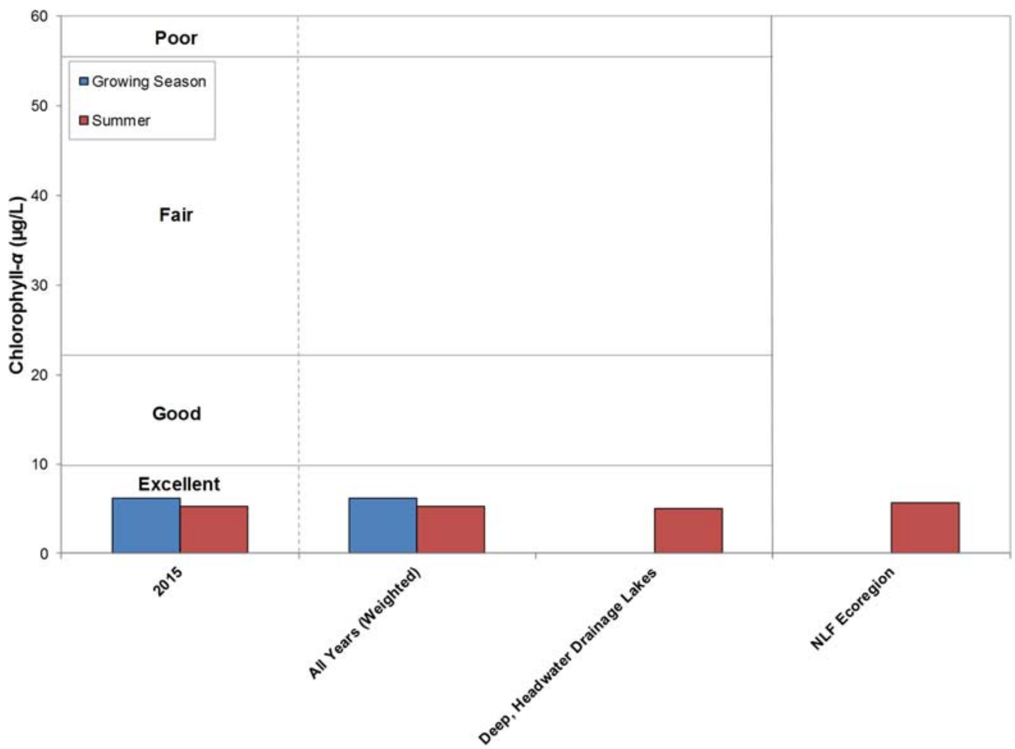

Figure 8.2.1-2. Little Pickerel Lake, state-wide deep, headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

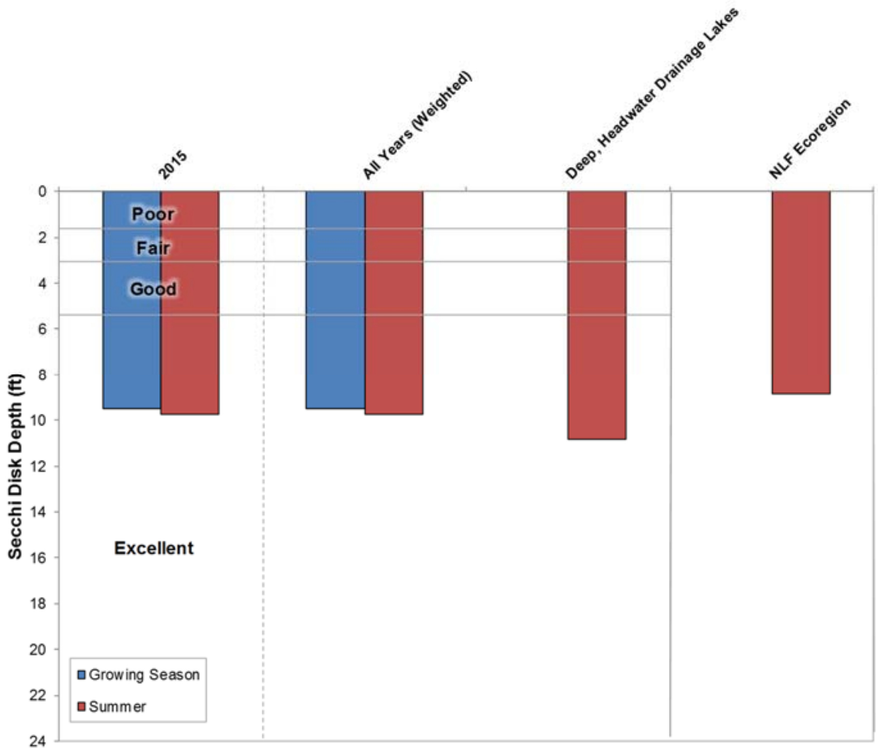

Figure 8.2.1-3. Little Pickerel Lake, state-wide deep, headwater drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

During times when water temperatures are high and nitrogen is in short supply compared to phosphorus, and is limiting the growth of other algal species, some blue-green algae are able to fix nitrogen from the air. Other forms of algae cannot use atmospheric nitrogen, giving blue-green algae a great advantage. As a result, the blue-greens dominate the system and a heavy bloom can occur. It was this phenomenon, if it occurred, that was to be documented by the additional sampling performed by PCLA volunteers.

Figure 8.2.1-4 displays total phosphorus, chlorophyll-*a*, and total nitrogen data collected during the summer of 2015 by Onterra and PCLA volunteers. At no point in time do any values of these parameters exceed what would be considered good or excellent, nor above expected levels for Little Pickerel Lake or lakes of its type (deep headwater). Further, nitrogen:phosphorus ratios remain well above 15:1, ranging between 18.5 and 29.3, indicating the lake is strongly phosphorus limited. These data indicate that no blue-green algae bloom occurred during 2015. While it is possible for a lake like Little Pickerel Lake to have a blue-green bloom, it is not common. However, this does not mean that some other algae related phenomenon may be occurring in the lake intermittently, for example, while 2015 did not see abnormally high algae levels, 2013 and 2014 did. Analysis of the dissolved oxygen and temperature profiles collected at the lake during this project point to the possible existence of certain types of algae that may exist deeper in the lake than were sampled at the surface (3-feet). This analysis and algae are discussed below.

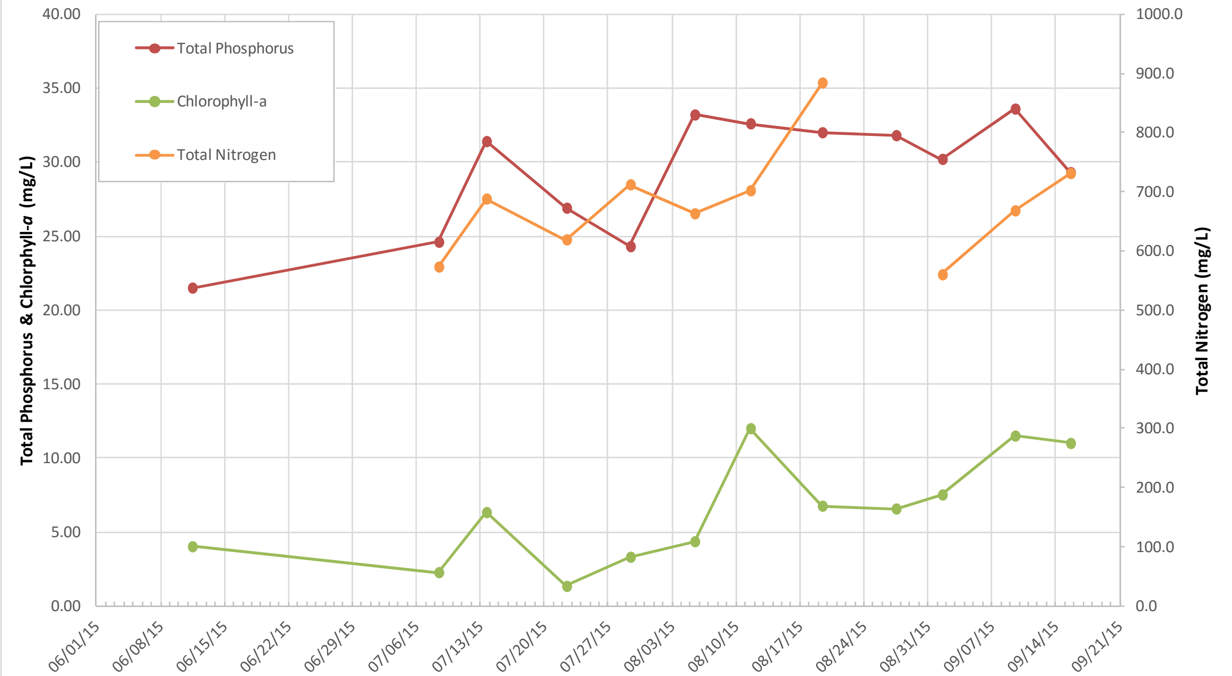

Figure 8.2.1-4. Little Pickerel Lake total phosphorus, chlorophyll-*a*, and total nitrogen data during summer 2015.

Little Pickerel Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from mesotrophic to eutrophic (Figure 8.2.1-5). 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 Little Pickerel Lake is in an upper mesotrophic state.

Dissolved Oxygen and Temperature in Little Pickerel Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Little Pickerel Lake by Onterra staff and several times over the summer by association volunteers. Graphs of those data are displayed in Figure 8.2.1-5 for all sampling events. Additional profiles were collected during the winter of 2016 by PCLA volunteers. These results are discussed in the chain-wide sections above.

Little Pickerel Lake was found to be almost stratified during the spring, but quickly stratified once the weather warmed the uppermost layers of water in June. Throughout the summer months, the lake remained thermally stratified at about 15 feet. This is not uncommon in lakes that are moderate in surface acreage, but fairly deep. Energy from the wind is sufficient to mix only the upper layer of water, allowing the cooler, denser water to remain below. Decomposition of organic matter along the lake bottom is the cause of the decrease in dissolved oxygen observed in the summer months. In October, the lake is mixed once again by cooling surface water temperatures and fall winds. Oxygen is once again found throughout the water column. During the winter months, dissolved oxygen depletes within the deeper depth of the lake because of decomposition and the water is not able to exchange oxygen with the air through the ice.

Dissolved oxygen levels remained sufficient in the upper 15 feet of the water column year-round to support most aquatic life found in northern Wisconsin lakes.

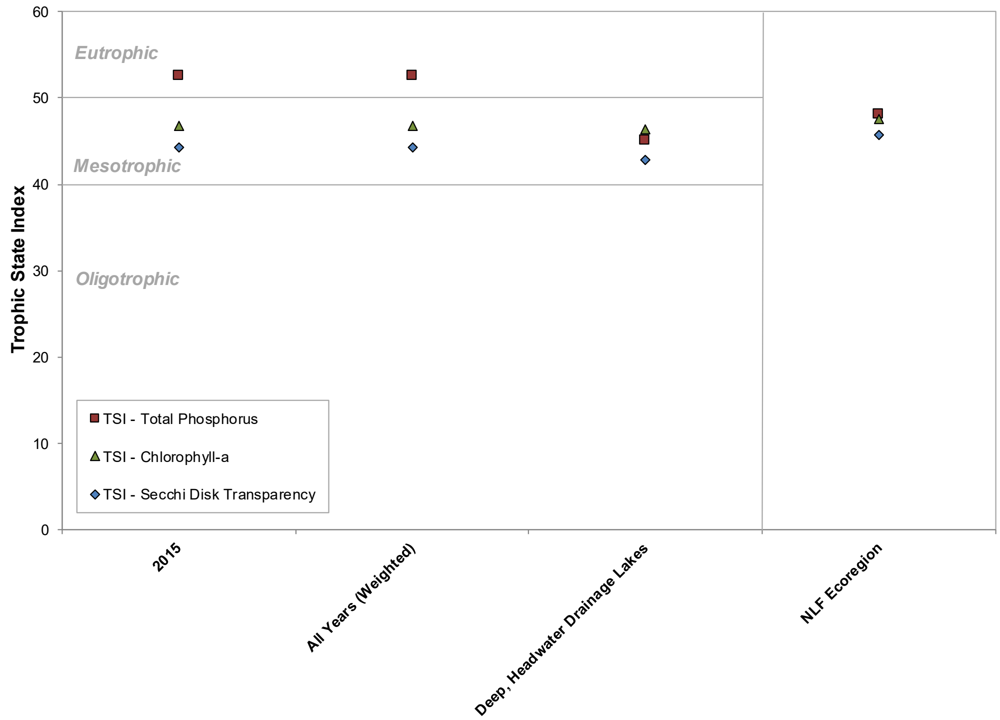

Figure 8.2.1-5. Little Pickerel Lake, state-wide deep, headwater drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Beginning in June, dissolved oxygen concentrations were found to be higher at depths of approximately 13-15 feet than those measured at shallower depths (Figure 8.2.1-6). These elevated dissolved oxygen concentrations just above the hypolimnion indicate a higher concentration of photosynthesizing algae inhabiting these depths. It is common in deeper, mesotrophic lakes with clear water for a layer of cool-water algae to form just above the hypolimnion. These deep-water algae blooms are typically comprised of diatoms, chrysophytes (golden algae), and/or *Oscillatoria* (a cold-growing blue-green algae). These algae require cooler water, and the clear water found in Little Pickerel Lake allows these algae to still receive adequate amounts of light deeper in the water column where the water is cooler.

During a summer when lake stratification holds, these algae will remain in this deeper layer of water just above the hypolimnion. However, in late-summer/early-fall, the surface waters begin to cool to a similar temperature to which these algae are growing. Once surface waters have cooled enough and the lake begins to mix, the algae may be visible from the surface. They could also become visible during the summer when the lake is mixed by strong winds brought on by storm events.

From year-to-year, the growth of these deep-water algae may be more or less intense, and as a result may be more noticeable in certain years. During years of intense growth, the mixing of these algae into the upper layers, especially during the summer, may result in higher than normal growth or even as a blue-green algae bloom. While it may not be the cause of every concerning bloom occurring on the lake, this phenomenon may be part of what raises concern regarding blue-green algae blooms in Little Pickerel Lake. The topic of algae blooms in Little Pickerel Lake and Pickerel Lake is expanded upon in the Summary & Conclusions Section as well as the Implementation Plan.

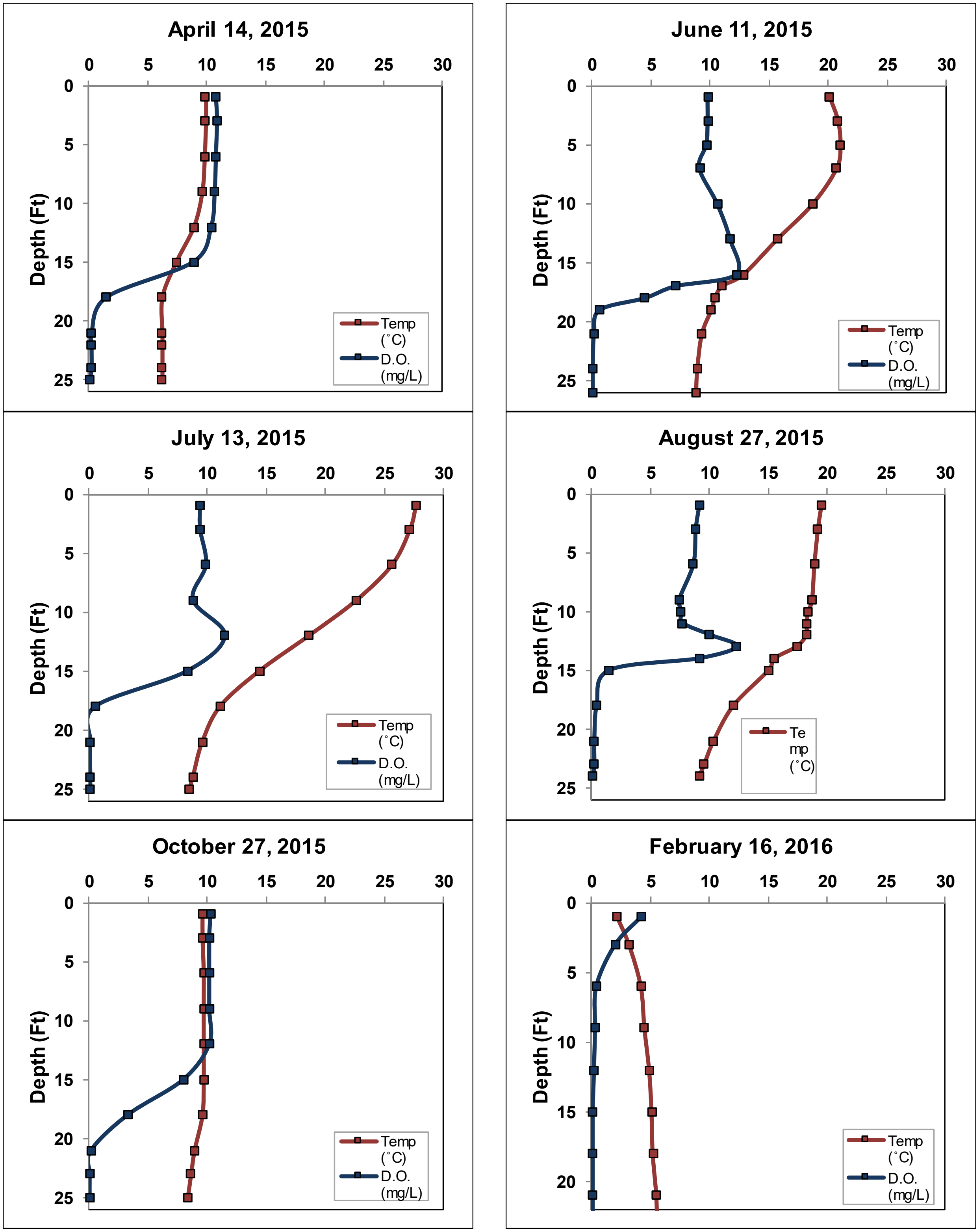

Figure 8.2.1-6. Little Pickerel Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Little Pickerel Lake

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

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Little Pickerel Lake's pH was measured at roughly 8.2in the summer months of 2015. This value is above neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Little Pickerel Lake was measured at 126 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Little Pickerel Lake during the summer of 2015. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Little Pickerel Lake's pH of 8.2 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Little Pickerel Lake was found to be 31.0 mg/L, falling well outside the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2015 and these samples were processed by the WDNR for larval mussels. No veligers (larval mussels) were found within these samples.

8.2.2 Little Pickerel Lake Watershed Assessment

Little Pickerel Lake's watershed is 185 acres in size. Compared to Little Pickerel Lake's size of 28 acres, this makes for a small watershed to lake area ratio of 5:1. As mentioned in the chain-wide section above, lakes with small watershed to lake area rations typically have less nutrients being delivered to them. Little Pickerel Lake's watershed is largely made up of excellent land cover types; include forests at 40%, wetlands at 29% and Little Pickerel Lake itself at 15% (Figure 8.2.2-1). Pasture/grasslands cover 7% of the watershed, row crop agriculture occupies 9%, and Rural Residential areas occur in less than 1%.

Figure 8.2.2-2 displays the breakdown of phosphorus contributions to Little Pickerel Lake by each land cover type. Overall, an estimated 36 lbs of phosphorus enters Little Pickerel Lake from its watershed. This would be considered a very small amount of loading. The bulk of the phosphorus entering Little Pickerel Lake likely originates from the row crop agriculture occurring northwest of the lake near State Hwy 32. Other contributions include 18% from forested lands, 18% being directly deposited to the lake surface from the atmosphere, and 12% each originating from wetlands and pasture/grasslands.

While the delivery of 36% of the lake's load from row crop agriculture may seem like a concern, it likely should not be overbearing. Rerunning the model analysis to include the conversion of all row crop acreage to pasture/grasslands, a somewhat realistic possibility, reduces the anticipated load to Little Pickerel Lake to 26 lbs annually. The predicted growing season mean total phosphorus concentration would decrease to roughly 28 mg/L or less. Even with this reduction, changes in the lake's water quality, such as clarity, would likely be undetectable by riparians.

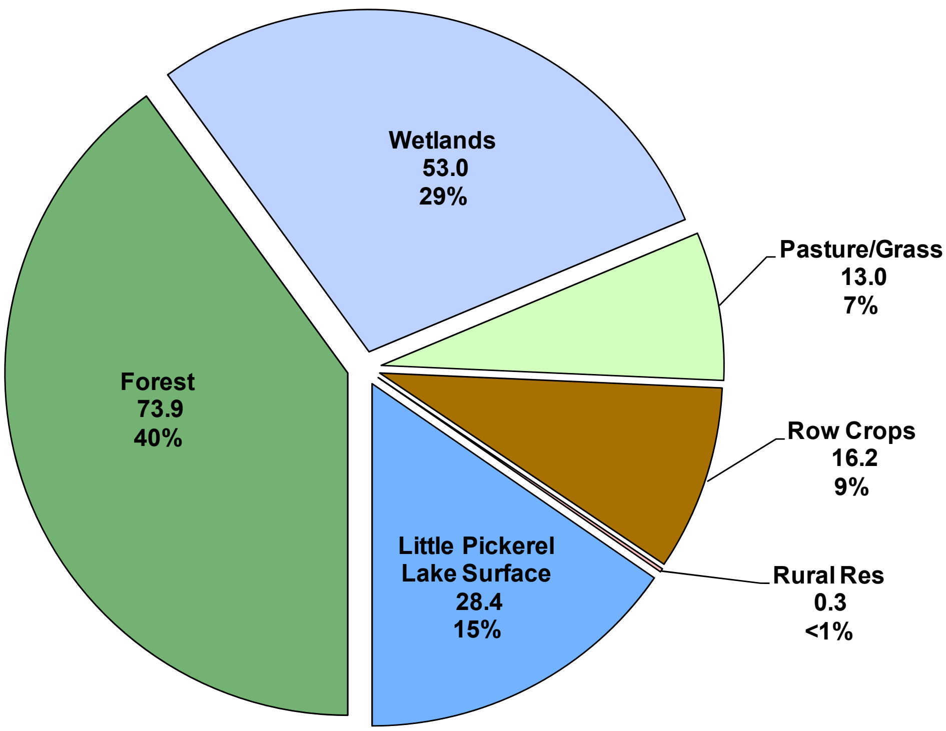

Figure 8.2.2-1. Little Pickerel Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The WiLMS analysis for Little Pickerel Lake also included an estimate for septic system inputs to the lake based upon data collected through the stakeholder survey. The estimate takes into account the types of septic systems utilized around the lake and how much they are used. The estimate indicates that approximately 1 lb of phosphorus may enter the lake from septic systems, which would be considered extremely low.

Using standard predictive equations, an estimated in-lake, growing season average phosphorus concentration can be determined for Little Pickerel Lake based upon its morphology and typical precipitation levels for Oconto County. The Little Pickerel Lake modeling indicated a predicted average concentration of 36 mg/L phosphorus, which is higher than the actual average concentration of 28.9 mg/L. This indicates that the modeling effort over-estimated the amount of phosphorus entering the lake, further evidencing the healthy nature of the Little Pickerel Lake watershed. It also indicates that unknown sources of phosphorus, like internal nutrient loading and/or excessive inputs from shoreland properties or septic systems are not impacting the lake.

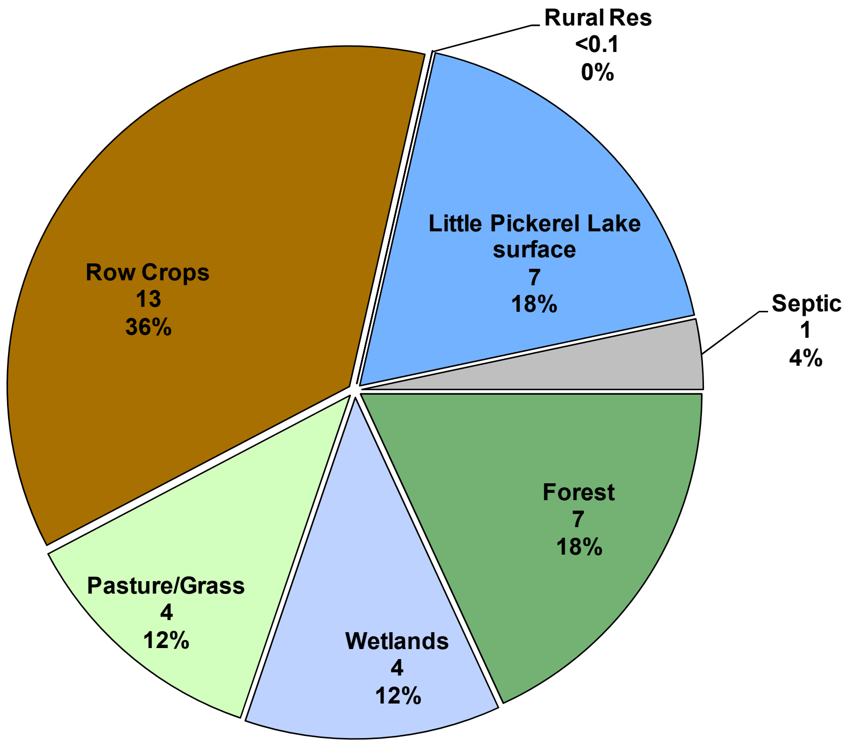

Figure 8.2.2-2 Little Pickerel Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.2.3 Little Pickerel Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2015, Little Pickerel Lake's immediate shoreline was assessed in terms of its development. Little Pickerel Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.6 miles of natural/undeveloped and developed-natural shoreline (94% of the entire shoreline) were observed during the survey (Figure 8.2.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural/near-natural state if at all possible. During the survey, about 0.05 miles of urbanized and developed–unnatural shoreline (2% of the total shoreline) was observed. If restoration of the Little Pickerel Lake shoreline 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. Little Pickerel Lake Map 1 displays the location of these shoreline lengths around the entire lake.

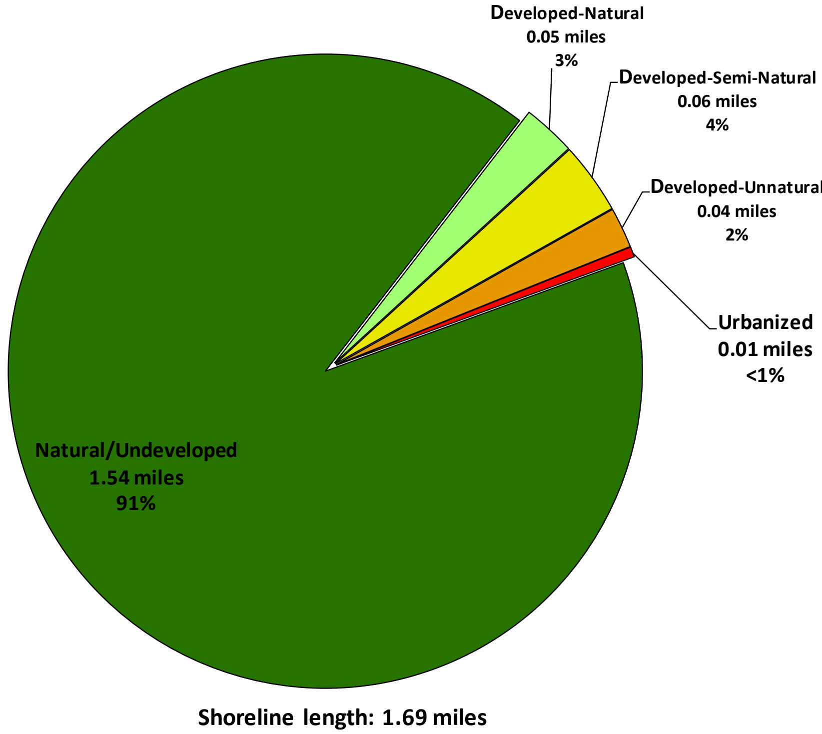

Figure 8.2.3-1. Little Pickerel Lake shoreland categories and total lengths. Based upon a late summer 2015 survey. Locations of these categorized shorelands can be found on Little Pickerel Lake Map 1.

Coarse Woody Habitat

Little Pickerel Lake was also surveyed in the fall of 2015 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 101 total pieces of coarse woody habitat were observed along 1.7 miles of shoreline, which gives Little Pickerel Lake a coarse woody habitat to shoreline mile ratio of 60:1. Locations of coarse woody habitat are displayed on Little Pickerel Lake Map 2. 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).

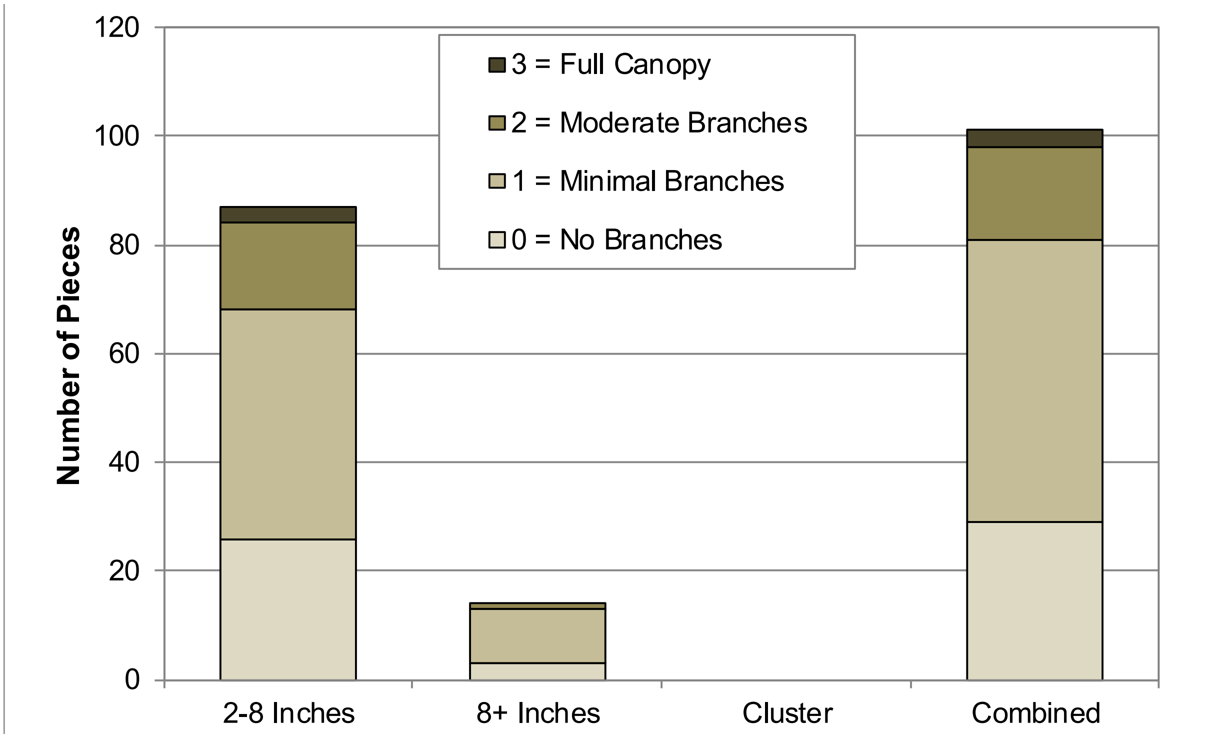

Figure 8.2.3-2. Little Pickerel Lake coarse woody habitat survey results. Based upon a fall 2015 survey. Locations of Little Pickerel Lake coarse woody habitat can be found on Little Pickerel Lake Map 2.

8.2.4 Little Pickerel Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Little Pickerel Lake on June 3, 2015. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Little Pickerel Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Little Pickerel Lake on July14, 2015 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on July 15, 2015 to create the aquatic plant community map (Little Pickerel Lake Map 3). During all surveys, 27 species of native aquatic plants were located in Little Pickerel Lake (Table 8.2.4-1). Twenty-one of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of 21 feet, which is deep relative to the other lakes within the Pickerel Chain of Lakes. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and relatively diverse.

Of the 114 point-intercept locations sampled within the littoral zone, approximately 85% contained aquatic vegetation. Little Pickerel Lake Map 4 depicts the total rake fullness of the 399 sampled locations. Approximately 0% of the point-intercept sampling locations where sediment data was collected at were sand, 99% consisted of a fine, organic substrate (muck) and 1% were determined to be rocky.

Table 8.2.4-1. Aquatic plant species located in the Little Pickerel Lake during the 2015 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2015 (Onterra)
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I
	Eleocharis palustris	Creeping spikerush	6	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
	Sparganium sp.	Bur-reed sp.	N/A	X
Submergent	*Ceratophyllum demersum*	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Myriophyllum sibiricum	Northern water milfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton friesii	Fries' pondweed	8	X
	Stuckenia pectinata	Sago pondweed	3	X
	Utricularia gibba	Creeping bladderwort	9	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Schoenoplectus subterminalis*	Water bulrush	9	X

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

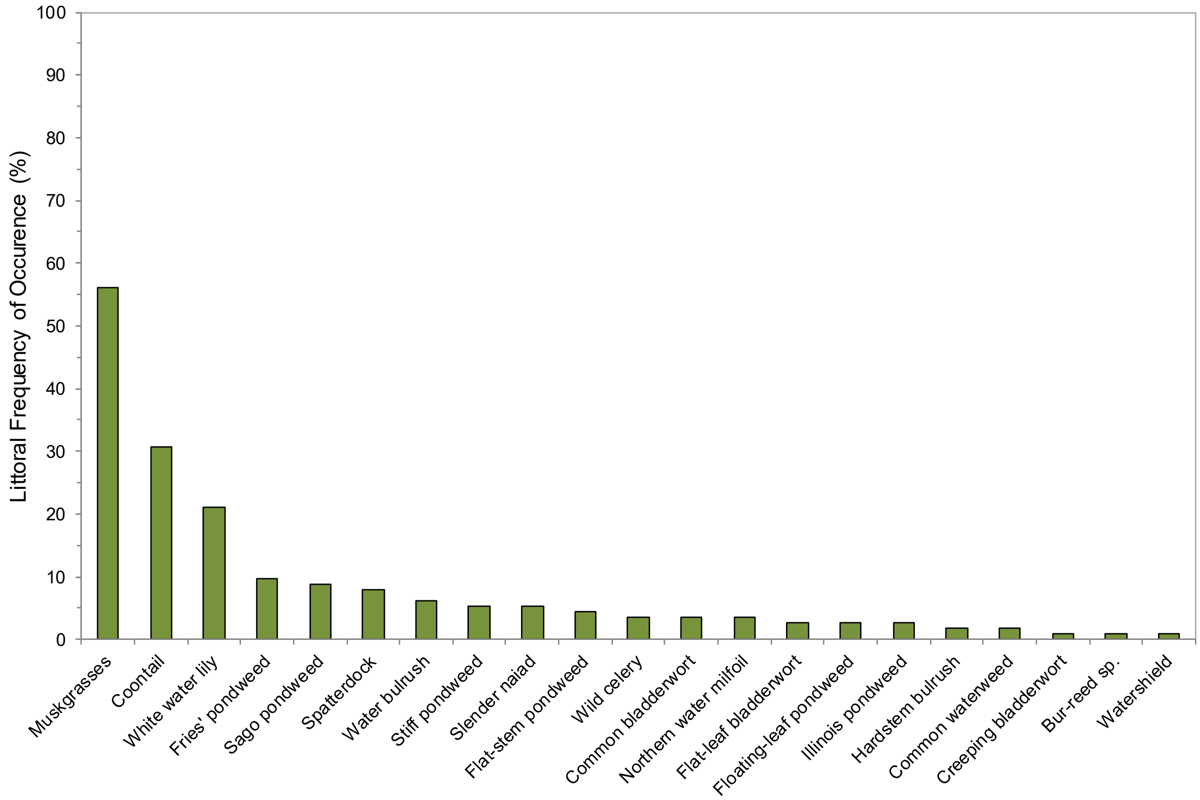

Figure 8.2.4-1 Little Pickerel Lake aquatic plant littoral frequency of occurrence analysis. Chart includes all species. Created using data from a 2015 point-intercept survey.

Figure 8.2.4-1 (above) shows that muskgrasses, coontail and white water lily were the most frequently encountered plants within Little Pickerel Lake. Muskgrasses were found to the most encountered plant with a littoral frequency of occurrence of 56.1%. Members of the muskgrasses, while similar to many submersed aquatic plants, are actually marcroalgae. In calcium-rich lakes, like the Pickerel Chain, muskgrasses have a competitive advantage over most other plants. Muskgrasses also helps stabilize bottom sediments while working as a phosphorus sink. Coontail was the second most encountered species in Little Pickerel Lake, with a littoral frequency of 30.7%. Coontail is found throughout lakes in Wisconsin and North American, often being a dominant plant. It provides valuable aquatic habitat while its ability to derive nutrients directly from the water improves water quality. White water lily was the third most encountered plant. This floating-leaf plant provides a lot of underwater structure and protection for many fish and aquatic invertebrates.

Of the seven milfoil species (genus *Myriophyllum*) found in Wisconsin, only one (northern water milfoil) was located from Little Pickerel Lake. Northern water milfoil, arguably the most common milfoil species in Wisconsin lakes, is frequently found growing in soft sediments and higher water clarity. Northern water milfoil is often falsely identified as Eurasian water milfoil, especially since it is known to take on the reddish appearance of Eurasian water milfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern water milfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern water milfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic.

Twenty-seven species of aquatic plants (including incidentals) were found in Little Pickerel Lake and because of this, one may assume that the system would also have some diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Little Pickerel Lake's plant community (0.85) lies just below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds the typical amount of diversity.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while muskgrass was found at 56% of the sampling locations, its relative frequency of occurrence is 31%. Explained another way, if 100 plants were randomly sampled from Little Pickerel Lake, 31 of them would be wild celery. This distribution can be observed in Figure 8.2.4-2, where together three species account for 60% of the population of plants within Little Pickerel Lake, and the other 18 species account for the remaining 40%. Six additional species were found incidentally within the lake (not from of the point-intercept survey), and are indicated in Table 8.2.4-1 as incidentals.

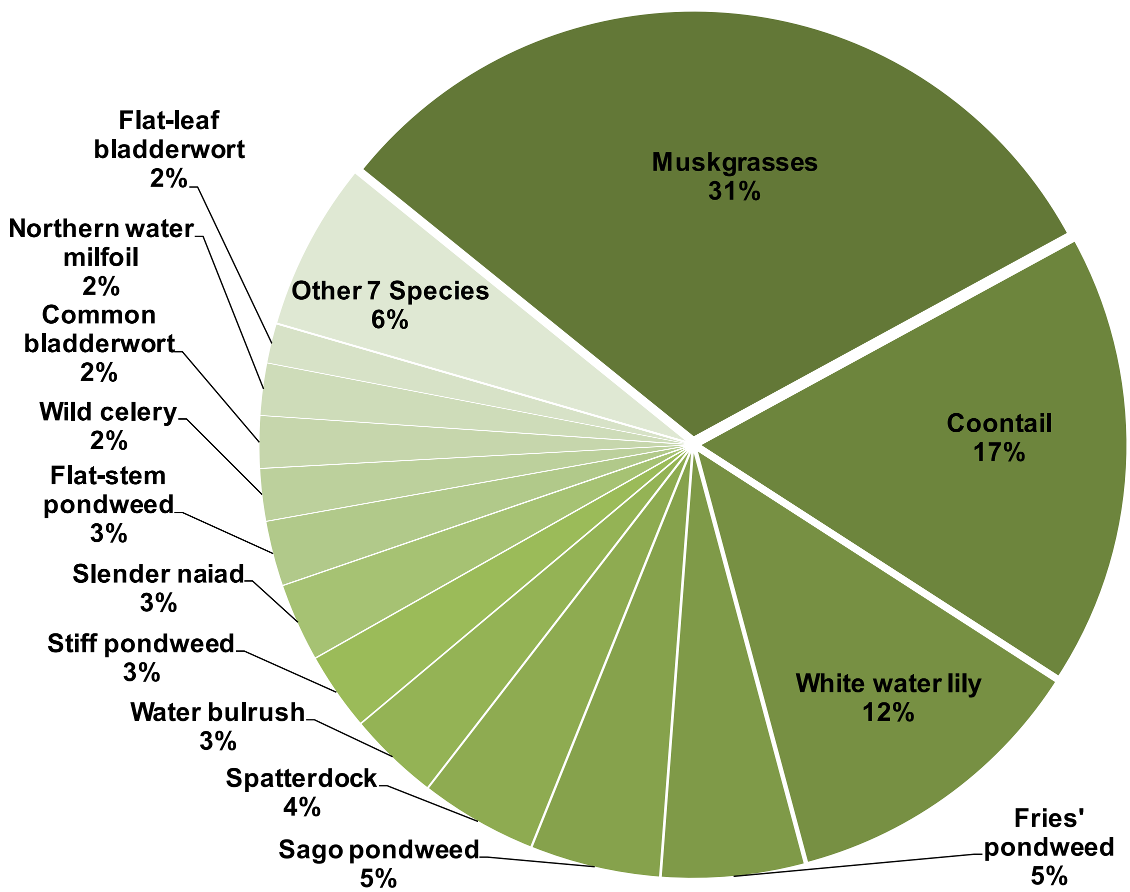

Figure 8.2.4-2 Little Pickerel Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2015 point-intercept survey.

Little Pickerel Lake's average conservatism value (6.3) is the same as the state (6.3) and lower than the ecoregion (6.7) median. This indicates that the plant community of Little Pickerel Lake is indicative of a somewhat undisturbed system. This is not surprising considering Little Pickerel Lake's plant community has good diversity and decent species richness. Combining Little Pickerel Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 28.9 which is similar to the median values of the ecoregion and state.

The quality of Little Pickerel Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2015 community map indicates that approximately 11.7 acres of the lake contains these types of plant communities (Little Pickerel Lake Map 3, Table 8.2.4-2). Six floating-leaf and emergent species were located on Little Pickerel Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.2.4-2. Little Pickerel Lake acres of emergent and floating-leaf plant communities from the 2010 community mapping survey.

Plant Community	Acres
Emergent	0.06
Floating-leaf	11.6
Mixed Floating-leaf and Emergent	0.04
Total	11.7

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Little Pickerel 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 shorelines when compared to undeveloped shorelines 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 shorelines.

Note: Methodology, explanation of analysis and scientific background on Smoke Lake studies are contained within the Pickerel Chain-wide Management Plan document.

8.3 Smoke Lake

An Introduction to Smoke Lake

Smoke Lake, Oconto County, is a spring lake with a maximum depth of 9 feet and a surface area of 51 acres. This eutrophic lake has a small watershed when compared to the size of the lake. Smoke Lake contains 21 native plant species, of which muskgrass is the most common plant. No exotic plants were observed during the 2015 lake surveys.

Field Survey Notes

Shallow lake with clear water makes the bottom visible throughout. Smoke Lake accessed through a river channel cutting through a unique wetland area.

Photo 8.3.1 Smoke Lake, Oconto County

Lake at a Glance* – Smoke Lake

Morphology	
Acreage	51
Maximum Depth (ft)	9
Shoreline Complexity	3.0
Vegetation	
Curly-leaf Survey Date	June 3, 2015
Comprehensive Survey Date	July 14, 2015
Number of Native Species	21
Threatened/Special Concern Species	-
Exotic Plant Species	-
Simpson's Diversity	0.78
Average Conservatism	6.1

These parameters/surveys are discussed within the Chain-wide portion of the management plan.

8.3.1 Smoke Lake Water Quality

During 2015/2016, water quality data was collected from Smoke Lake on six occasions. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples.

There was no previous monitoring on Smoke Lake before the 2015/2016 session. Consistent monitoring efforts provide reliable data on which a comparable database may be built. Monitoring beyond 2016 should be continued in order to understand trends in the water quality of Smoke Lake in the years to come.

During this project, summer average total phosphorus concentrations have ranged consistently between 10.7 and 21.4 µg/L (Figure 8.3.1-1). All of these average annual concentrations rank within the category of *Excellent*. A weighted value across all years is lower than the median for shallow, headwater drainage lakes in the state of Wisconsin. As with the total phosphorus values, average summer chlorophyll-*a* concentrations also rank within the category *Excellent*, and a weighted average is less than the median concentration for similar lakes across the state (Figure 8.2.1-2).

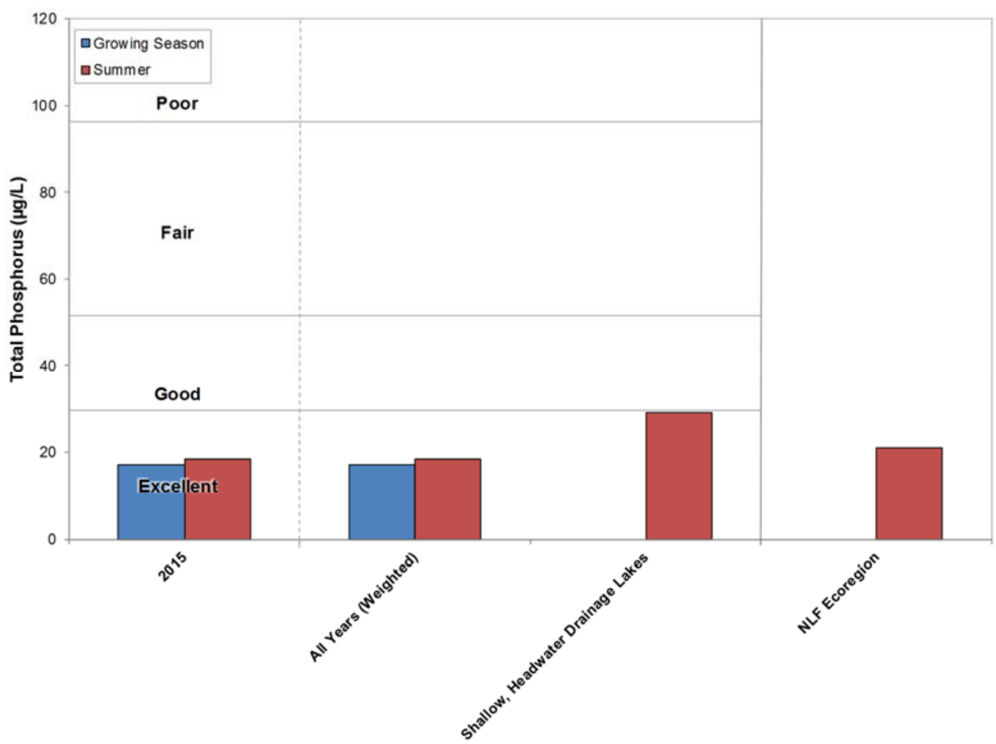

Figure 8.3.1-1. Smoke Lake, state-wide shallow, headwater drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

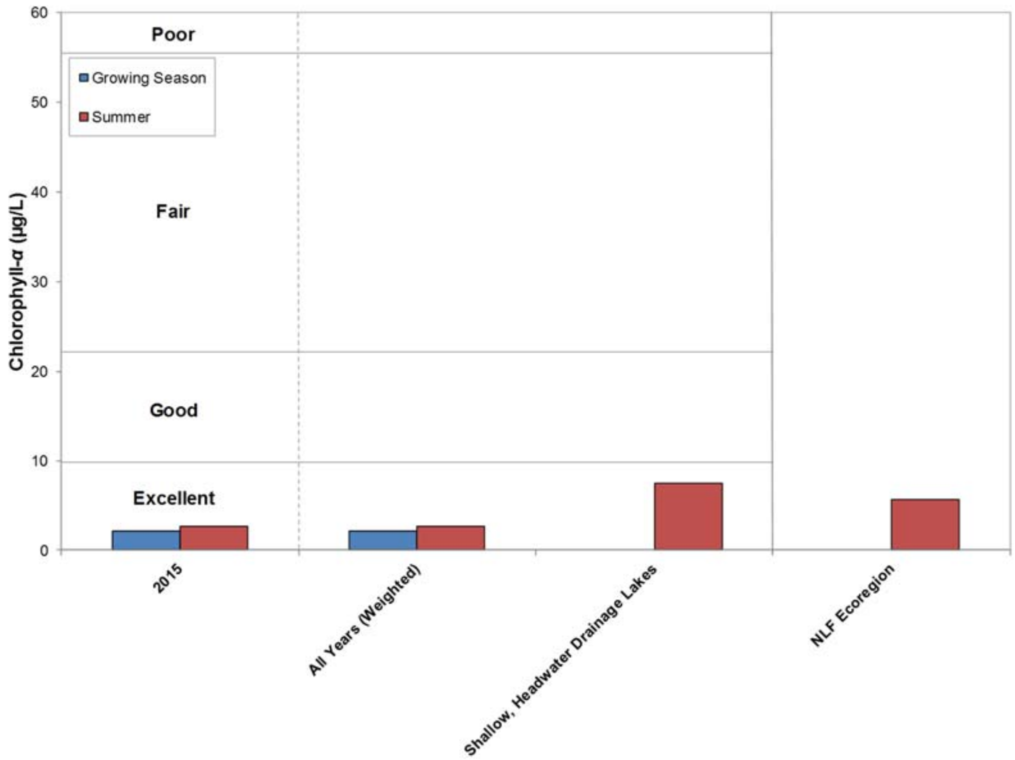

Figure 8.3.1-2. Smoke, state-wide shallow, headwater drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2012A.

The Secchi disk hit bottom during all sampling events on Smoke Lake during the open water season. While this means that the lake is very clear, it also means that the measurements cannot be used in any analysis. Data supplied by the PCLA in summer of 2016, the Secchi disk did not reach bottom and the average was 7.2 feet, which is still considered excellent for state-wide shallow, headwater drainage lakes.

Smoke Lake Trophic State

The TSI values calculated with chlorophyll-*a*, and total phosphorus values fall solidly in the mesotrophic level (Figure 8.3.1-3).

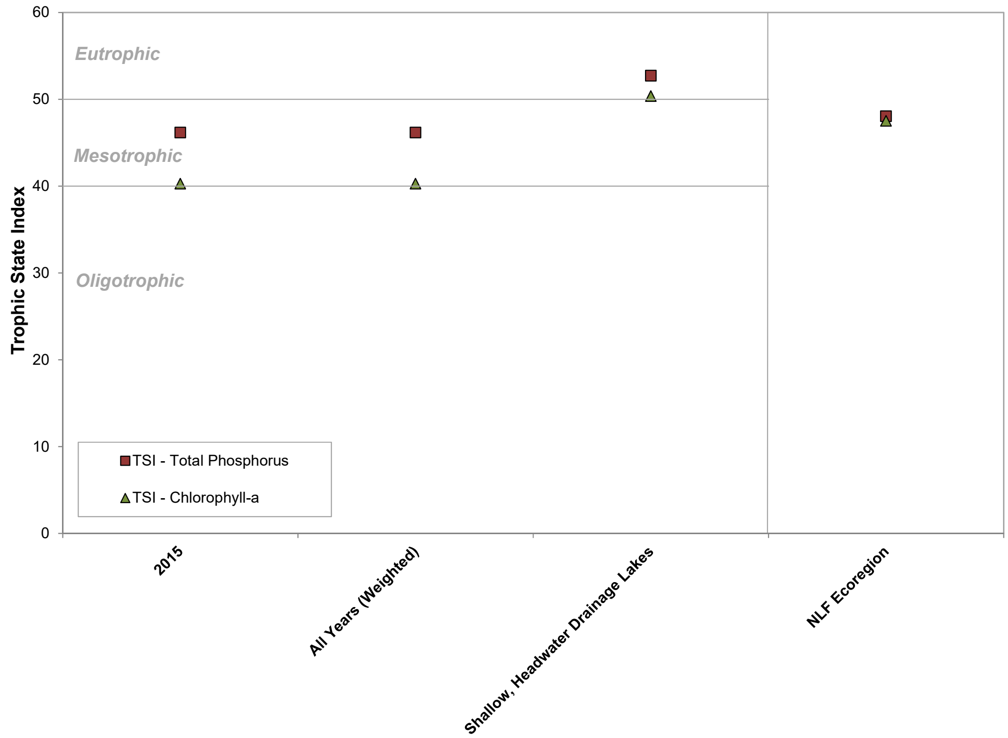

Figure 8.3.1-3. Smoke Lake, state-wide shallow, headwater drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2012A.

Dissolved Oxygen and Temperature in Smoke Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Smoke Lake by Onterra staff. Graphs of those data are displayed in Figure 8.3.1-4 for all sampling events.

Smoke Lake was found to be mixed during all sampling events. Energy from the wind is sufficient to mix the whole lake during the entire open water season.

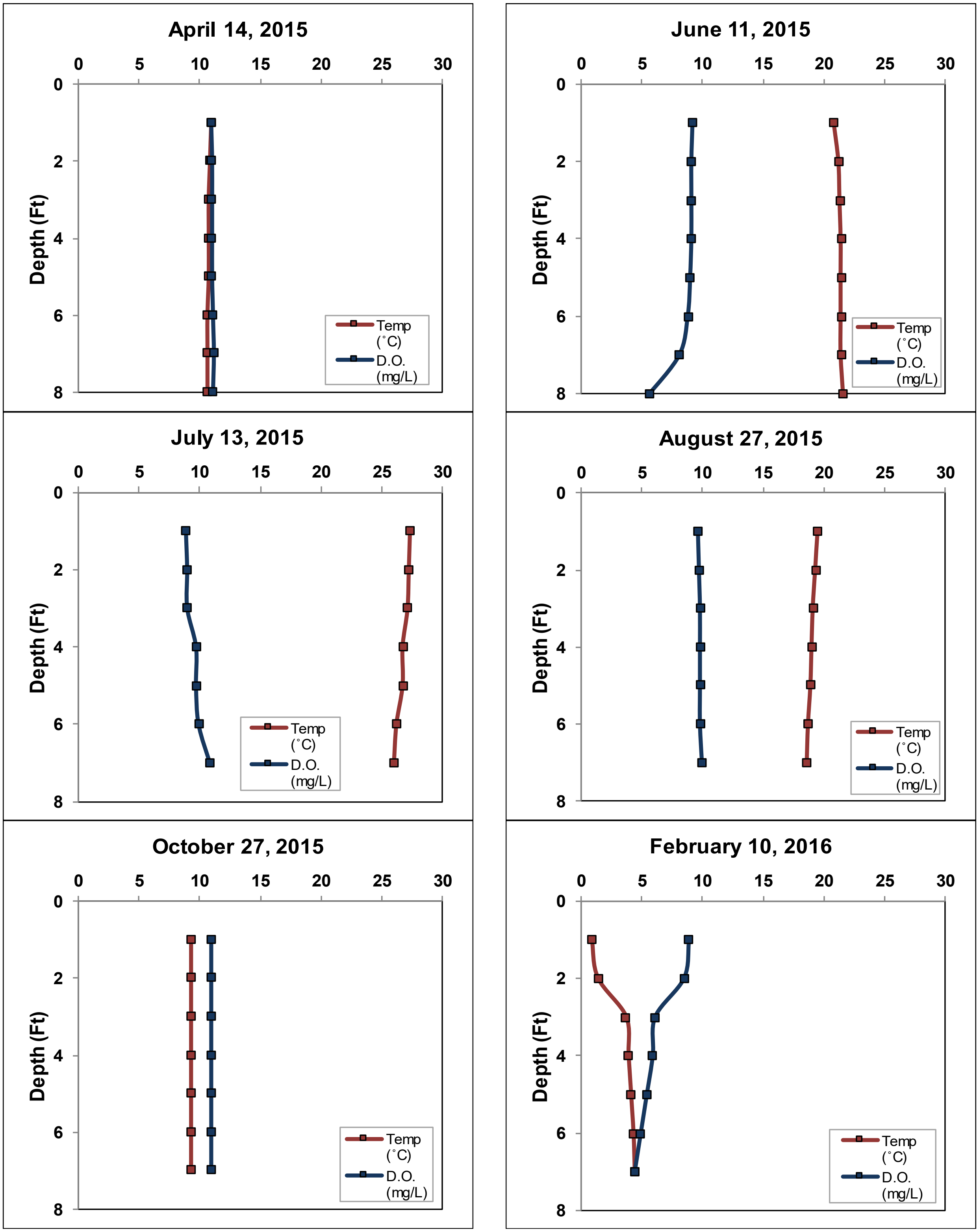

Figure 8.3.1-4. Smoke Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Smoke Lake

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

As the Chainwide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Smoke Lake's pH was measured at roughly 8.3 in the summer months of 2015. This value is above neutral and falls within the normal range for Wisconsin lakes.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Smoke Lake was measured at 136 (mg/L as $CaCO_3$), indicating that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Smoke Lake during the summer of 2015. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Smoke Lake's pH of 8.2 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Smoke Lake was found to be 27.2 mg/L, falling well outside the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2015 and these samples were processed by the WDNR for larval mussels. No veligers (larval mussels) were found within these samples.

8.3.2 Smoke Lake Watershed Assessment

Smoke Lake's watershed is 193 acres in size. Compared to Smoke Lake's surface area of 51 acres, this makes for a very small watershed to lake area ratio of 2:1. As mentioned in the chain-wide section above, lakes with small watershed to lake area rations typically have less nutrients being delivered to them. Smoke Lake's watershed is largely made up of excellent land cover types; include forests at 28%, wetlands at 23% and Smoke Lake itself at 31% (Figure 8.3.2-1). Pasture/grasslands cover 8% of the watershed, row crop agriculture occupies 9%, and Rural Residential areas occur in less than 1%, as do medium density residential areas.

Figure 8.3.2-2 displays the breakdown of phosphorus contributions to Smoke Lake by each land cover type. Overall, an estimated 46 lbs of phosphorus enters Smoke Lake from its watershed. While this is likely an overestimate it would still be considered a very small amount of loading. The bulk of the phosphorus entering Smoke Lake from overland runoff likely originates from the row crop agriculture occurring southwest of the lake near State Hwy 32. Other contributions include 9% from forested lands, 34% being directly deposited to the lake surface from the atmosphere, and 10% each originating from wetlands and pasture/grasslands.

While the delivery of 34% of the lake's load from row crop agriculture may seem like a concern, it likely should not be overbearing. Rerunning the model analysis to include the conversion of all row crop acreage to pasture/grasslands, a somewhat realistic possibility, reduces the anticipated load to Smoke Lake to 33 lbs annually. The predicted growing season mean total phosphorus concentration would decrease to roughly 30 mg/L or less. Even with this reduction, changes in the lake's water quality, such as clarity, would likely be undetectable by riparians.

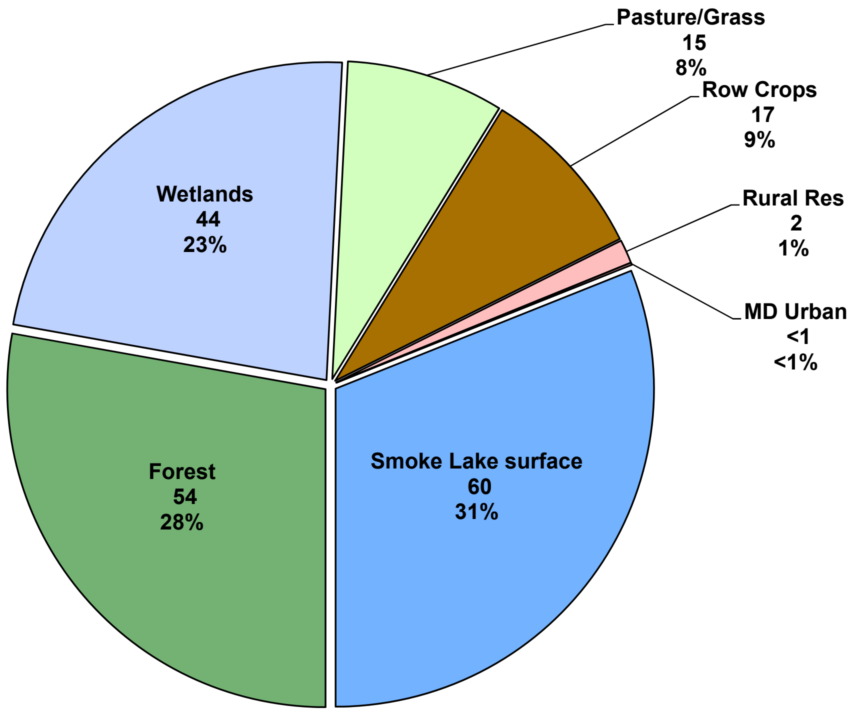

Figure 8.3.2-1. Smoke Lake watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

The WiLMS analysis for Smoke Lake also included an estimate for septic system inputs to the lake based upon data collected through the stakeholder survey. The estimate takes into account the types of septic systems utilized around the lake and how much they are used. The estimate indicates that approximately 2 lbs of phosphorus may enter the lake from septic systems, which would be considered very low.

Using standard predictive equations, an estimated in-lake, growing season average phosphorus concentration can be determined for Smoke Lake based upon its morphology and typical precipitation levels for Oconto County. The Smoke Lake modeling indicated a predicted average concentration of 36 mg/L phosphorus, which is significantly higher than the actual average concentration of 17.2 mg/L. This indicates that the modeling effort over-estimated the amount of phosphorus entering the lake, further evidencing the healthy nature of the Smoke Lake watershed. It also indicates that unknown sources of phosphorus, like internal nutrient loading and/or excessive inputs from shoreland properties or septic systems are not impacting the lake.

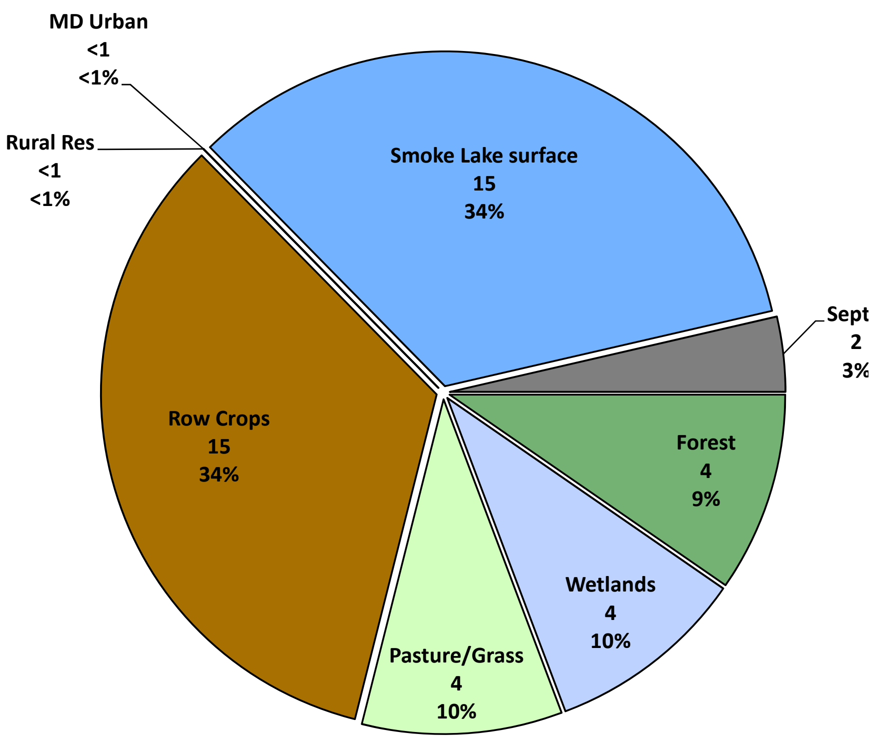

Figure 8.3.2-2 Smoke Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.3.3 Smoke Lake Shoreland Condition

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2015, Smoke Lake's immediate shoreline was assessed in terms of its development. Smoke Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.6 miles of natural/undeveloped and developed-natural shoreline (83% of the entire shoreline) were observed during the survey (Figure 8.3.3-1). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible.

During the survey, 0.07 miles of urbanized and developed–unnatural shoreline (3% of the total shoreline) was observed. If restoration of Smoke Lake shoreline 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. Smoke Lake Map 1 displays the location of these shoreline lengths around the entire lake.

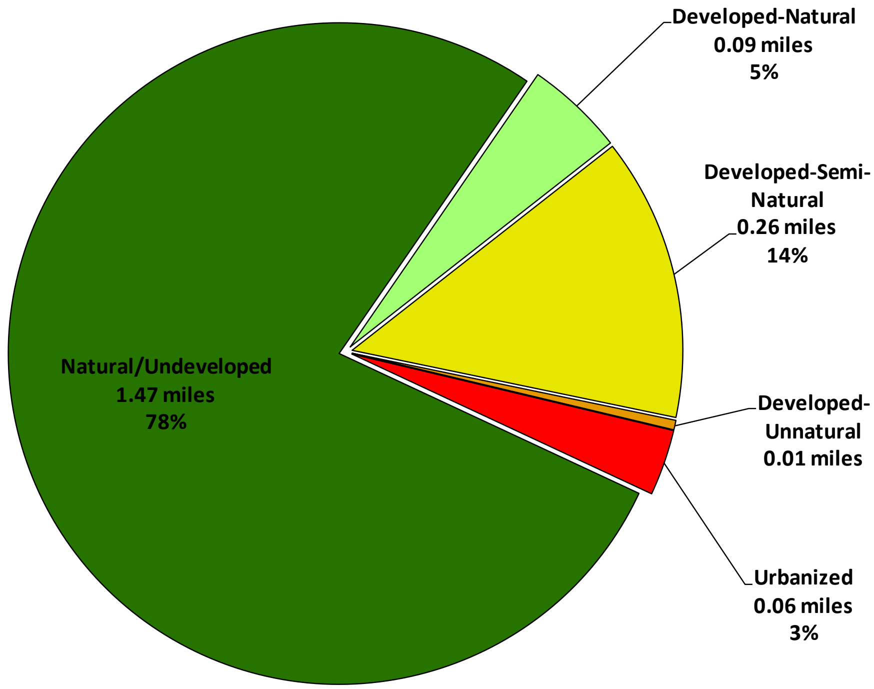

Figure 8.3.3-1. Smoke Lake shoreland categories and total lengths. Based upon a late summer 2015 survey. Locations of these categorized shorelands can be found on Smoke Lake Map 1.

Coarse Woody Habitat

Smoke Lake was also surveyed in the fall of 2015 to determine the extent of its coarse woody habitat. A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in two size categories (2-8 inches diameter, >8 inches diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 76 total pieces of coarse woody habitat were observed along 1.9 miles of shoreline, which gives Smoke Lake a coarse woody habitat to shoreline mile ratio of 40:1. Locations of coarse woody habitat are displayed on Smoke Lake Map 2. 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).

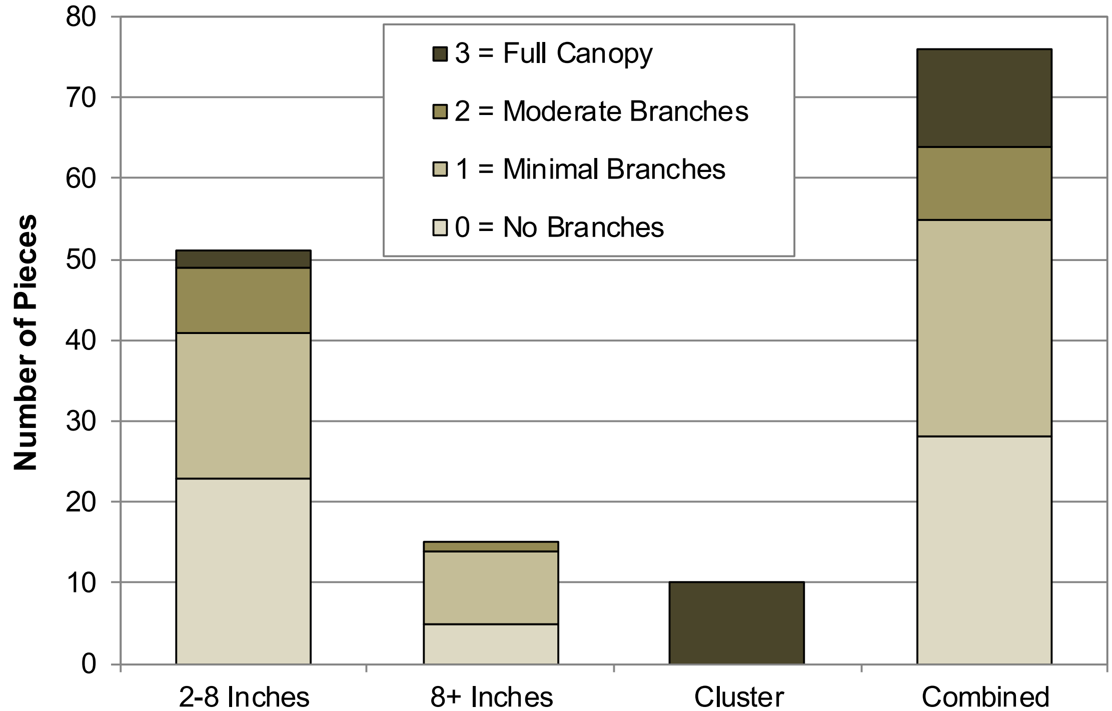

Figure 8.3.3-2. Smoke Lake coarse woody habitat survey results. Based upon a fall 2015 survey. Locations of Smoke Lake coarse woody habitat can be found on Smoke Lake Map 2.

8.3.4 Smoke Lake Aquatic Vegetation

The curly-leaf pondweed survey was conducted on Smoke Lake on June 3, 2015. This meander-based survey did not locate any occurrences of this exotic plant, and it is believed that this species either does not currently exist in Smoke Lake or is present at an undetectable level.

The aquatic plant point-intercept survey was conducted on Smoke Lake on July 14, 2015 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on July 14 & 15, 2015 to create the aquatic plant community map (Smoke Lake Map 3) during this time. During all surveys, 21 species of native aquatic plants were identified in Smoke Lake (Table 8.3.4-1). Twelve of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. Aquatic plants were found growing to a depth of nine feet. As discussed later on within this section, the species found in this survey indicate that the overall aquatic plant community is healthy and diverse.

Of the 217 point-intercept locations sampled within the littoral zone, approximately 78% contained aquatic vegetation. Smoke Lake Map 4 depicts the total rake fullness of the 399 sampled locations. Approximately 6% of the point-intercept sampling locations where sediment data was collected at were sand and 94% consisted of a fine, organic substrate (muck). No rocky areas where encountered.

Table 8.3.4-1. Aquatic plant species located in Smoke Lake during the 2015 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2015 (Onterra)
Emergent	*Carex lacustris*	Lake sedge	6	I
	Carex sp. 2	Sedge sp. 2	N/A	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Decodon verticillatus	Water-willow	7	I
	Phragmites australis subsp. Americanus	Common reed	5	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Typha spp.	Cattail spp.	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nymphaea odorata	White water lily	6	I
	Nuphar variegata	Spatterdock	6	X
	Persicaria amphibia	Water smartweed	5	I
Submergent	*Chara spp.*	Muskgrasses	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton friesii	Fries' pondweed	8	X
	Potamogeton illinoensis	Illinois pondweed	6	X
	Potamogeton natans	Floating-leaf pondweed	5	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Schoenoplectus subterminalis*	Water bulrush	9	X

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

Figure 8.3.4-1 (above) shows that muskgrasses, slender naiad, and variable-leaf pondweed were the most frequently encountered plants within Smoke Lake. Muskgrasses were found to the most encountered plant with a littoral frequency of occurrence of 43.3%. Members of the muskgrasses, while similar to many submersed aquatic plants, are actually marcroalgae. In calcium-rich lakes, like the Pickerel Chain, muskgrasses have a competitive advantage over most other plants. Muskgrasses also helps stabilize bottom sediments while working as a phosphorus sink. Southern naiad was the second most frequently encountered plant with a littoral frequency of occurrence of 39.6%. Southern naiad is an annual, growing back from seeds every year. It is a good food source for many aquatic organisms. Variable-leaf pondweed is a submersed plant that produces a thin, cylindrical stem that has numerous branches and was the third most encountered plant in Smoke Lake. Variable-leaf pondweed's branches produce linear leaves that grow anywhere from four to eleven centimeters and produce three to seven veins per leaf. It easily hybridizes with other pondweed (*Potamogeton*) species which is what creates the variability in size and shape.

21 species of aquatic plants (including incidentals) were found in Smoke Lake and because of this, one may assume that the system is diverse but less diverse than the other two Pickerel Chain Lakes. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Smoke Lake's plant community (0.78) lies well below the Northern Lakes and Forests Lakes ecoregion value (0.86), indicating the lake holds less than average diversity compared to other lakes in the northern portion of the state.

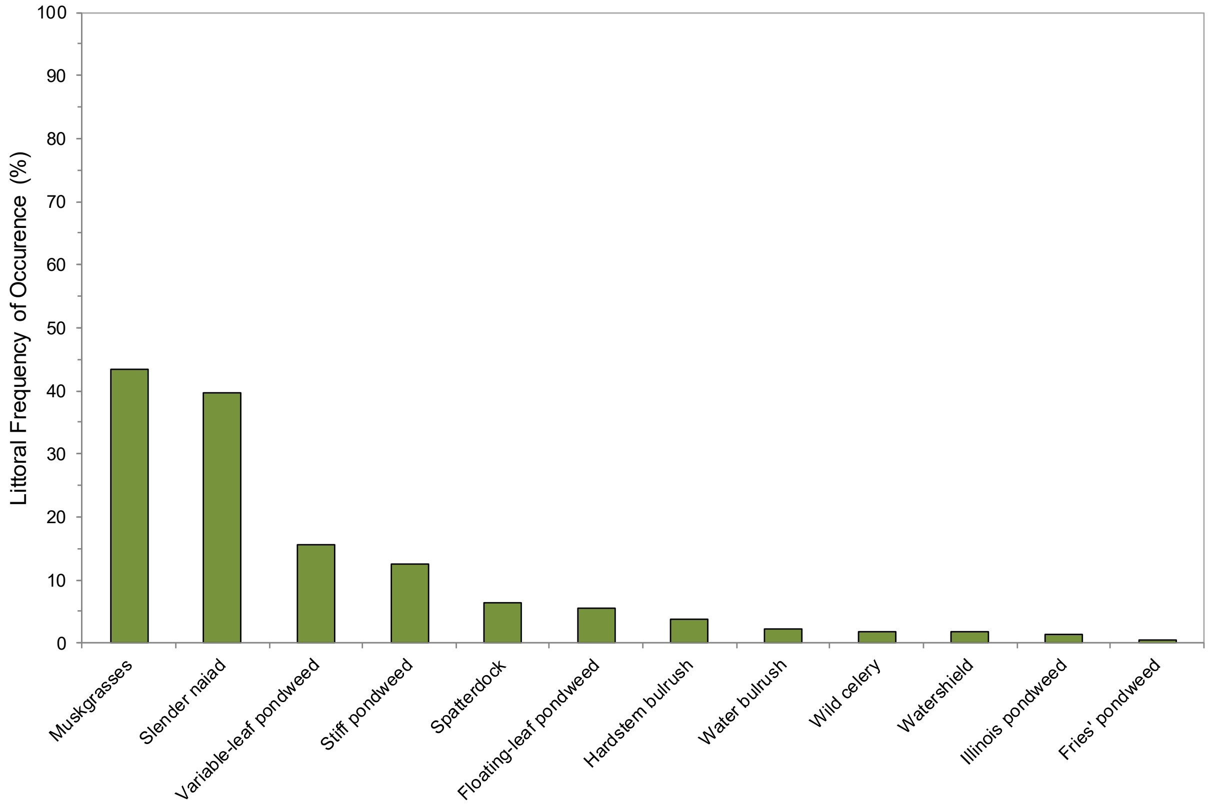

Figure 8.3.4-1 Smoke Lake aquatic plant littoral frequency of occurrence analysis. Chart includes all species. Created using data from a 2015 point-intercept survey.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while muskgrass was found at 55% of the sampling locations, its relative frequency of occurrence is 32%. Explained another way, if 100 plants were randomly sampled from Smoke Lake, 32 of them would be muskgrass. This distribution can be observed in Figure 8.3.4-2, where together 2 species account for 61% of the population of plants within Smoke Lake and the other 10 species account for the remaining 39%. Nine additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.3.4-1 as incidentals.

Smoke Lake's average conservatism value (6.1) is lower than both the state (6.3) and ecoregion (6.7) median. This indicates that the plant community of Smoke Lake is indicative of an relatively undisturbed system. Combining Smoke Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 28.0 which is above the state (27.2) but below the ecoregion (30.8) medium.

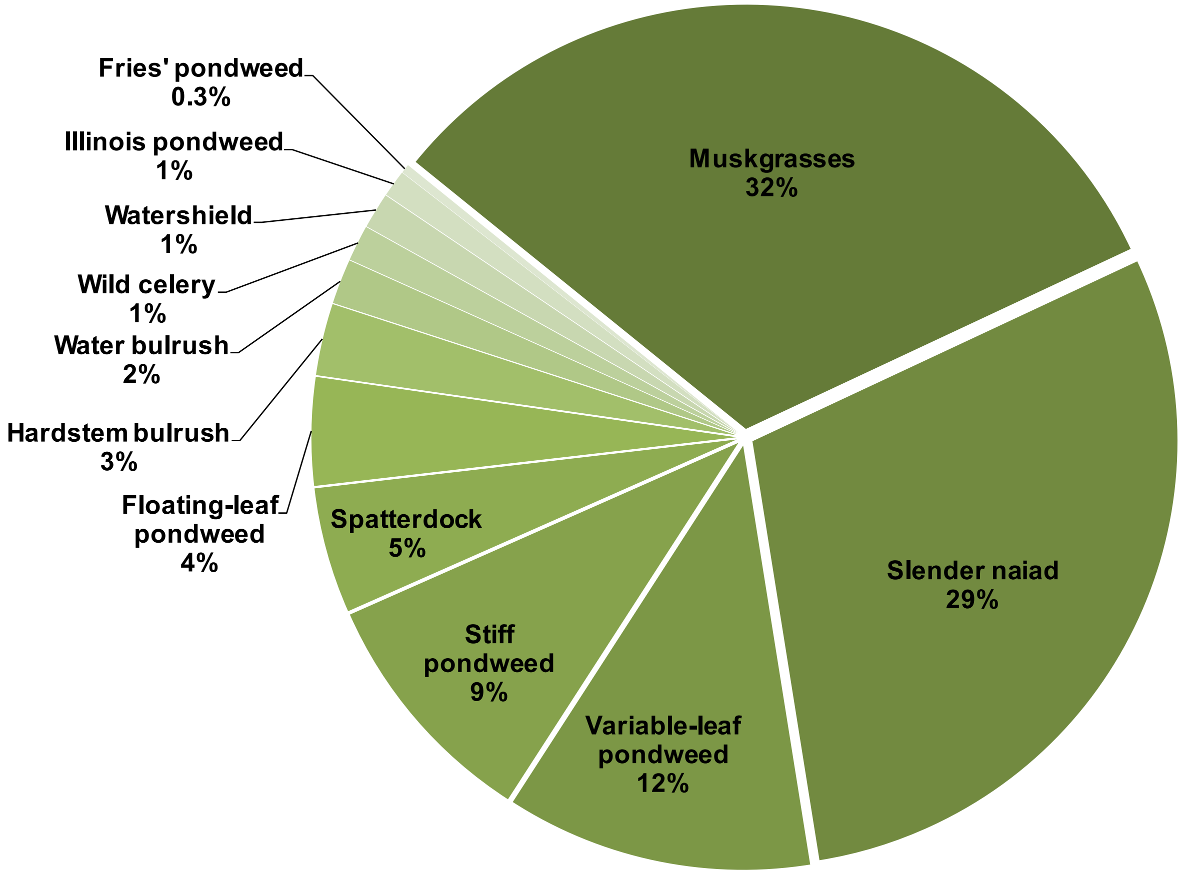

Figure 8.3.4-2 Smoke Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2015 point-intercept survey.

The quality of Smoke Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2015 community map indicates that approximately 11.1 acres of the lake contains these types of plant communities (Smoke Lake Map 3, Table 8.3.4-2). Nine floating-leaf and emergent species were located on Smoke Lake (Table 8.3.4-1), all of which provide valuable wildlife habitat.

Table 8.3.4-2. Smoke Lake acres of emergent and floating-leaf plant communities from the 2015 community mapping survey.

Plant Community	Acres
Emergent	0.7
Floating-leaf	9.1
Mixed Floating-leaf and Emergent	1.4
Total	11.1

The community map represents a 'snapshot' of the emergent and floating-leaf plant communities, replications of this survey through time will provide a valuable understanding of the dynamics of these communities within Smoke 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 shorelines when compared to undeveloped shorelines 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 shorelines.