Phillips Chain

Price County, Wisconsin

Comprehensive Management Plan

December 2021

Sponsored by:

Phillips Chain O' Lakes Association

WDNR Surface Water Grant Program

AEPP-584-19

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Onterra, LLC
Lake Management Planning

Phillips Chain

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Acknowledgements

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

Phillips Chain O' Lakes Planning Committee

Blake Plumer- Chair	Brian Baratka
Travis Nez	John Barko
Mike Derkez	Glen Konshak

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1.0 INTRODUCTION

The Phillips Chain, Price County (Map 1), comprises four lakes with a surface area of nearly 1,221 acres. These lakes are classified as an impoundment, and were formed through the damming of the Elk River. Before the dam was installed, Duroy, Elk, and Long Lakes were natural lakes and Wilson Lake did not exist. Instead, Wilson Creek flowed through the area and met the Elk River as a tributary stream. Duroy Lake is the most upstream lake and water flows from the lake into Elk Lake and then into Long Lake. Water from Wilson Lake also flows into Long Lake. Although the lakes are connected, they vary greatly in many respects due to their morphology and substrate type. These differences are most apparent in the bathymetry of each lake (Map 1). The total area of the watershed is 127,288 acres. This eutrophic system has a very large watershed when compared to the combined surface area of the lakes.

Field Survey Notes

Lakes very different in structure and aquatic plant abundance. Steeply sloped sides and gravel-lined substrate likely keep plant growth down in Long and Elk Lakes. EWM growth in Wilson is substantial, dominating much of lake. Large, lush wetlands surround Duroy Lake with many emergent species present and great wildlife habitat (Photograph 1.0-1).

Photograph 1.0-1 Phillips Chain, Price County

Lakes at a Glance – Phillips Chain

		Duroy Lake	Elk Lake	Long Lake	Wilson Lake
Morphology	**Acreage**	375	91	407	348
	Max. Depth (ft)	18	25	54	11
	Volume (Acre-ft)	1,914	678	4,223	1,785
	Mean Depth (ft)	5.1	7.5	10.4	6.0
Vegetation	**Number of Native Species**	36	14	32	41
	Non-Native Species	EWM, PL, CLP,PYI	EWM	EWM	EWM, PL
	Threatened/Special Concern Species	Vasey's pondweed, Autumnal water starwort	None	None	Vasey's pondweed
Water Quality	**Trophic State**	Eutrophic			
	Limiting Nutrient	Transitional and Phosphorus			
	pH	Range from 6.9 – 7.8			
	Sensitivity to Acid Rain	Non-Sensitive			
	Watershed to Lake Area Ratio	104:1			

EWM = Eurasian Watermilfoil, PL = Purple Loosestrife, CLP = Curly-Leaf Pondweed, PYI = Pale-Yellow Iris

The City of Phillips, it's chain of lakes, and the surrounding area sees a large amount of tourism due to an abundance of summer festivals, an annual triathlon, and all the outdoor recreational opportunities that a Northwood's Wisconsin city has to offer. Like many lakes in northern Wisconsin, invasive species establishment threatens the health and beauty of the Phillips Chain, as well as the economy of the surrounding area. The Phillips Chain is known to harbor Eurasian water milfoil, rusty crayfish, and banded mystery snail. In 2009, a small patch of purple loosestrife was found by Onterra staff on the shores of Duroy Lake. In particular, Eurasian water milfoil has become quite prevalent in the system and is of great concern to the Phillips Chain O' Lakes Association (PCOLA), as well as others. Eurasian water milfoil was first discovered in Duroy Lake in 2000. By 2002, it was confirmed in the rest of the Chain (Elk, Long, and Wilson lakes).

This management plan is an update from the plan completed in 2011. The current plan that has resulted from this project is the combination of scientific study results and the sociologic aspects of the Chain and its stakeholders. Many entities have contributed in to the progress of this management project, which is vital when a resource such as the Phillips Chain is at stake. The results of those studies will not only lead to better management decisions, but also act as a reference point for future studies.

The main sections of this plan (1.0-7.0) are written from a chain-wide perspective. Section 3.0 of the Plan contain the encyclopedia-like parts of the document that simply share data and information. At the beginning of each report section, there is a primer sub-section that provides an understanding of ecological principals, methods, and analysis tools. Following the Section 3.0 report sections is the Summary and Conclusions Section (4.0). This section provides a succinct overview of the health of the Phillips Chain (Click Here), similar to an executive summary. Section 5.0 of the Plan is the actual Implementation Plan that was constructed as part of the project. Many refer to this section as the actual *management plan* whereas the other sections are simply supporting materials.

Because the system is comprised of four separate and distinct lakes, Section 8.0 contains additional lake-specific information in a similar format to Section 3.0. It is likely that many stakeholders will simply read the chain-wide section and their individual lake-specific section. Therefore, some of the text may seem redundant if one reads the entire document, including each lake-specific section.

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 and the completion of a stakeholder survey.

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

Planning Committee Meeting

On October 13, 2020, Eddie Heath of Onterra met virtually with the PCOLA Planning Committee for nearly 4 hours. Carol Warden, acting local WDNR lakes biologist, was also in attendance for a large portion of this meeting. In advance of the meeting, attendees were provided an early draft of the study report sections (3.0 & 8.0) to facilitate better discussion. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. Study components including AIS survey results, aquatic plant inventories, water quality analysis, watershed modeling, and shoreland assessment results were presented and discussed.

Planning Committee Meeting II

Based upon the discussion from the previous planning meeting and a focused teleconference on EWM management, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee. Written comments were provided back to Onterra. In addition, the PCOLA Planning Committee met virtually on July 22, 2021 for over1.5 hours methodically going through each management action contained within the draft Implementation Plan Section (5.0).

Management Plan Review and Adoption Process

On July 28, 2021, the Official First Draft of the PCOLA's Comprehensive Management Plan for the Phillips Chain was supplied to WDNR (lakes and fisheries programs), Price County (conservation and dams departments), Great Lakes Indian Fish and Wildlife Commission, and Lac du Flambeau Tribe to solicit comments. At that time the Official First Draft was posted to the PCOLA website for public review, with outreach efforts requesting riparians to provide comments. The posting remained active until it was replaced with the finalized version. No comments were received from the general public.

The WDNR (Madeline Mathes) provided official comments on November 18, 2021. These comments were address and extracted relevant pages were provided to Ms. Mathes and her team for final approval.

On July 28, 2021, the WDNR was asked to review specific areas of the Implementation Plan Section for future grants and permit. Further, the PCOLA submitted a letter on September 2, 2021 specifically requesting an eligibility determination from the WDNR in regards to a forthcoming November 1 grant application. Following a 45-day review period, the WDNR did not provide notification of ineligibility, which allows these specific plan recommendations to be eligible for future funding under the Surface Water Grant Program (NR 193).

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to riparian property owners/Phillips Chain O' Lakes Association (PCOLA) members and property renters around the Phillips Chain. The survey was designed by Onterra staff and the PCOLA planning committee and reviewed by a WDNR social scientist. During November 2019, the nine-page, 45-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis. Thirty-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. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for The Phillips Chain. Stakeholders (45%) use their property as a year-round residence, 23% visit their property seasonally as a vacation home, 10% use their seasonal residence (longer than summer), and 6% have a rental property. 56% of stakeholders have owned their property for over 15 years, and 35% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. More than half of survey respondents indicate that they use either a pontoon boat, larger motor boat, canoe/kayak, or a combination of these three vessels on the Phillips Chain (Figure 2.0-1). Paddleboats were also a popular option. The need for responsible boating increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question 18, several of the top recreational activities on the lake involve boat use (Figure 2.0-2). Although boat traffic was listed as a factor potentially impacting the Chain in a negative manner, it was ranked 7th on a list of stakeholder's top concerns regarding the lake (Figure 2.0-3).

A concern of stakeholders noted throughout the stakeholder survey (see Question 29 and survey comments – Appendix B) was aquatic invasive species introduction and aquatic plant management within the Chain. This topic is touched upon in the Aquatic Plants, Summary & Conclusions section as well as within the Implementation Plan.

Question 15: What types of watercraft do you currently use on the Phillips Chain O' Lakes?

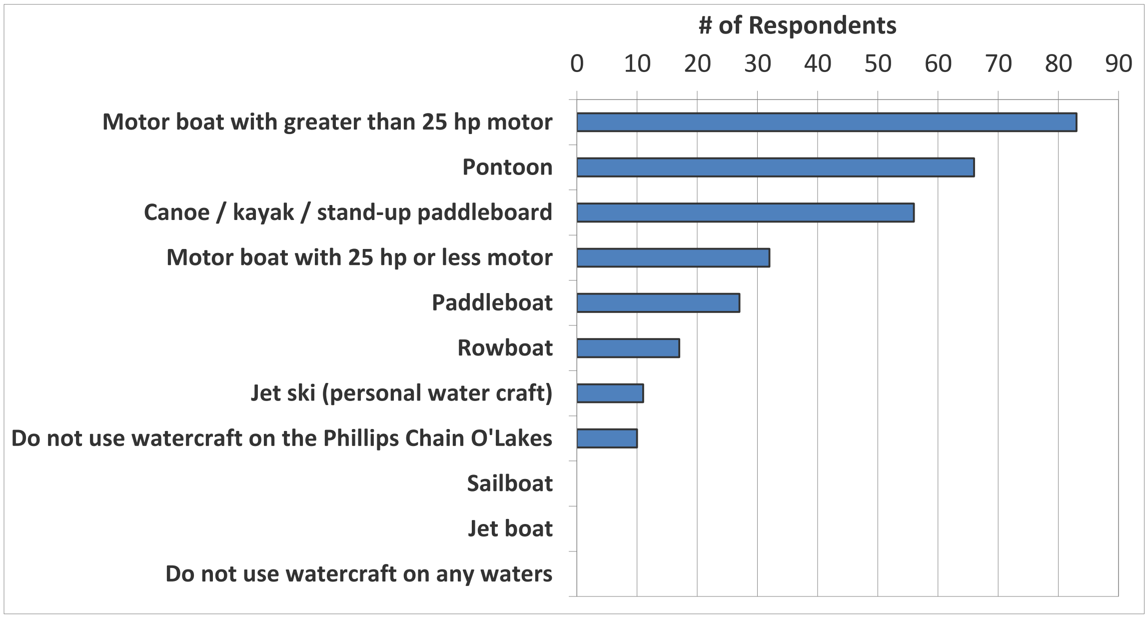


Figure 2.0-1. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 18: Please rank up to three activities that are important reasons for owning your property on or near the Phillips Chain O' Lakes.

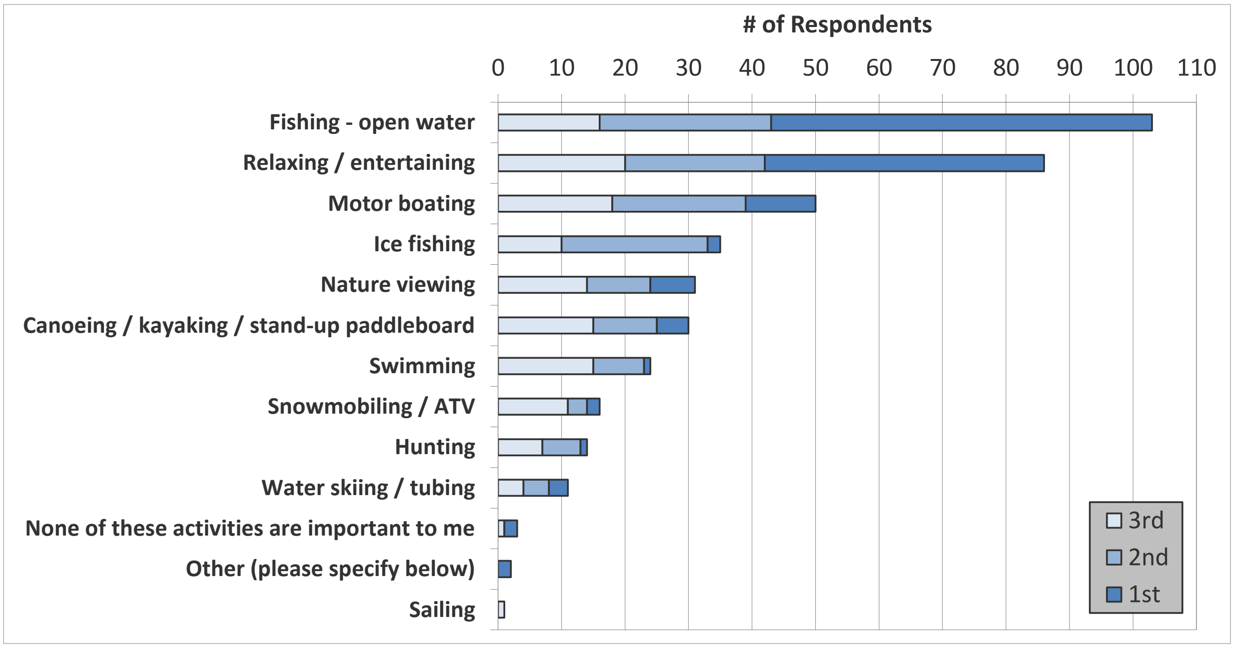


Figure 2.0-2. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 29: Please rank your top three concerns regarding the Phillips Chain O' Lakes.

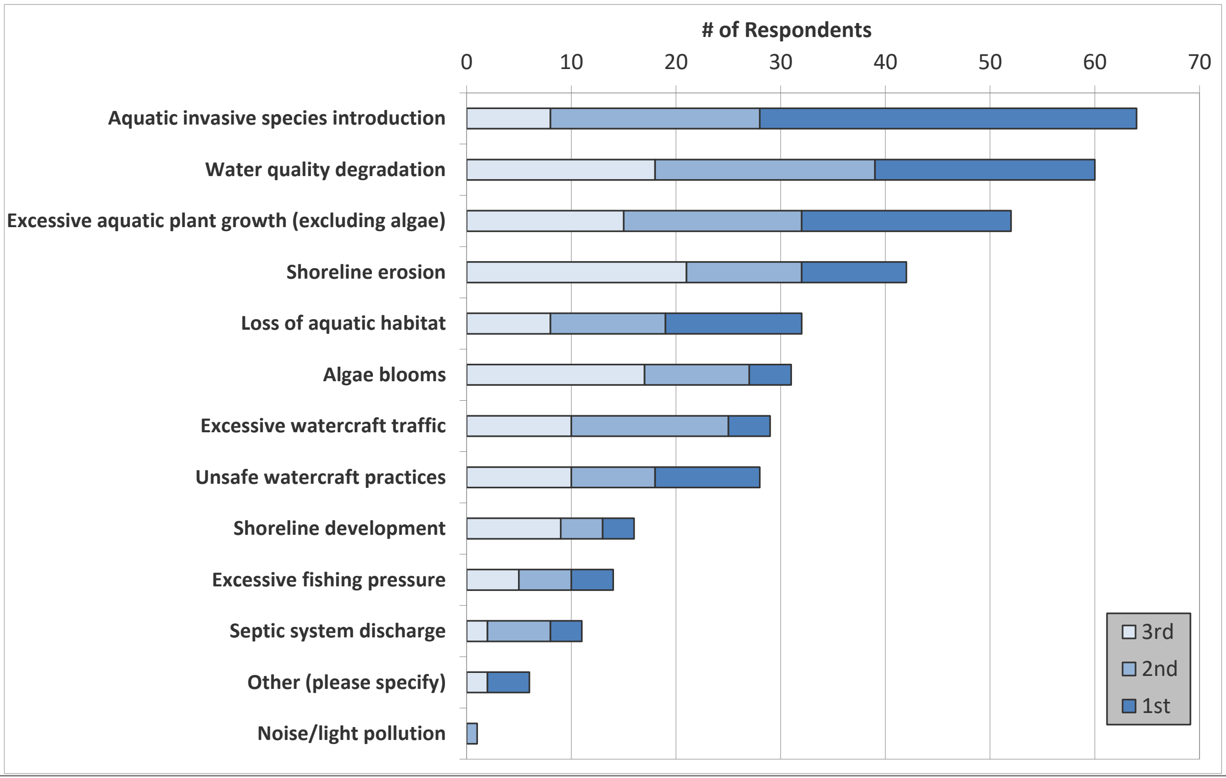


Figure 2.0-3. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

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 Phillips Chain 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 Phillips Chain' water quality analysis:

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

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

Trophic State

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature gradients are developed with depth in a lake. During stratification the lake can be broken into three layers: The *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 processes that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading*

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR 2017) 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 Phillips Chain will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). 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.

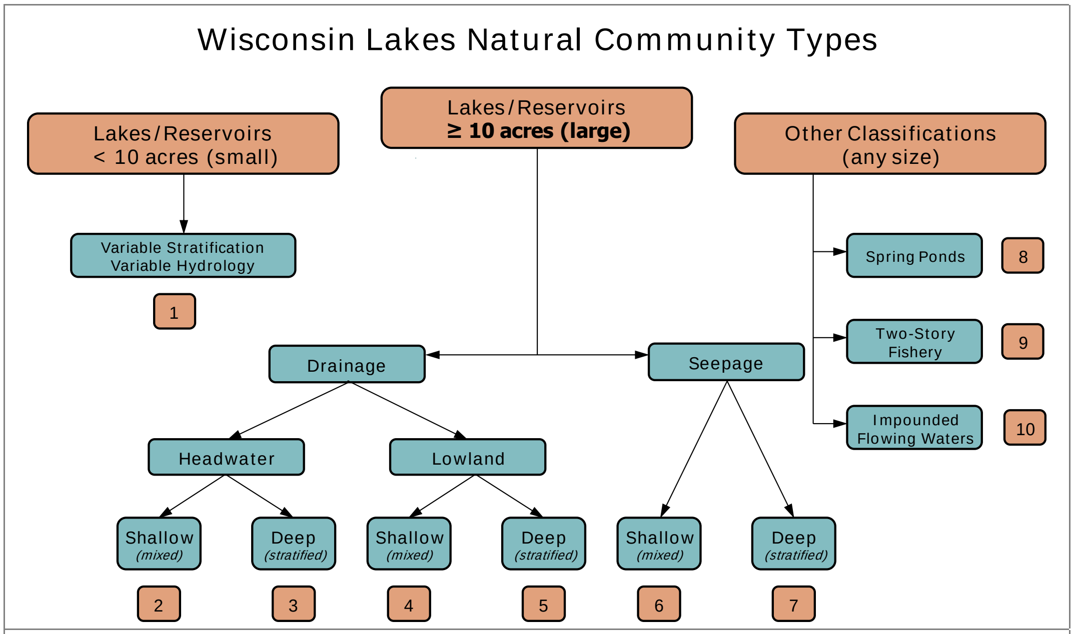


Figure 3.1-1. Wisconsin Lake Classifications. Adapted from WDNR 2017.

Lathrop and Lillie developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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 Phillips Chain is within the Northern Lakes and Forests ecoregion.

The Wisconsin 2018 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act. It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and phosphorus concentrations when nuisance algal blooms occur.

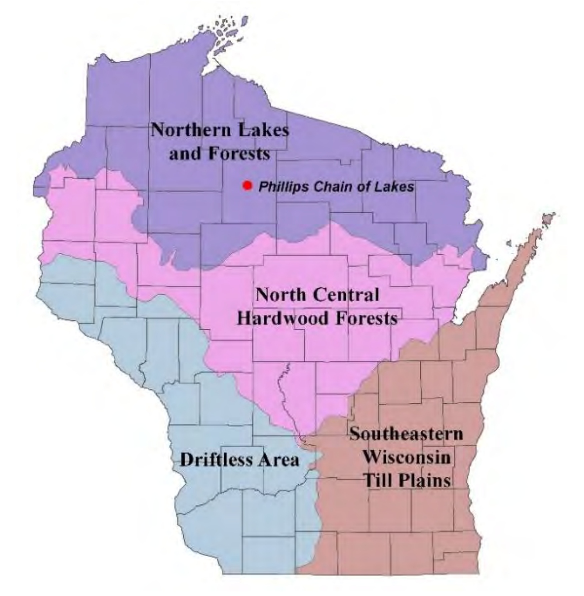


Figure 3.1-2. Location of the Phillips Chain within the ecoregions of Wisconsin. After Nichols 1999.

Water quality data from the Phillips Chain project lakes are presented along with comparable data from similar lakes throughout the state and lakes within the NLF ecoregion in the subsequent section. Please note that these data represent samples collected during the growing season (April – October) or summer months (June, July, and August) unless otherwise indicated. The chlorophyll-*a* data represent only samples collected from the near-surface because they represent the depths at which phytoplankton grow.

Phillips Chain Water Quality Analysis

Phillips Chain Trophic Parameters

Total Phosphorus

As discussed previously, phosphorus is the primary nutrient controlling the growth of algae (phytoplankton) in the majority of Wisconsin's lakes. To determine whether phosphorus is the limiting nutrient within a lake, the concentration of phosphorus is compared to the concentration of nitrogen. Mid-summer samples for nitrogen and phosphorus were collected in 1996 and 2000 for Long, Elk, and Duroy lakes while the same data was collected from Wilson Lake in 2000 and 2002. The total phosphorus and total nitrogen concentrations from the Phillips Chain lakes indicate that Wilson and Long lakes are phosphorus-limited but Duroy and Elk lakes are considered transitional as they may be both phosphorus and nitrogen limited at times (Figure 3.1-3). The mid-summer nitrogen to phosphorus ratios ranged from 12:1 in Elk Lake to 21:1 in Long Lake. In general, this means that increases in phosphorus inputs would likely result in increased algal production in the lakes even the lakes considered transitional.

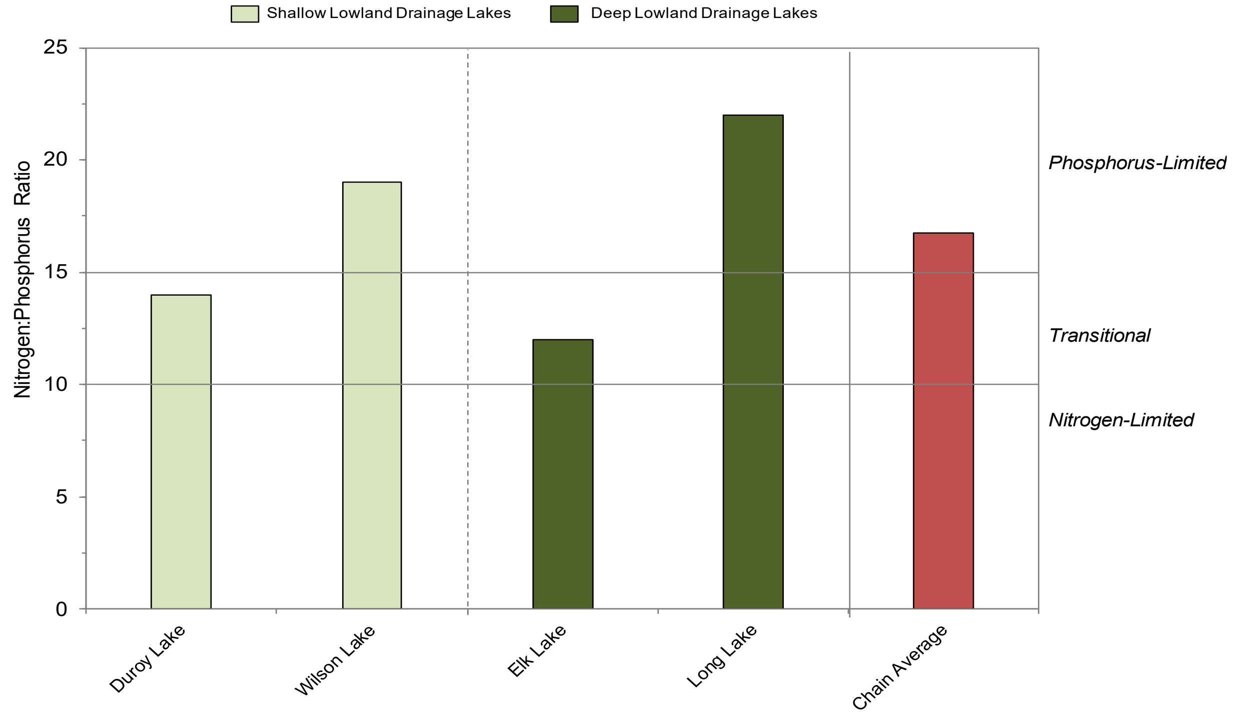


Figure 3.1-3. Phillips Chain lakes mid-summer total nitrogen to total phosphorus ratios. Data represent surface samples collected during mid-summer during each respective project phase.

All of the lakes in the Phillips Chain have short hydraulic residence times of less than 14 days which in the classification scheme of the Wisconsin Department of Natural Resources makes these water bodies officially *impounded flowing waters*. For phosphorus standards the value for rivers (100 μg/L) is used. The reason for this classification is that with the short residence times, the water quality of these water bodies is mostly reflective of the water quality of the incoming Elk and Little Elk rivers and Squaw Creek. The short residence times also mean that in lake processes have little impact on the lake's water quality. Because there are not comparables for impounded flowing waters, for this report the water bodies will be treated as lakes when comparing their water quality to other lakes within the ecoregion and state wide. Wilson Lake has a hydraulic residence time of greater than 14 days so this lake is officially considered a lake. The residence time of Wilson Lake is about 51 days.

Average summer near-surface total phosphorus concentrations were calculated for the Phillips Chain lakes using data collected as part of this project along with any available historical data. Near-surface summer total phosphorus concentrations ranged from 57.3 μg/L in Long Lake to 67.3 μg/L in Elk Lake (Figure 3.1-4). The summer total phosphorus concentrations for all the lakes fall within the *fair* and *poor* categories for their respective lake types in Wisconsin.

Although these lakes (except Wilson Lake) are impoundments with water levels controlled by the Jobes Dam, the concentration of the trophic parameters will be compared with lakes that are a similar lake type, e.g. shallow lowland drainage, since there are not comparables for impoundments. Total phosphorus concentrations for all of the lakes are considerably higher than the median value for deep and shallow lowland drainage lakes as well all lake types within the NLF ecoregion.

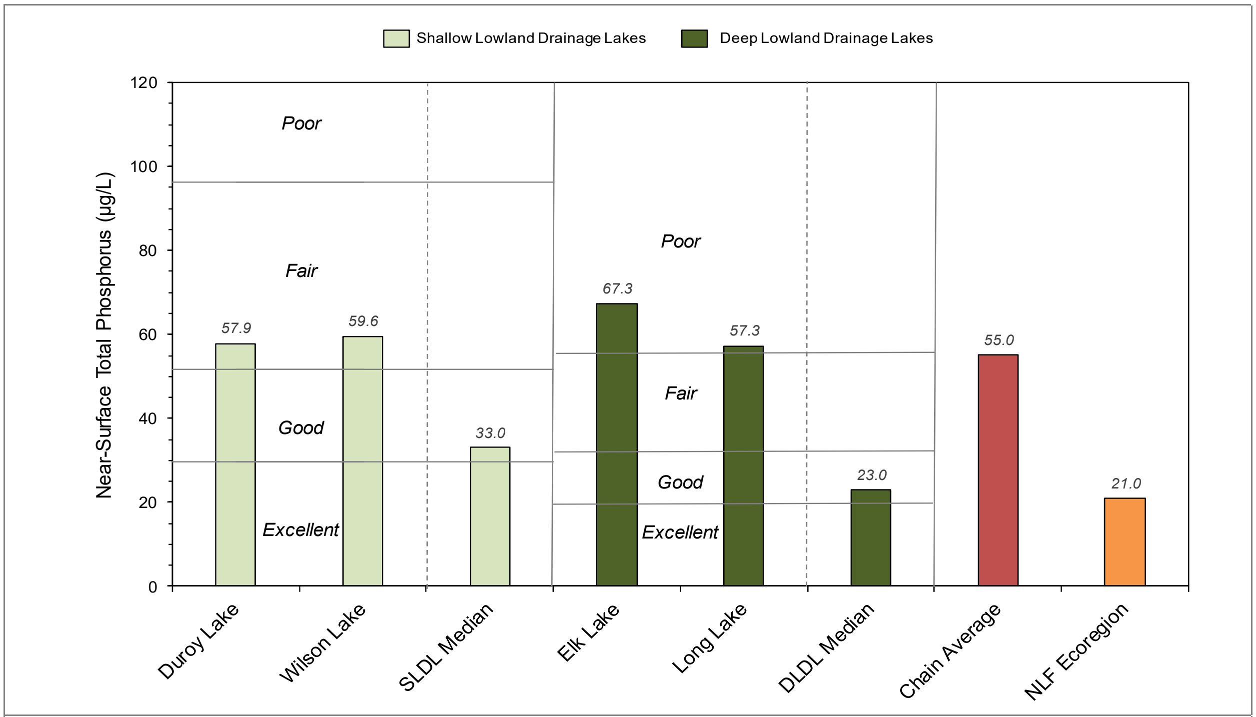


Figure 3.1-4. Phillips Chain Lakes, summer average near-surface total phosphorus concentrations and median summer near-surface total phosphorus concentrations from comparable lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Chlorophyll-α

As discussed earlier, chlorophyll-*a*, or the measure of free-floating algae within the water column, is usually positively correlated with total phosphorus concentrations. While phosphorus limits the amount of algae growth in the majority of Wisconsin's lakes, other factors also affect the amount of algae produced within the lake. Water temperature, sunlight, and the presence of small crustaceans called zooplankton, which feed on algae, also influence algal abundance.

Summer average chlorophyll-*a* concentrations measured within the Phillips Chain lakes ranged from 12.0 µg/L in Duroy Lake to 23.6 µg/L in Wilson Lake (Figure 3.1-5). Summer average chlorophyll-*a* concentrations for Duroy Lake falls within the *good* category for shallow lowland drainage lakes in Wisconsin, while Wilson Lake falls in the *fair* category. Chlorophyll-*a* concentrations for Elk and Long lakes fall within the *fair* category for deep lowland drainage lakes in Wisconsin. These classifications are generally better than they are for phosphorus. This is because with the short hydraulic residence times in Duroy, Elk, and Long lakes, there is not sufficient time for the algal growth to occur. Wilson Lake is the exception because of its longer residence time (51 days) which is why the phosphorus and chlorophyll-*a* category is similar in this lake. The chlorophyll-*a* concentrations in all of the lakes are higher than the median value for similar lake types as well as much higher than the median value for all lake types in the NLF ecoregion.

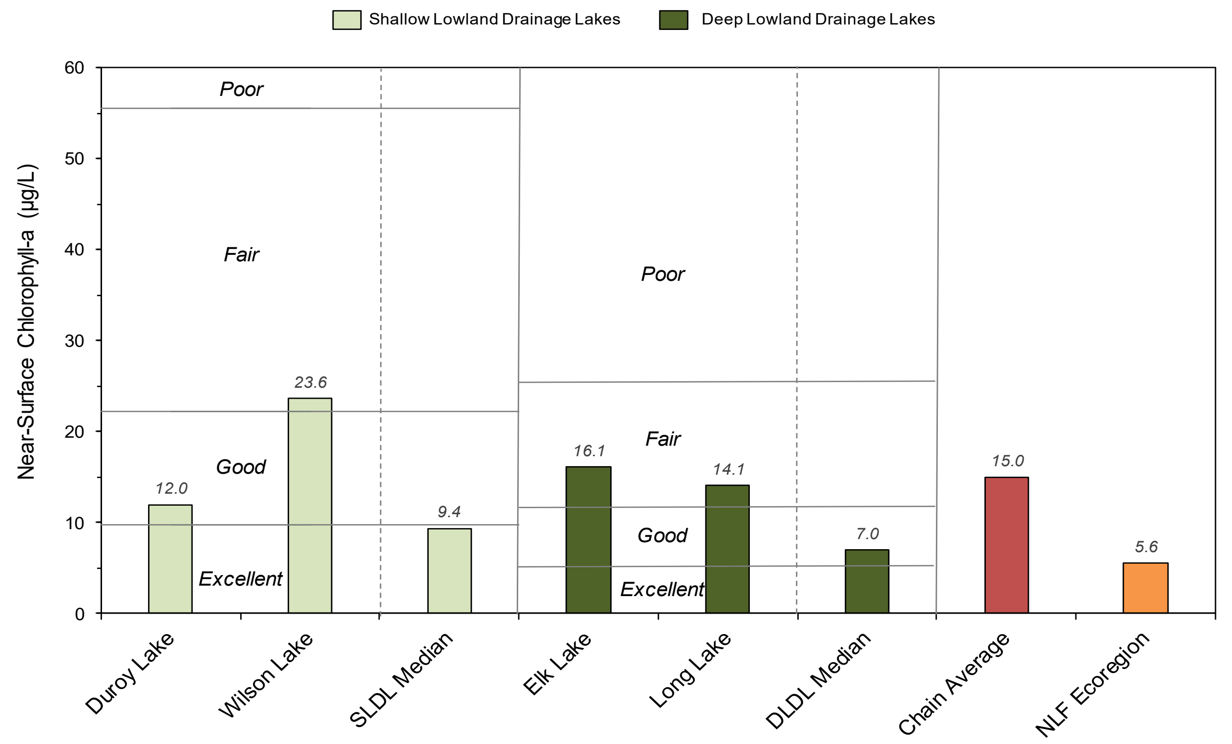


Figure 3.1-5. Phillips Chain lakes summer average near-surface chlorophyll-α concentrations and median summer near-surface chlorophyll-α concentrations from comparable lakes. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Water Clarity

Average summer Secchi disk depth measured in the Phillips Chain lakes ranged from 2.8 feet in Elk Lake to 4.2 feet in Long Lake (Figure 3.1-6). The Secchi disk depth for Duroy Lake places it in the *good* category for shallow lowland drainage lakes while Wilson Lake is in the *fair* category for shallow lowland drainage lakes. Elk and Long lakes are in the *fair* category for deep lowland drainage lakes in Wisconsin. The water clarity for all the lakes is much worse than the median values for other shallow and deep lowland drainage lakes in the state and all lake types within the NLF ecoregion. These classifications are the same as for chlorophyll-*a* suggesting that algal levels are an important component of water clarity.

A measure of water clarity once all of the suspended material (i.e. algae and sediments) have been removed, is termed *true color*, and indicates the level of dissolved organic material within water. The mid-summer true color values were highly colored with the lakes ranging from *tea-colored* to the border of *highly tea-colored* (Figure 3.1-7). The highly colored water reduces water clarity as well as light penetration into the water column which can restrict algal growth.

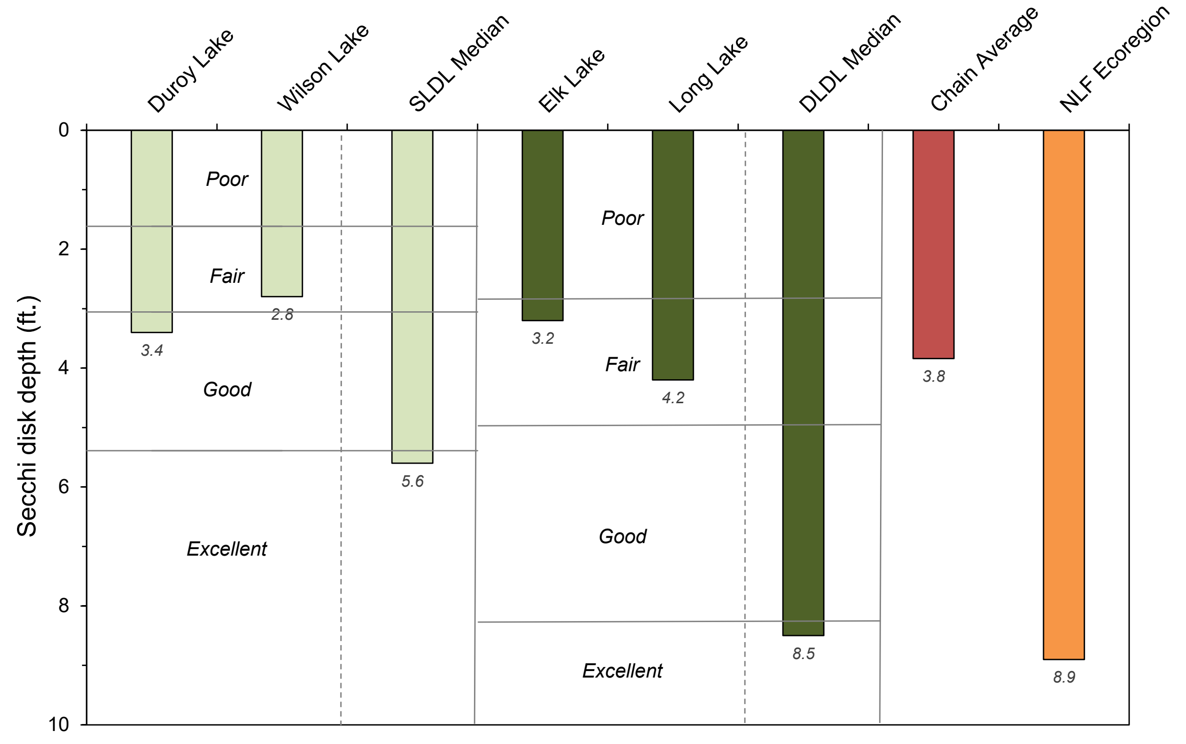


Figure 3.1-6. Phillips Chain lakes summer average Secchi disk transparency and median summer Secchi disk transparency from comparable lakes. Water Quality Index values adapted from WDNR PUB WT-913.

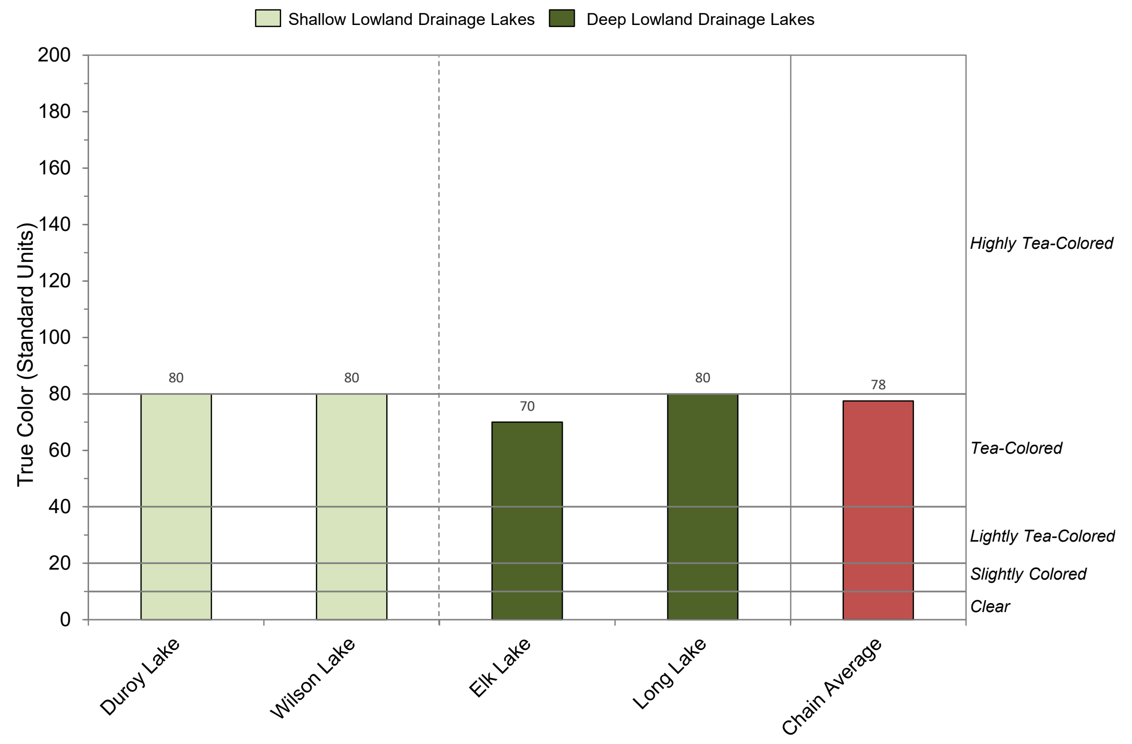


Figure 3.1-7. Phillips Chain lakes mid-summer true color values. Samples were collected from the near-surface. Color range adapted from UNH Center for Freshwater Biology (2014).

Phillips Chain Project Lakes Trophic State

Figure 3.1-8 contains the weighted average Trophic State Index (TSI) values for each of the Phillips Chain project lakes. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds within the water.

The weighted TSI values for total phosphorus and chlorophyll-*a* in the project lakes were all eutrophic (Figure 3.1-8). The primary reason that the productivity is so high in these lakes when compared to other lakes in the NLF ecoregion is that the hydraulic residence times in these lakes is very short. This means that incoming nutrients do not have time to settle out of the water column and the productivity is more reflective of that in the incoming rivers and streams.

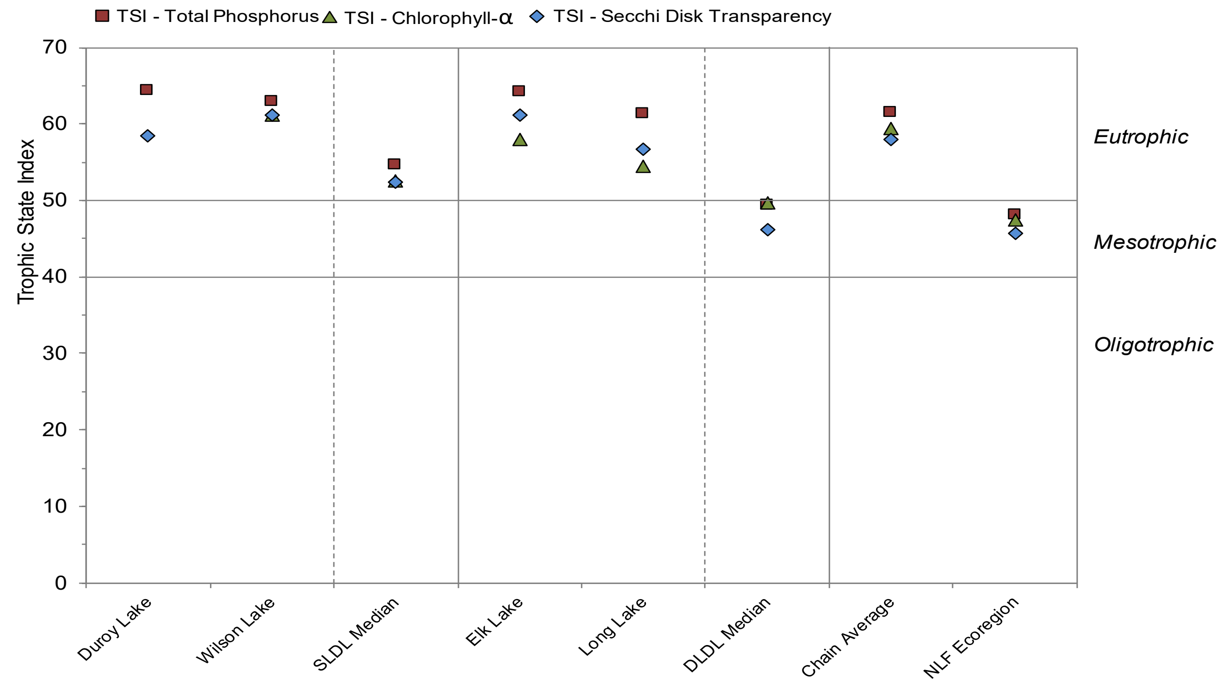


Figure 3.1-8. Phillips Chain project lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193. SHDL = Shallow Lowland Drainage Lake, DLDL = Deep Lowland Drainage Lake.

Additional Water Quality Data Collected in the Phillips Chain Project 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 Phillips Chain project lakes' water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

pH

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic, meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes and highly productive 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 summer pH values in all the lakes were very similar, 7.5-7.8, (Figure 3.1-9) which reflects the fact that these lakes are closely connected. This value is near neutral and falls within the normal range for Wisconsin lakes.

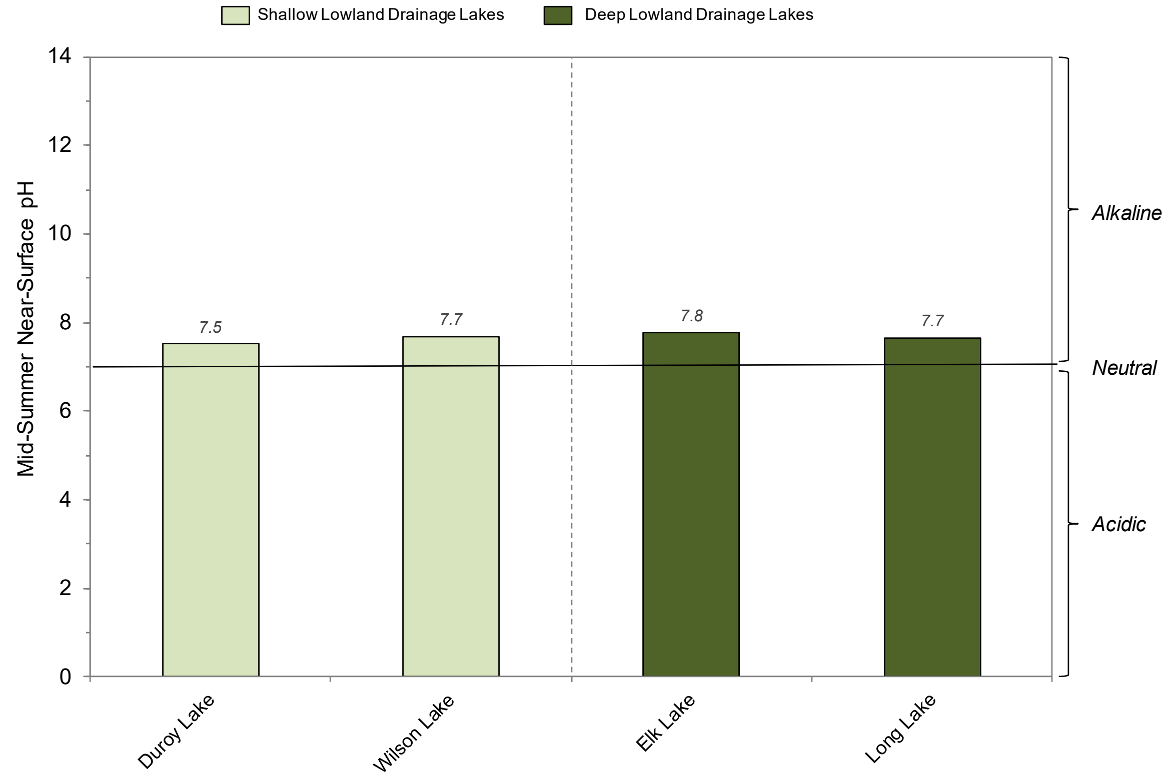


Figure 3.1-9. Phillips Chain project lakes mid-summer near-surface pH values. Samples were collected from near-surface.

Alkalinity

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 with a pH of around 5.0 due to dissolved carbon dioxide from the atmosphere. Consequently, lakes with low alkalinity have lower pH values due to their inability to buffer against acid inputs.

The alkalinity concentrations in July were very similar in all of the lakes, ranging from 37-41 mg/L (Figure 3.1-10). Given the alkalinity in these lakes, none are sensitive to inputs from acid rain. Alkalinity values were much lower in the spring (< 2.5 mg/L) which reflects the impact of runoff from snow melt. Snow contains very low concentrations since it is derived from the atmosphere and these low concentrations are only present for a short period of time during the year.

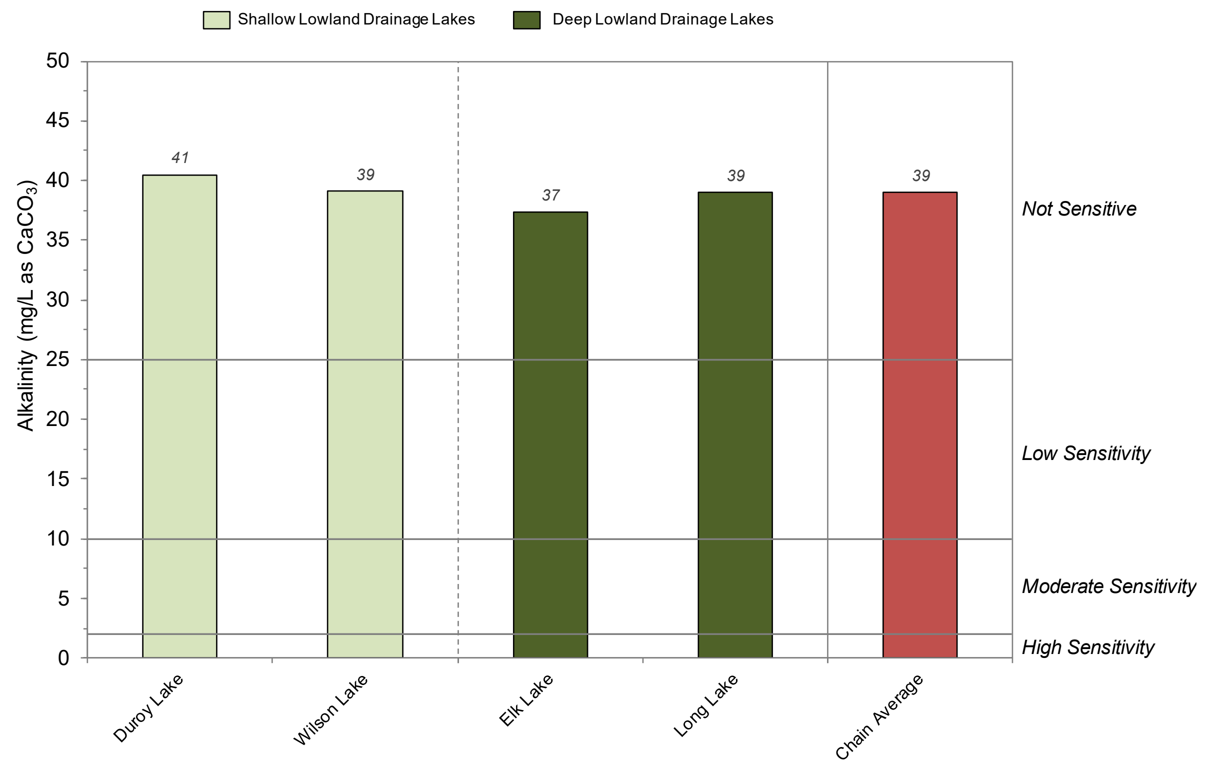


Figure 3.1-10. Phillips Chain project lakes mid-summer total alkalinity and sensitivity to acid rain. Samples were collected from near-surface.

Calcium

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine which lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and the pH of the project lakes fall within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have *very low susceptibility* to zebra mussel establishment. Measured calcium concentrations within the project lakes were similar and ranged from 10.9 to 12.0 (Figure 3.1-11). Calcium concentrations fall within the *very low susceptibility* category for zebra mussel establishment. The calcium concentrations in these lakes indicate zebra mussels have a low probability of establishing if they were to be accidentally introduced.

Like alkalinity, calcium concentrations were much lower in April compared with the July samples because of the low concentrations found in snow during the spring runoff.

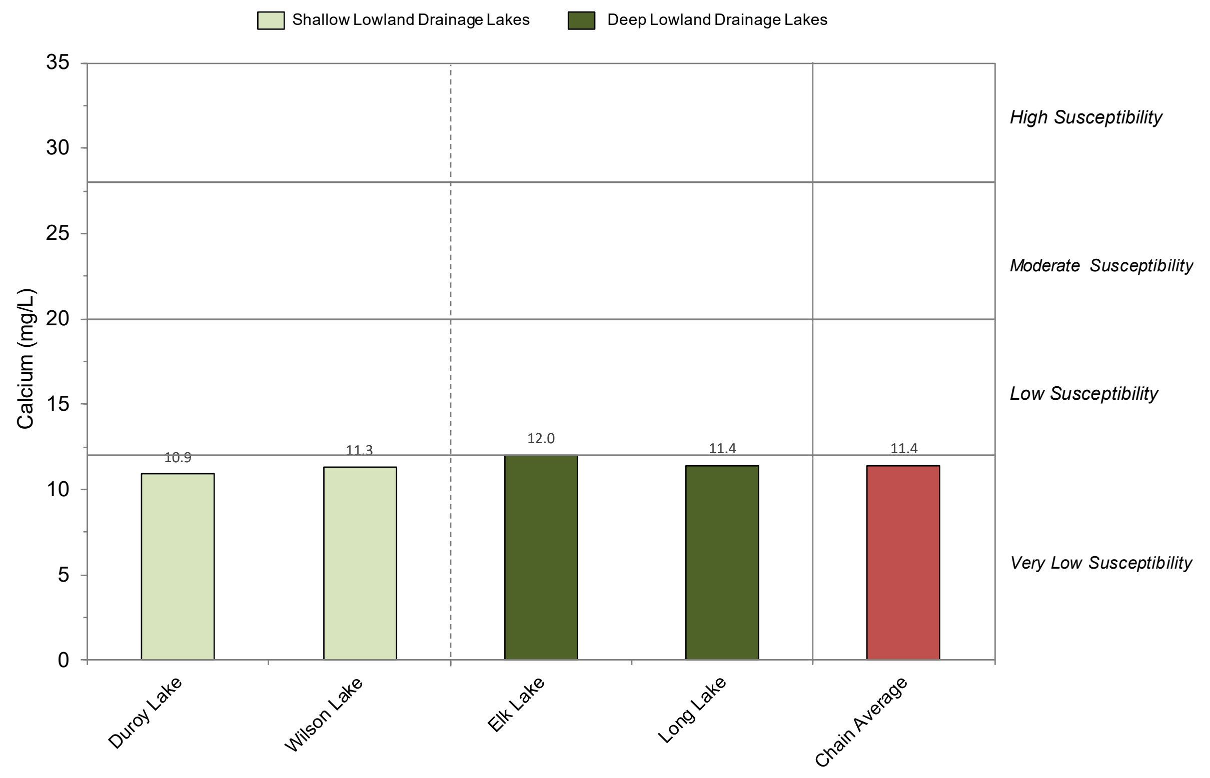


Figure 3.1-11. Phillips Chain project lakes mid-summer calcium concentrations and susceptibility to zebra mussel establishment. Samples were collected from the near-surface in July.

Blue-Green Algae Blooms

Photograph 3.1-1. Blue-green algae bloom on Long Lake. Photo credit: Onterra August 2013.

Blue-green algae blooms have been periodically noted on the Phillips Chain (Photograph 3.1-1). 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 high-nutrient systems like the Phillips Chain.

Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis. Many species of blue-green algae can naturally be found in Wisconsin waters, some of which can produce toxins potentially dangerous to people and animals. Exposure to these toxins occurs from ingestion of water, skin contact, and by inhaling aerosolized water droplets. It is unknown if the blue-green algae blooms noted in the past on the Phillips Chain produced toxins.

The largest risk of exposure consists of swallowing water containing the toxins, usually during water-sporting activities. Symptoms include nausea, vomiting, diarrhea and in severe cases, liver failure or paralysis. Skin contact with algae can produce blistering of the exposed skin. Allergy-like symptoms including coughing, watery eyes, and nose/throat irritation are most commonly associated when wind and motor boat activity cause the toxins to become aerosolized.

Stakeholder Survey Responses to Phillips Chain Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.1-12 and 3.1-13 display the responses of members of Phillips Chain stakeholders to questions regarding water quality and how it has changed over their years visiting the chain.

Question 19: How would you describe the overall current water quality of the Phillips Chain?

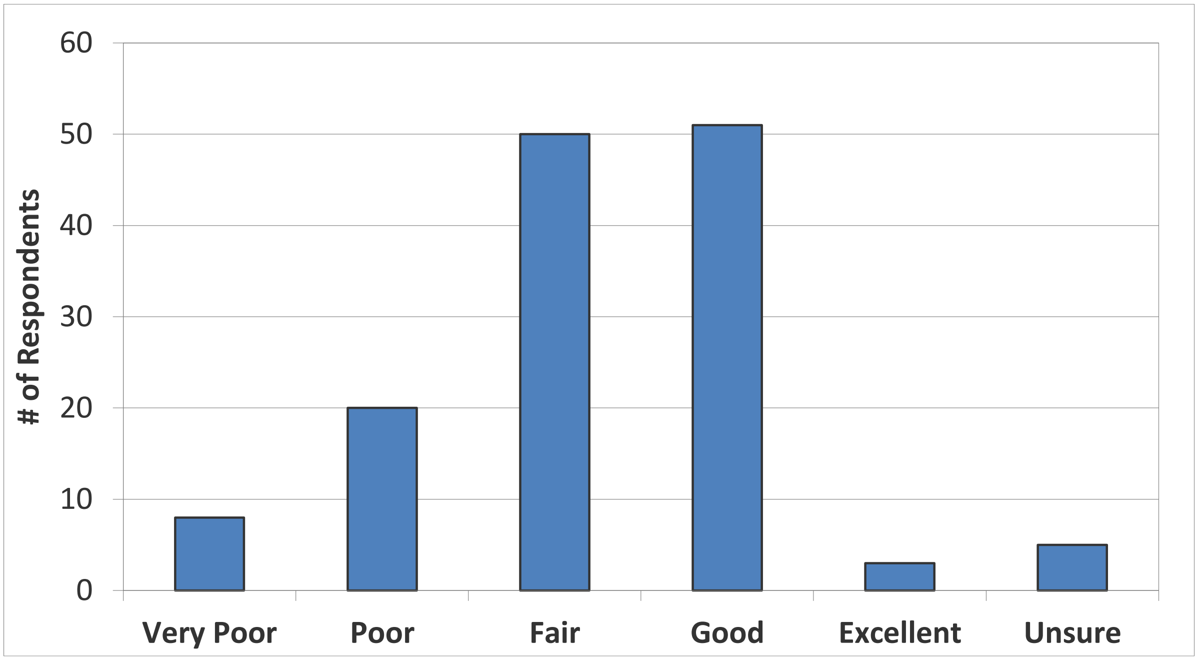


Figure 3.1-12. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 20: How as the overall water quality changed in the Phillips Chain O' Lakes since you first visited the lake?

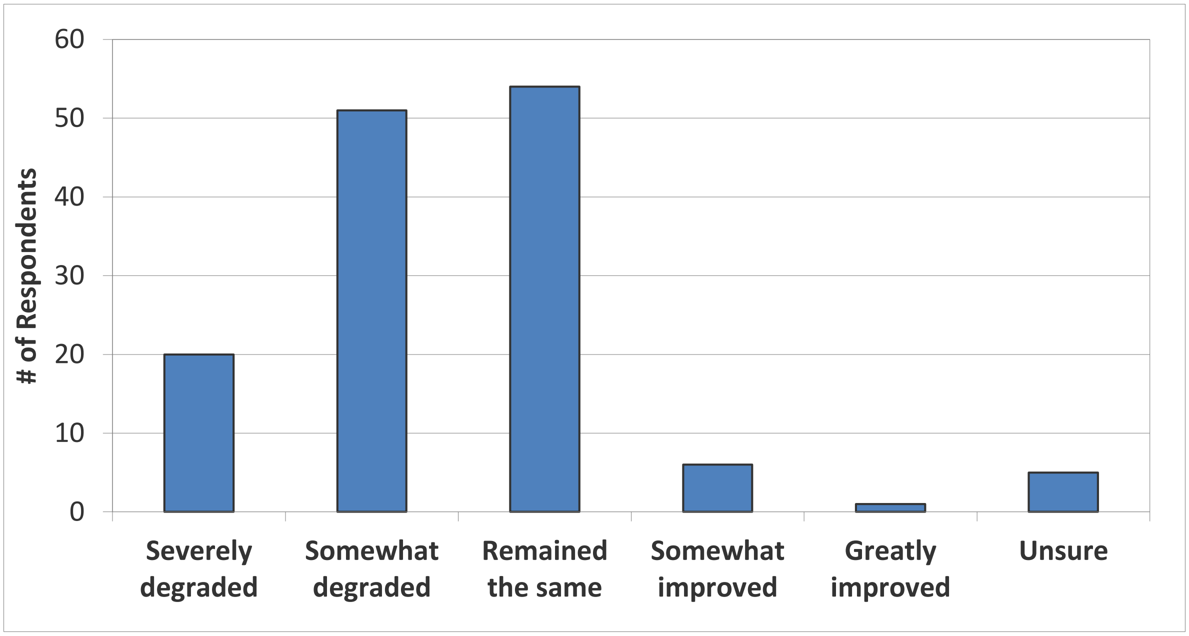


Figure 3.1-13. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Within the 2019 riparian stakeholder survey, respondents were asked what they perceive impacts water quality (Figure 3.1-14). *Aquatic plant growth* was chosen by respondents as the most important aspect that they felt contributed to their evaluation of water quality. Aquatic plant growth can affect and be affected by water quality, but is not a water quality metric. Water clarity and algae blooms were also factors that more than half of respondents indicated contributed to their assessment of water quality.

Question 21: Considering how you answered the questions above, what do you think of when describing water quality?

Answer Options	**Response Percent**	**Response Count**
Water clarity (clearness of water)	56.2%	77
Aquatic plant growth (not including algae blooms)	72.3%	99
Water color	32.9%	45
Algae blooms	51.1%	70
Smell	21.9%	30
Water level	25.6%	35
Fish kills	17.5%	24
Other (please specify)	5.1%	7
	answered question	**137**
	skipped question	**24**

Figure 3.1-14. Select survey responses from the Phillips Chain O' Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

Phillips Chain Watershed Assessment

The Phillips Chain has a concrete dam built in 1943 located on Long lake which creates the four impoundments of water known as the Phillips Chain.

The Upper and Lower Chippewa watersheds are approximately 6,441,016 acres (10,064 square miles) and includes portions of twenty-one counties. The Chippewa River originates by the merging of the West Fork Chippewa River and East Fork Chippewa River. Eventually the Chippewa River discharges into the Mississippi River. The Upper and Lower Chippewa watersheds are subdivided into forty-seven sub-watersheds, with the Phillips Chain and its direct watershed being located in the Elk River sub-watershed (Figure 3.2-1).

Figure 3.2-1. The Upper and Lower Chippewa watersheds and Phillips Chain location within them.

The Phillips Chain watershed encompasses approximately 127,288 acres (199 sq. mi.), extending across Price County (Figure 3.2-2 and Map 2). In this system, the natural flow of water begins with the Elk River, which flows south into Duroy Lake. From there, water flows into Elk Lake and then into Long Lake. Wilson Lake drains into Long Lake, and the water from these lakes exits the chain through the Jobes Dam, which is located in southwestern Long Lake (Figure 3.2-3, at location of red arrow). Because the Phillips Chain is an impoundment, water flows very quickly through the chain.

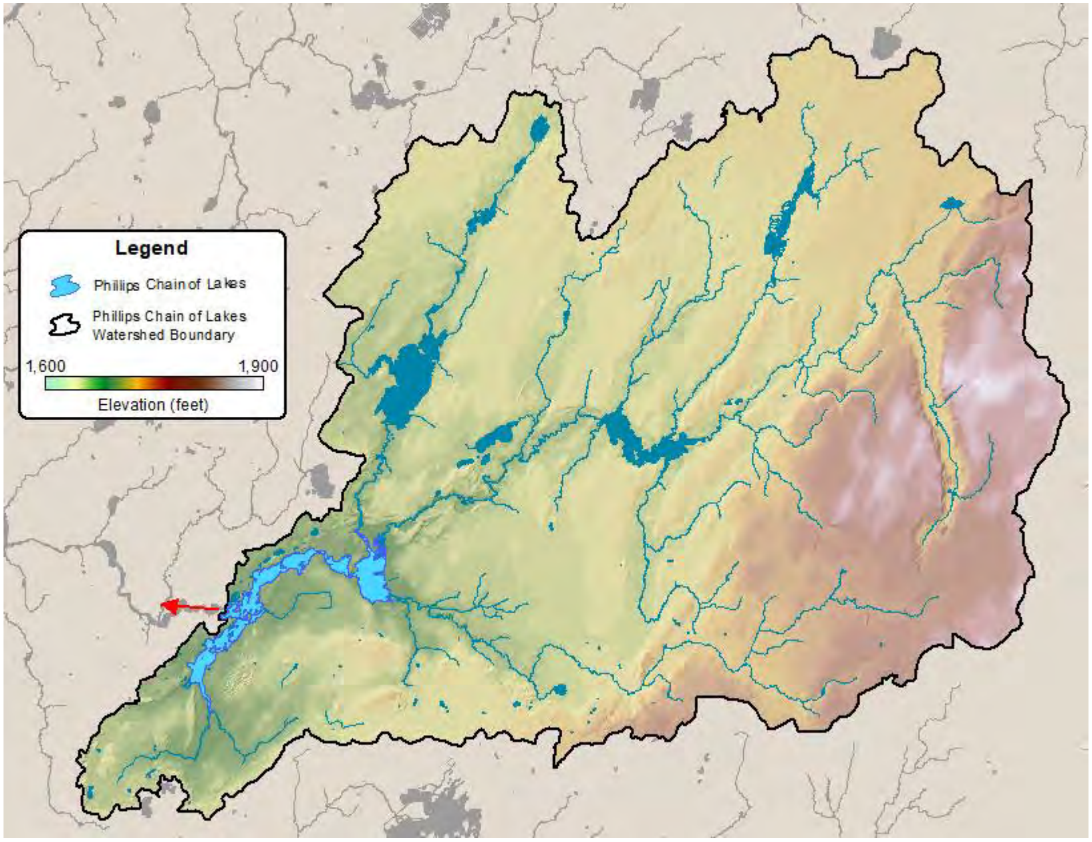


Figure 3.2-2. Phillips Chain watershed and land elevation.

WiLMS modeling was used to estimate that average water residence time for each of the lakes in the Phillips Chain. Water residence time, or the amount of time it takes the entire volume of water within the lake to be replaced, depends on primarily on the lake's volume and amount of water inflow. Since the Phillips Chain empties through Long Lake and exits the Jobes Dam, Long Lake serves as an accurate representation of water residence time within the Chain. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates Long Lake's residence time is approximately four days (Figure 3.2-4), or the water within the lake is completely replaced 107 times per year. The very short residence time in Long Lake is due to amount flow in the inflowing rivers and streams, especially the Elk River. Compared to a seepage or natural drainage lakes, a flowage benefits from this natural flushing by minimizing the rate at which nutrients will build up within the system's sediments, as well as mixing oxygen throughout at least a portion of the water column.

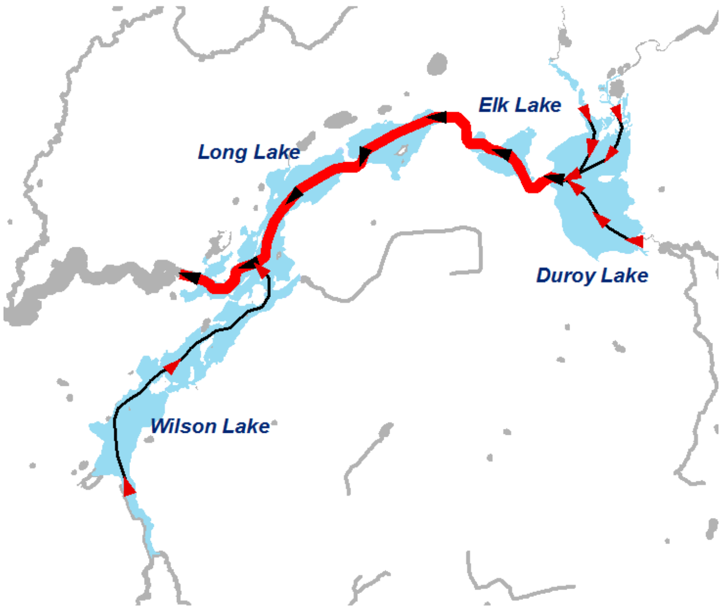


Figure 3.2-3. Phillips Chain water flow.

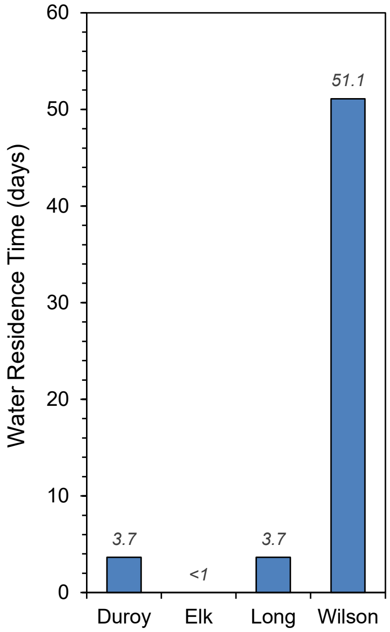


Figure 3.2-4. Phillip Chain of Lakes estimated water residence times. Estimated with WiLMS. Residence times under 14 days are considered *impounded flowing waters* and not true lakes.

Map 2 shows the landcover types present within the Phillips Chain watershed. Forest and wetlands combine to comprise approximately 88% of the watershed (Figure 3.2-5). These are the landcover types that deliver the least amount of phosphorus to a waterbody. Row crop agriculture and human development (e.g. rural residential, urban areas) export the highest amounts of phosphorus to waterbodies. Within the Phillips Chain's watershed, these landcover types comprise less than 3% of the overall landcover types.

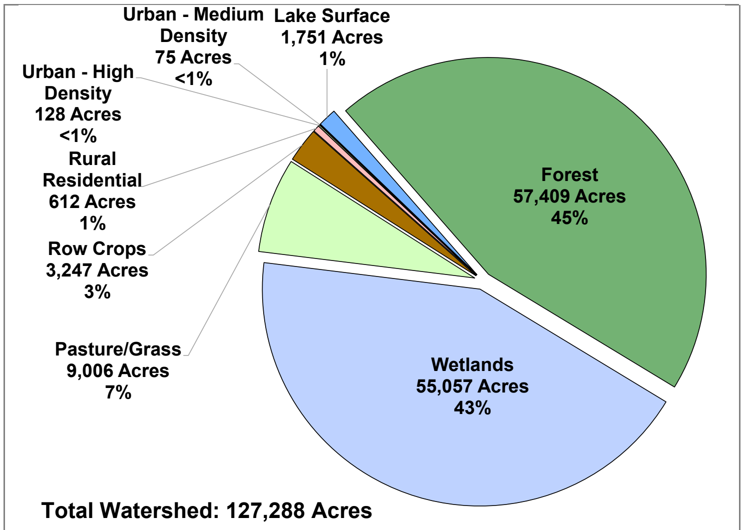


Figure 3.2-5. Landcover types within the Phillips Chain watershed.

As discussed earlier, the water quality of a system is largely a reflection of what is occurring on land within their watersheds. Using land cover data, the WiLMS model is able to estimate the annual potential phosphorus load that runs off of that watershed. The model is also able to estimate potential septic impacts from nearshore properties based upon data received from the stakeholder survey. When one lake feeds into another and phosphorus data are available from the upstream lake, the upstream lake can be modeled as a point source for the downstream lake. This strengthens the model, as upstream waterbodies act as a nutrient settling basin as some amount of nutrients are used before sending downstream. These lakes are modeled in series, with phosphorus outflow from the upstream lake estimated using total phosphorus concentrations and by estimating how much water is draining from the upstream lake to the downstream lake.

Figure 3.2-6 shows a flowchart of the modeling conducted for the Phillips Chain. When Duroy Lake was modeled, point-sources from the three upstream lakes with available water quality data were used as inputs, as well as the watershed that directly drains to Duroy Lake. When Elk Lake is modeled, Duroy Lake served as a point source and the available measured phosphorus data were used in combination with the watershed that directly drains to Elk Lake. Wilson Lake does not have any upstream waterbodies so the phosphorus load modeling was conducted solely based on the types of land covers within the Wilson Lake watershed. Long Lake used Elk Lake and Wilson Lake as a point-source in addition to its own direct watershed.

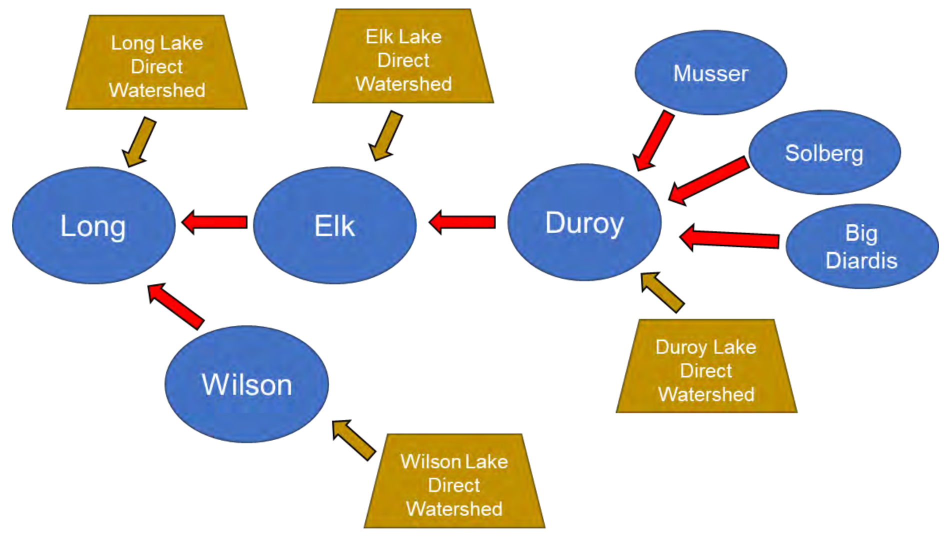


Figure 3.2-6. Phillips Chain watershed modeling flowchart.

Figure 3.2-6 shows the amount of annual phosphorus loading that the WiLMS model predicts occurs in each of the Phillips Chain of Lake waterbodies. The modeling of each individual waterbody will be discussed in additional detail within each lake-specific section. Because the Phillips Chain is a flowage and drains many acres of land, it will likely always be highly productive (eutrophic). In other words, the size of the watershed, no matter what land cover it supports, will keep the lakes productive. However, one area where improvements could be made upon is the immediate shoreline, which is discussed in the next section (3.3).

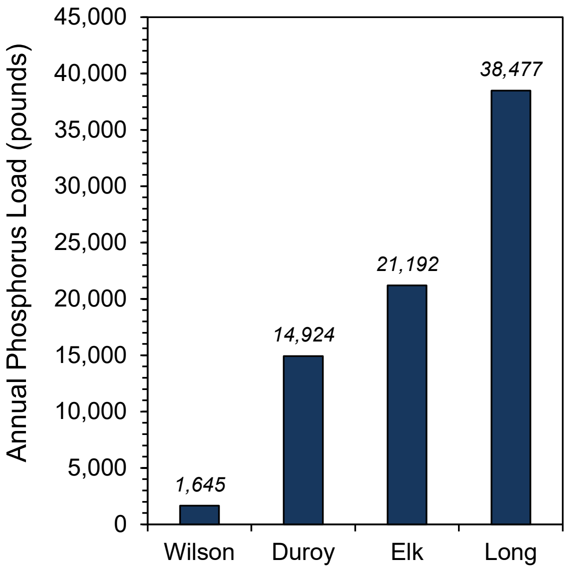


Figure 3.2-7. Phillip Chain of Lakes annual total phosphorus load (WiLMS).

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

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

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

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

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. 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, Willis and St. Stauver 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.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

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

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

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

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

Wisconsin's Healthy Lakes & Rivers Action Plan

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

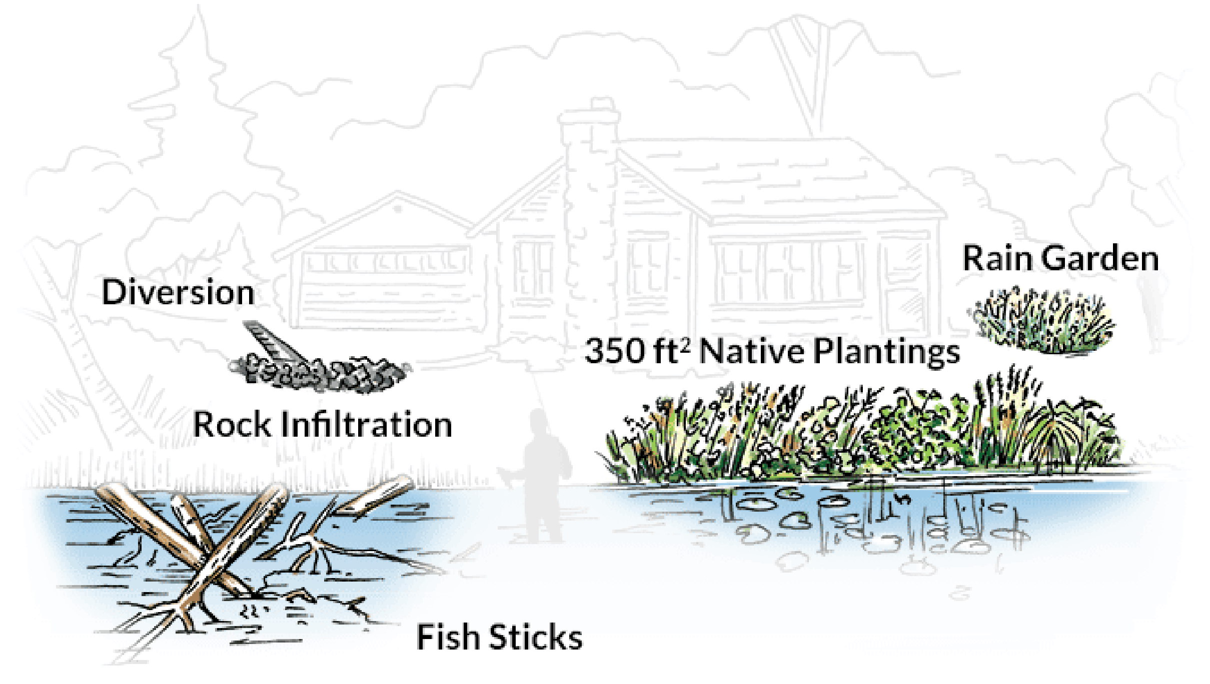


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

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

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

https://healthylakeswi.com/

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

Phillips Chain Shoreland Zone Condition

Shoreland Development

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

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

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

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

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

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

Figure 3.3-2. Shoreland assessment category descriptions.

On the Phillips Chain, the development stage of the entire shoreland was surveyed during fall of 2019, using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-2.

The Phillips Chain has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 22.0 miles of natural/undeveloped and developed-natural shoreland were observed during the survey (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 5.5 miles of urbanized and developed–unnatural shoreland were observed. If restoration of the Phillips Chain shoreland is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Map 3 displays the location of these shoreland lengths around the entire lake.

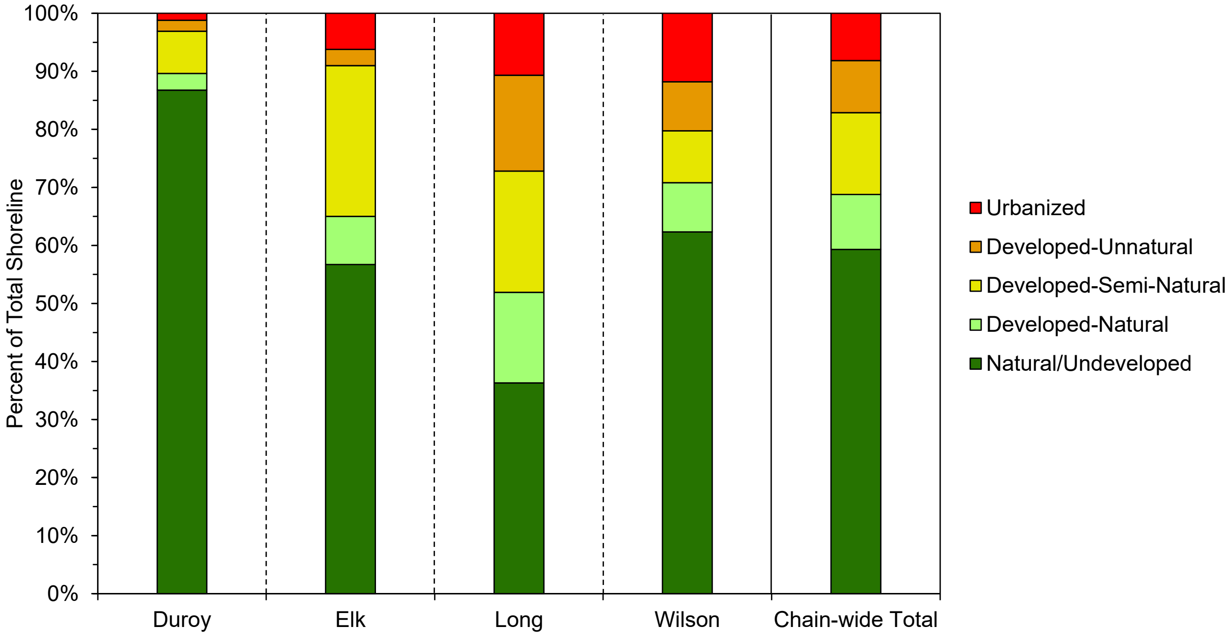


Figure 3.3-3. Phillips Chain shoreland categories and percent of total shoreline. Based upon fall 2019 surveys. Locations of these categorized shorelands can be found on Map 3.

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

Coarse Woody Habitat

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

During this survey, 788 total pieces of coarse woody habitat were observed along 32.0 miles of shoreline (Map 4), which gives the Phillips Chain a coarse woody habitat to shoreline mile ratio of 25:1 (Figure 3.3-3). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. 638 pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, 150 pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

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). Please note the methodologies between the surveys done on the Phillips Chain and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

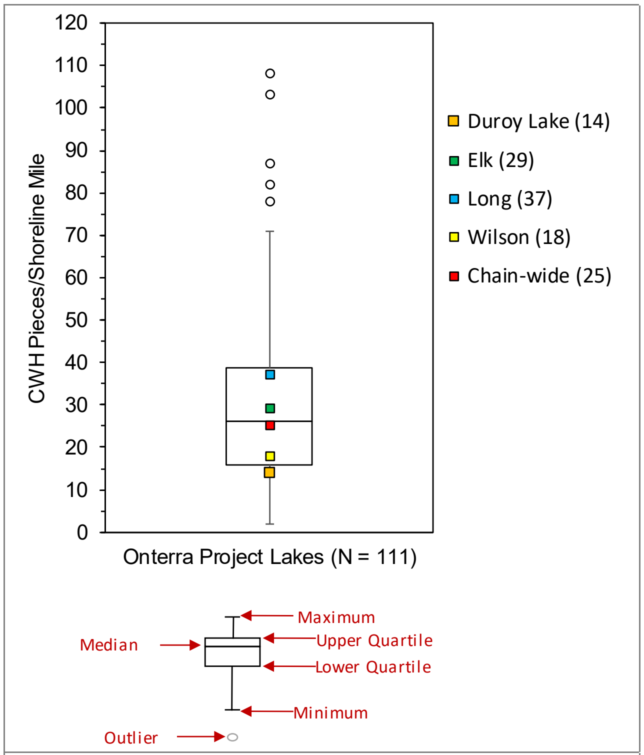


Figure 3.3-4. The Phillip Chain of Lakes coarse woody habitat survey results. Based upon a fall 2019 survey. Locations of the Phillips Chain coarse woody habitat can be found on Map 4.

Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in the Phillip Chain of Lakes falls between the 18th and 70th percentile of these 111 lakes (Figure 3.3-3).

A volunteer from the PCOLA (Bill Ruff) has led an initiative to increase the coarse woody habitat in the Phillips Chain by adding and anchoring tree drops since 2015. At of the time of this writing in spring 20201, the volunteer team has paced 69 structures across 20 sperate properties.

3.4 Aquatic Plants

Introduction

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

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

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

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

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

Aquatic Plant Management and Protection

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 Phillips Chain, 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 Phillips Chain 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 (Hand-Harvesting & DASH)

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

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

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

Cost
Contracting aquatic invasive species removal by third-party firm can cost approximately $1,000 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,000 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

Advantages	***Disadvantages***

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

Mechanical Harvesting

Photograph 3.4-3. Mechanical harvester.

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

Cost

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $100,000 and $200,000. Larger harvesters or stainless-steel models range between $200,000 and $300,000. Shore conveyors cost approximately $30,000 and trailers range from $15,000 to $40,000. Smaller harvesters have recently been more common and range between $75,000 and $125,000, depending on features and materials. Used equipment may be available at lower costs, but increased maintenance would be associated. Storage, maintenance, insurance, and operator salaries vary greatly.

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

Herbicide Treatment


Photograph 3.4-4. Liquid herbicide application.

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent. Resource managers employ strategic management techniques towards aquatic invasive species, with the objective of reducing the target plant's population over time; and an overarching goal of attaining long-term ecological restoration. For submergent vegetation, this largely consists of implementing control strategies early in the growing season; either as spatially-targeted, small-scale spot treatments or low-dose, large-scale (whole lake) treatments. Treatments occurring roughly each year before June 1 and/or when water temperatures are below 65°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, Haller and (eds) 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. Table 3.5-1 provides a general list of commonly used aquatic herbicides in Wisconsin and is synthesized from (Netherland 2009).

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

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

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.

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 watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• 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. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

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

Cost

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods 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.

Four aquatic plant surveys were completed by Onterra on each of the Phillips Chain lakes during this project. The first, the Early-Season Aquatic Invasive Species (ESAIS) Survey, is a meander-based survey completed in June. The primary goal of this survey is to detect potential occurrences of non-native plants, primarily curly-leaf pondweed and pale-yellow iris. Curly-leaf pondweed typically reaches its peak growth in June before naturally dying back by July, while pale-yellow iris reaches peak bloom in June making it easier to locate. The second survey completed was the whole-lake point-intercept (PI) survey, a quantitative survey designed to determine the frequency of occurrence of each plant species, both native and non-native, within the lake. An Emergent and Floating-leaf Aquatic Plant Mapping Survey was also completed focused upon mapping areas of emergent and floating-leaf aquatic plants in each lake. During these surveys, each plant species not previously located in each lake was collected, pressed, and sent to the University of Wisconsin-Stevens Point Herbarium. The correct identification of these plants was confirmed by Dr. Robert Freckmann. The final survey included a Late-Season Aquatic Invasive Species (LSAIS) Survey, aimed at locating Eurasian watermilfoil which is typically at peak growth late in the summer.

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

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

Floristic Quality Assessment

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

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

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

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from each lake is compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

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

Exotic Plants

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

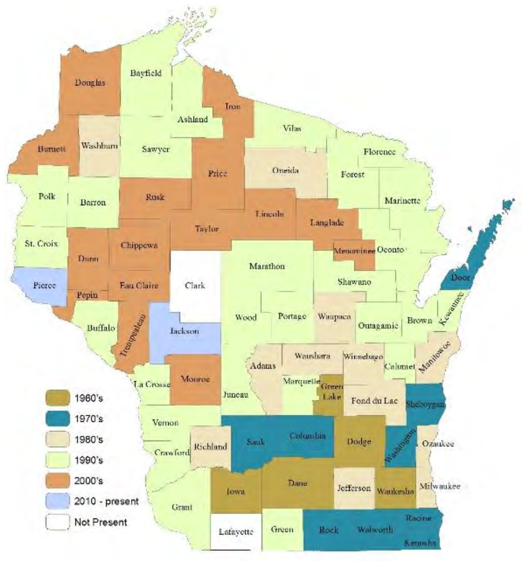


Figure 3.4-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

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

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

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrences within the lake. Although Eurasian watermilfoil starts to grow earlier than native plants, it is typically at peak biomass during most of the summer, so it is often inventoried during the comprehensive aquatic plant survey completed in mid to late summer. Since curly-leaf pondweed has only been found in Duroy Lake, it will be discussed in the lake-specific section for Duroy. Eurasian watermilfoil will be discussed in further detail at the end of the Aquatic Plants section.

Phillips Chain Aquatic Plant Survey Results

As part of the previous management planning project completed in 2011, Onterra completed point-intercept surveys on Duroy, Elk, and Long lakes in 2009. The WDNR had completed a point-intercept survey on Wilson Lake in 2007, so these results were used to compare to the other lakes within the chain. Wilson Lake had additional point-intercept surveys in 2011, 2012, and 2014 completed by Onterra, and in 2015 by the WDNR. The results from these surveys are included in the analysis. The point-intercept survey method as described by the Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on the Phillips Chain. The sampling location spacing (resolution) and resulting total number of locations varied by lake and were created based upon guidance from the WDNR (Table 3.4-2). The 2019 point-intercept (PI) survey was conducted on the Phillips Chain on July 23-24 by Onterra. A matrix of all point-intercept summary results is included as Appendix D.

Table 3.4-2. Phillips Chain point-intercept resolutions.

Lake	Distance Between Sampling Points (meters)	Number of Sampling Locations
Duroy	78	231
Elk	32	343
Long	52	630
Wilson	78	225

During the 2019 point-intercept surveys on the Phillips Chain, aquatic plants were found growing out to a maximum depth of 7 feet in Long Lake (Figure 3.4-2). The maximum depth of plants in 6 feet in Wilson, 5 feet in Duroy, and 4 feet in Elk. Surveys conducted in 2007 (Wilson) and 2009 (Duroy, Elk, Long) indicated plants growing to slightly deeper depths.

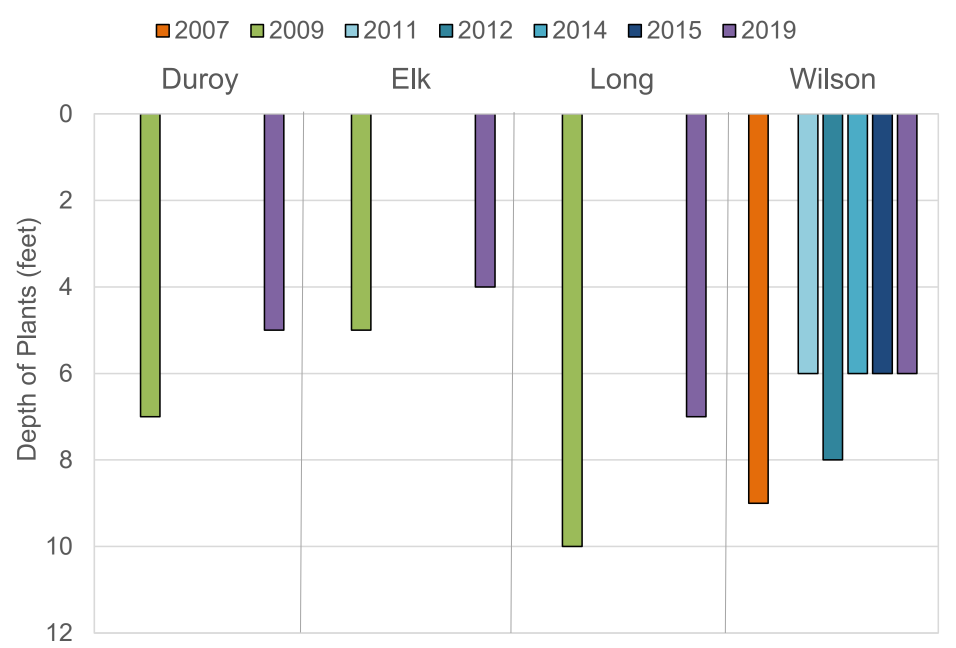


Figure 3.4-2. Maximum depth at which aquatic plants were found growing in the Philips Chain of Lakes. Created using data from the aquatic plant point-intercept surveys.

A total of 53 aquatic plant species were located within or along the margins of Phillips Chain (Table 3.4-3), five of which are considered non-native species. More information about these invasive species can be found in Section 3.5, and Eurasian watermilfoil and curly-leaf pondweed will be discussed in depth in a subsection following the point-intercept analysis results. Species lists for each lake including all years of available data can be found within each lake-specific report section.

Table 3.4-3. Aquatic plant species located on Phillips Chain during surveys.

Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	Growth Form	Duroy 2019	Elk 2019	Long 2019	Wilson 2019
Bidens beckii	Water marigold	Native	8	S	X		X	
Brasenia schreberi	Watershield	Native	7	FL	I		I	X
Calla palustris	Water arum	Native	9	E	X			I
Callitriche hermaphroditica	Atumnal water starwort	Native - Special Concern	9	S	X			
Callitriche palustris	Common water starwort	Native	8	S	I			
Carex utriculata	Common yellow lake sedge	Native	7	E	I			I
Ceratophyllum demersum	Coontail	Native	3	S	X	X	X	X
Ceratophyllum echinatum	Spiny hornwort	Native	10	S	X			X
Chara spp.	Muskgrasses	Native	7	S	X			X
Eleocharis palustris	Creeping spikerush	Native	6	E	X			I
Elodea canadensis	Common waterweed	Native	3	S	X	X	X	X
Elodea nuttallii	Slender waterweed	Native	7	S	X			X
Glyceria canadensis	Rattlesnake grass	Native	7	E				I
Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A	E			I - P	
Iris versicolor	Northern blue flag	Native	5	E			I - P	
Lemna turionifera	Turion duckweed	Native	2	FF		I		I
Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	E	I			I
Myriophyllum heterophyllum	Various-leaved watermilfoil	Native	7	S	X	X		X
Myriophyllum sibiricum	Northern watermilfoil	Native	7	S		X		
Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	S	X	I		X
Myriophyllum verticillatum	Whorled watermilfoil	Native	8	S			X	
Najas flexilis	Slender naiad	Native	6	S	X		X	X
Nitella spp.	Stoneworts	Native	7	S	X	X	X	X
Nuphar variegata	Spatterdock	Native	6	FL	X		X	X
Nymphaea odorata	White water lily	Native	6	FL	X	X	X	X
Phalaris arundinacea	Reed canary grass	Non-Native - Invasive	N/A	E				I
Pontederia cordata	Pickerelweed	Native	9	E	X	I	I	
Potamogeton amplifolius	Large-leaf pondweed	Native	7	S	X			X
Potamogeton berchtoldii	Slender pondweed	Native	7	S	X		X	X
Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	S	X			
Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	S	X	X	X	X
Potamogeton foliosus	Leafy pondweed	Native	6	S				X
Potamogeton natans	Floating-leaf pondweed	Native	5	S	X			X
Potamogeton obtusifolius	Blunt-leaved pondweed	Native	9	S	X			X
Potamogeton pusillus	Small pondweed	Native	7	S	X			X
Potamogeton robbinsii	Fern-leaf pondweed	Native	8	S	X	X	X	X
Potamogeton spirillus	Spiral-fruited pondweed	Native	8	S	X	X	X	
Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	S	I			X
Potamogeton zosteriformis	Flat-stem pondweed	Native	6	S	X			X
Riccia fluitans	Slender riccia	Native	7	FF				X
Sagittaria latifolia	Common arrowhead	Native	3	E	I			I
Sagittaria rigida	Stiff arrowhead	Native	8	E				I
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	S				X
Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	E	I		I	X
Scirpus cyperinus	Wool grass	Native	4	E			I	I
Sparganium emersum var. acaule	Short-stemmed bur-reed	Native	8	FL/E	X			
Sparganium eurycarpum	Common bur-reed	Native	5	E	X			I
Sparganium fluctuans	Floating-leaf bur-reed	Native	10	FL	X		I	I
Sparganium sp.	Bur-reed sp.	Native	N/A	FL/E		I	I	I
Spirodela polyrhiza	Greater duckweed	Native	5	FF	I			X
Stuckenia pectinata	Sago pondweed	Native	3	S				X
Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A	E				I
Typha spp.	Cattail spp.	N/A	N/A	E		I	I	I
Utricularia vulgaris	Common bladderwort	Native	7	S	X			X
Vallisneria americana	Wild celery	Native	6	S				X
Zizania palustris	Northern wild rice	Native	8	E	X			I

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; FF = Free Floating; S= Submergent; E = Emergent
X = Located on rake during point-intercept survey; I = Incidental Species, P = Probable but ID not confirmed

Photograph 3.4-5. Vasey's pondweed (left) and autumnal starwort (right).

There were also two species found which are listed as special concern species in Wisconsin, indicating that there is a low abundance of the species within the state and attention should be focused to help prevent it from becoming threatened or endangered. Vasey's pondweed (*Potamogeton vaseyi;* Photograph 3.4-5a) was found in Wilson and Duroy lakes (as well as Long Lake in 2009), and autumnal starwort (*Callitriche hermaphroditica*; Photograph 3.4-5b) was found in Duroy Lake. Both of these plants require high-quality conditions to survive, and their presence in these lakes is indicative of environments with minimal disturbance.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, and management, all of which influence aquatic plant community composition. Like terrestrial plants, aquatic plants vary in their preference for a particular substrate type; some species are usually only found growing in soft sediments, others only course substrates like sand, while some are more generalists and can be found growing in either. Lakes with varying types of substrates generally support a higher number of aquatic plant species because of the different habitat types that are available.

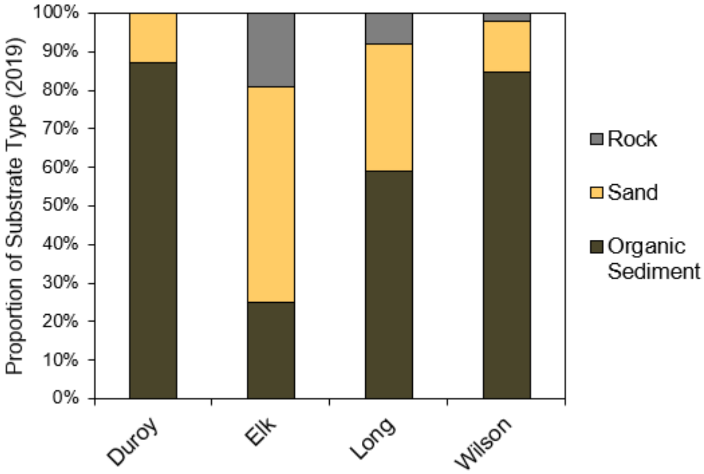


Figure 3.4-3. Phillips Chain proportion of substrate types within littoral areas. Created using data from July 2019 aquatic plant point-intercept surveys.

The sediment within most of the littoral areas of the Phillips Chain is conducive for supporting lush aquatic plant growth. The proportion of substrate types varied among the four lakes, with Elk Lake having a higher proportion of sandy and rocky substrates than the others (Figure 3.4-3). This could be a contributing factor to Elk Lake's very low frequency of aquatic plants which is discussed further in the lake-specific section (8.2.1).

The littoral frequency of occurrence of aquatic vegetation in 2019 ranged from 9% in Long Lake to 71% in Wilson Lake (Figure 3.4-4). Figure 3.4-4 also shows a semi-quantitative analysis of the abundance of aquatic plants through looking at total rake fullness ratings (i.e. how full of plants is the sampling rake at each location). Long and Elk lakes show much lower plant biomass compared to Duroy and Wilson lakes. Map 5 shows the 2019 vegetated locations and their rake fullness ratings. More detailed information about aquatic plant biomass and changes over time can be found in each respective lake-specific section and maps.

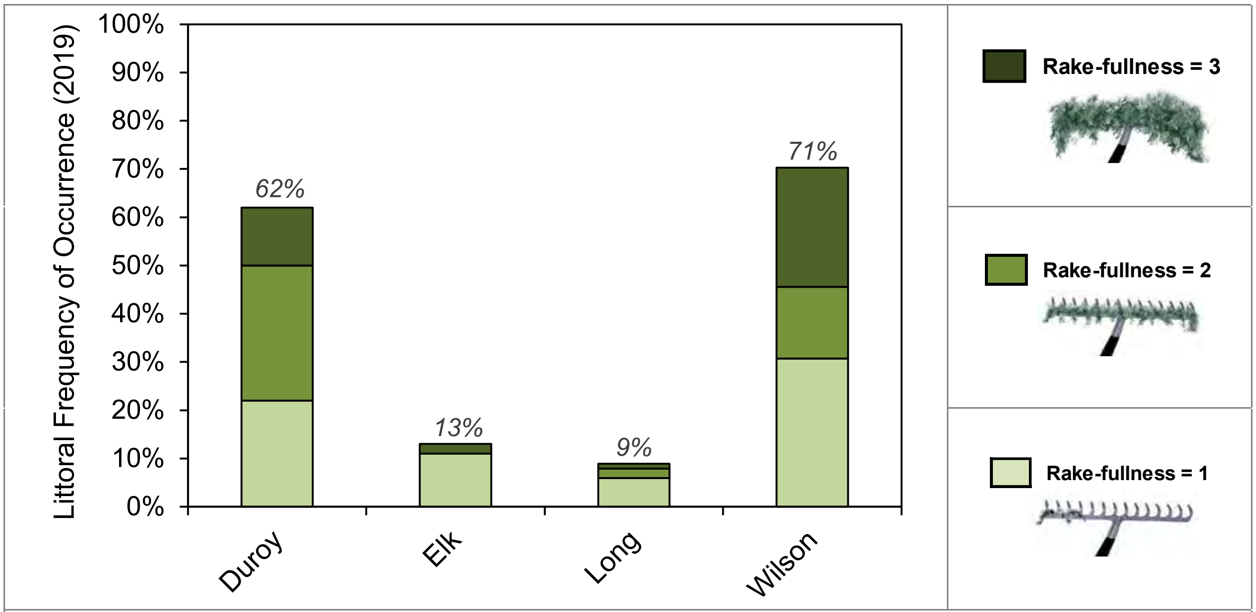


Figure 3.4-4. Phillips Chain 2019 littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF).

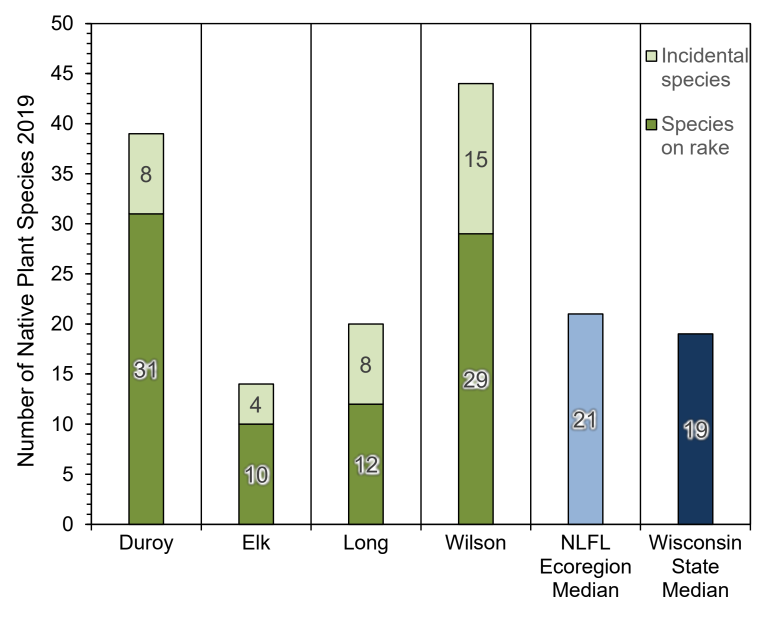


Figure 3.4-5. Species richness in the Phillips Chain. Created using data from July 2019 point-intercept surveys.

Wilson Lake contained the highest number of native aquatic plants within the chain with 29 species being located on the rake, and an additional 15 species being located *incidentally*. An incidentally-located species means the plant was not directly sampled on the rake during the point-intercept survey at any of the sampling locations but it was observed in the lake by Onterra ecologists and was also recorded and collected. The majority of incidentally-located plants typically include emergent species growing along the lake's margins and submersed species that are relatively rare within the lake's plant community. Wilson and Duroy Lakes each contained a higher number of native plant species than both the ecoregion (21) and state (19) medians, while Elk and Long fell slightly below the median values (Figure 3.4-5).

The most frequently encountered species with the chain in 2019 are listed below (Figure 3.4-6). Some species were combined for the analysis due to their similar morphological characteristics which makes it difficult to differentiate them in the field.

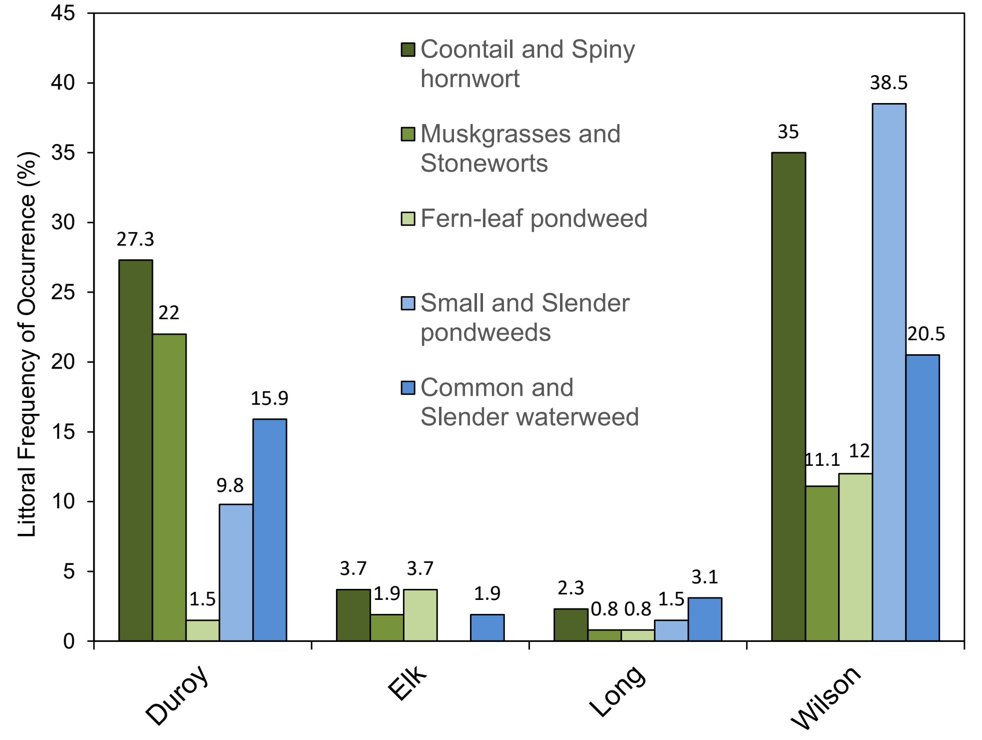


Figure 3.4-6. Frequency of occurrence at littoral depths for several Phillips Chain plant species. Created using data from July 2019 aquatic plant point-intercept survey.

Photograph 3.4-6. Coontail and spiny hornwort.

Coontail is one of the most common aquatic plants in Wisconsin, is also one of the most common plants in the Phillips Chain. Unlike most of the submersed plants found in Wisconsin, coontail does not produce true roots and is often found growing entangled amongst other aquatic plants or matted at the surface. Because it lacks true roots, coontail derives all of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with lower water clarity. Coontail has the capacity to form dense beds that mat on the water surface. Coontail also provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and therefore helps to improve water clarity.

Coontail (*Ceratophyllum demersum*) and spiny hornwort (*Ceratophyllum echinatum*) look very similar (Photograph 3.4-6) and function similarly in the aquatic ecosystem. Spiny hornwort is much more rare and often difficult to distinguish from the more-common coontail. Within this analysis, their occurrences were combined together.

Like coontail, common waterweed can be found in waterbodies across Wisconsin, is tolerant of high-nutrient, low-light conditions, and can grow to nuisance levels under ideal conditions. Common waterweed has blade-like leaves in whorls of three produced on long, slender stems. Like other submersed aquatic plants, common waterweed helps to stabilize bottom sediments and provides structural habitat and food for wildlife. Surveys also identified the more-rare slender naiad from the Phillips Chain. These two species are shown in Photograph 3.4-7 and lumped together in the analysis of this report.

Photograph 3.4-7. Common (*Elodea canadensis*) and slender waterweeds (*E. nuttallii*).

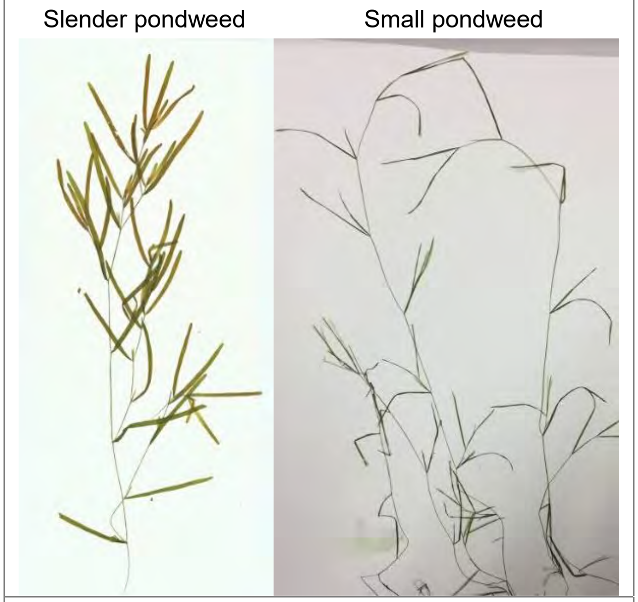
Muskgrasses, or species of the genus chara, are actually a form of macro-algae, not an actual aquatic macrophyte. They are grey to green colored and grow in large clumps in shallow to deep water. When growing in hard, mineral rich water, muskgrasses sometimes become coated with lime, giving them a rough, "gritty" feel. They are easily identified by their strong skunk-like odor. Stoneworts, or species of nitella, are also a form of macro-algae and can look very similar to muskgrasses (Photograph 3.4-8). Therefore, these two species are usually combined during analysis. Dense beds of these charophytes provide excellent habitat for small fish and other aquatic organisms.

Photograph 3.4-8. Muskgrasses (left) and stoneworts (right).

Small pondweed (*Potamogeton pusillus*) and slender pondweed (*Potamogeton berchtoldii*) were the most frequently encountered grouping of species (Photograph 3.4-9) located in Wilson Lake with a littoral frequency of occurrence of 38.5%. There is not a consensus amongst taxonomist of whether these two species are in fact different, or just variations (i.e. strains) of the same species.

As the name implies, these plants are small in stature, but can often produce very long stems and form dense colonies which can provide structural habitat and aid in the reduction of sediment resuspension.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For example, while Northern wild rice was found at just under 29% of the littoral sampling locations in Duroy Lake, its relative frequency of occurrence is 13%. Explained another way, if 100 plants were randomly sampled from Duroy Lake, 13 of them would be Northern wild rice. More detailed information about the relative frequency of aquatic plant species can be found within each lake-specific section.



Photograph 3.4-9. Slender (*Potamogeton berchtoldii*) and small pondweed (*P. pusillus*).

Figure 3.4-7 shows the number of native plant species found per sampling site during each of the surveys on the Phillips Chain. Since there have been more point-intercept surveys completed on Wilson Lake than the other three lakes, the line connecting the data points may appear as if the number of species within the lake are having large annual fluctuations; however, when comparing the first and last survey years' values (1.24 and 1.72, respectively), this component has actually remained relatively stable over time. The data line for Duroy Lake may appear as if the number of species per site is increasing; however, having only two years of data is not sufficient to make this determination – future surveys would be needed. This figure also provides another visual for how few aquatic plants grow in Elk and Long lakes.

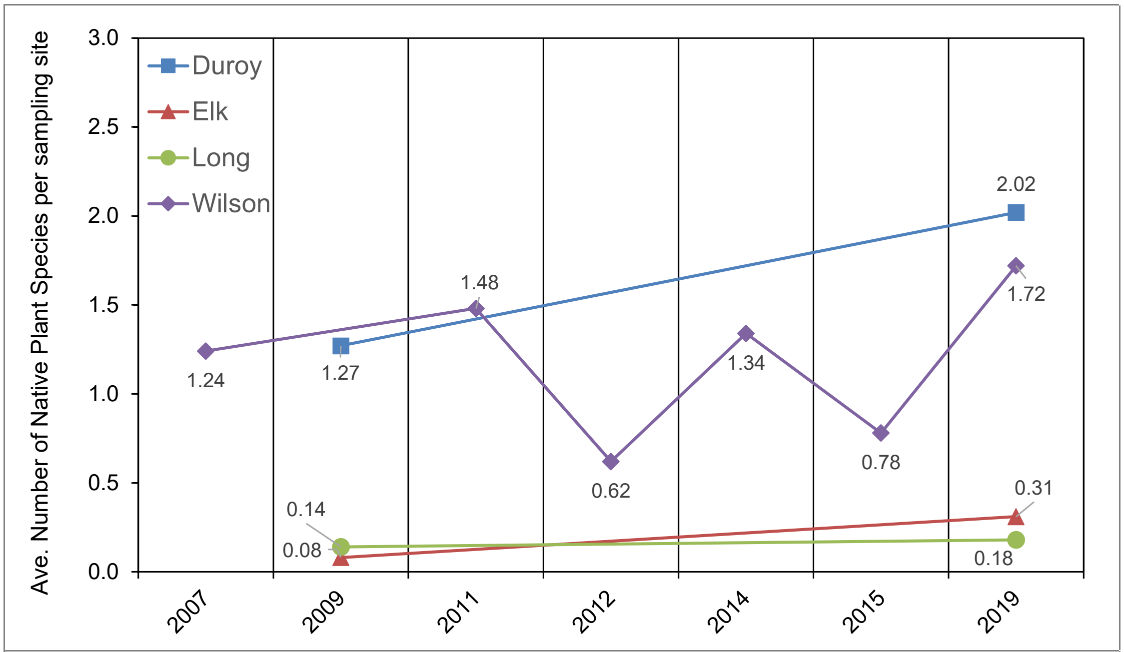


Figure 3.4-7. Average number of native species per sampling site for the Phillips Chain. Created using data from point-intercept surveys.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations can be driven by a combination of natural factors including variations in temperature, ice and snow cover (winter light availability), nutrient availability, water levels and flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition (Asplund and Cook 1997) (Lacoul and Freedman 2006).

Some of the species present within the chain are indicative of high-quality conditions. Data collected from the aquatic plant surveys show that the average conservatism value for each of the lakes across all years falls below the Northern Lakes and Forest Lakes Ecoregion median (6.7), aside from the 2019 value for Duroy Lake which was slightly above (7.0) the median. Most of the average conservatism values for the lakes in the Phillips Chain also either matched or fell below the state median (Figure 3.4-8), indicating that the majority of the plant species found in the chain are not considered sensitive to environmental disturbance and their presence signifies near average environmental conditions. Elk Lake is an exception, falling below the rest.

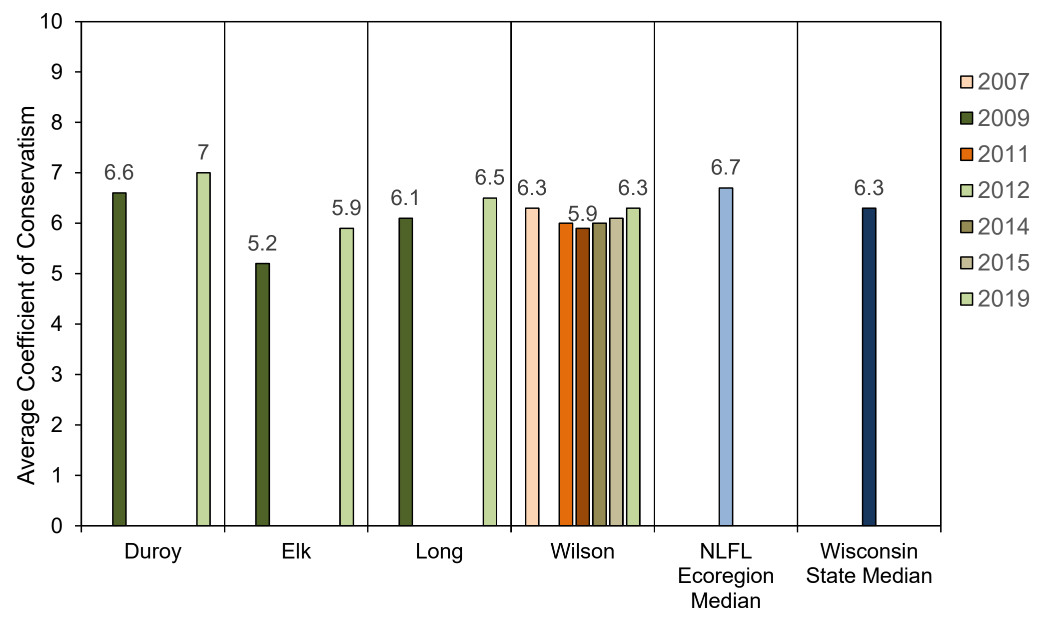


Figure 3.4-8. Average coefficient of conservatism values. NLFL = Northern Lakes and Forest Lakes Ecoregion.

Combining aquatic plant species richness and average conservatism values produces the Floristic Quality Index (FQI). As discussed previously, the calculations used for the FQI are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. Speaking specifically in regards to the 2019 surveys, this results in values which put Duroy and Wilson lakes well above the median values for the ecoregion and state, with Long and Elk lakes falling below both medians (Figure 3.4-9).

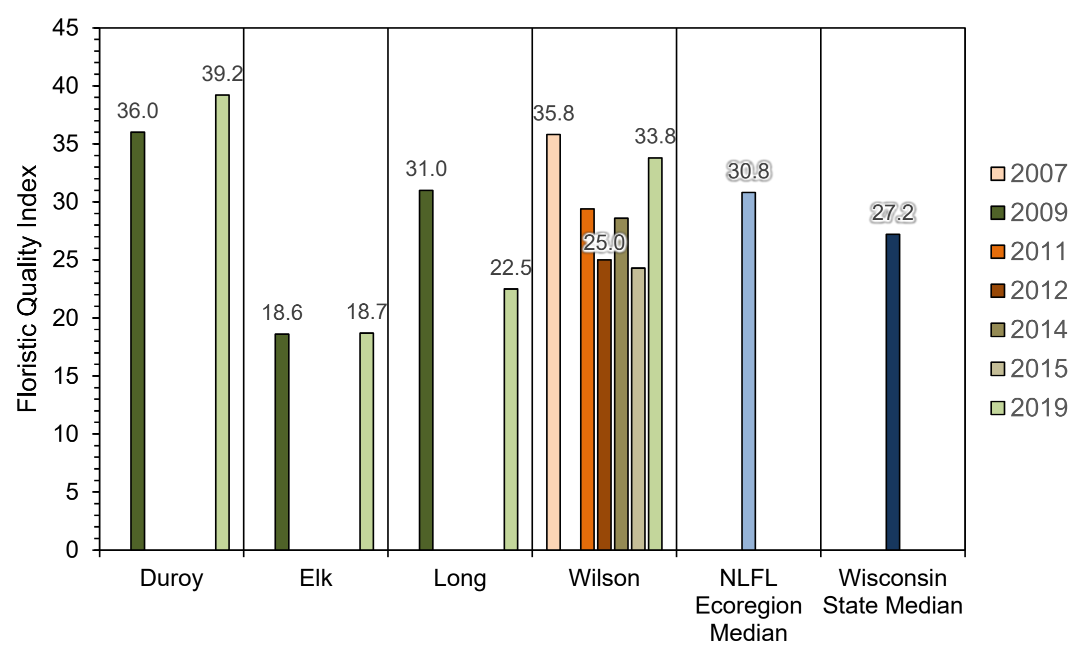


Figure 3.4-9. Phillips Chain Floristic Quality Assessment. Analysis following Nichols (1999) where NLFL = Northern Lakes and Forest Lakes Ecoregion.

Because Duroy and Wilson lakes contain a high number of native aquatic plant species, one may assume their aquatic plant communities have high species diversity. However, as discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community.

Aside from the 2009 survey on Elk Lake, the diversity of the aquatic plant community in each of the Phillips Chain lakes was found to be near or above average. With the NLFL ecoregion median being 0.88 and the state median at 0.86, the 2019 surveys (data labels shown in Figure 3.4-10) showed the diversity to be just above this with the exception of Elk Lake which was above the state median but below the ecoregion median. Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. A plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish and other wildlife with diverse structural habitat and various sources of food.

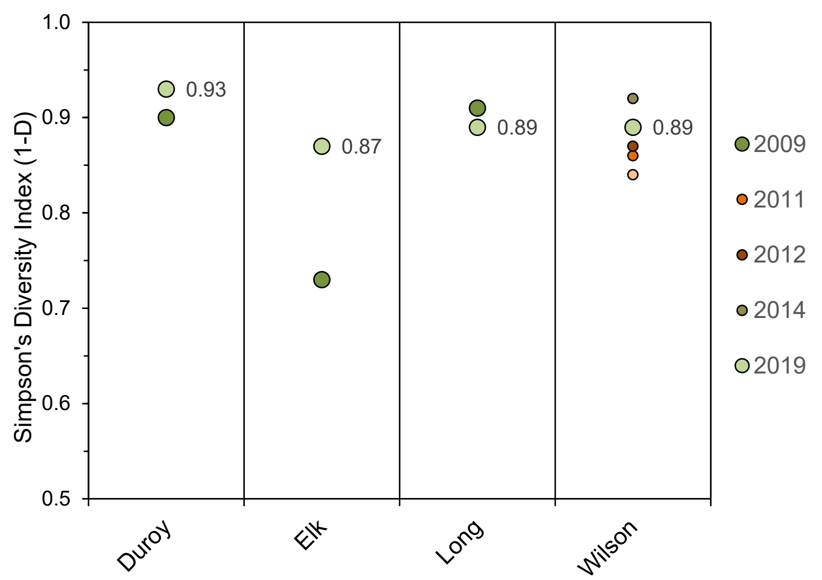


Figure 3.4-10. Phillips Chain species diversity index. Created using data from aquatic plant surveys.

The quality of the Phillips Chain plant community is also indicated by the incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lakes. The 2019 community map indicates that Duroy and Wilson lakes have an abundance of these types of plant communities (Figure 3.4-11 and lake-specific maps). Duroy Lake is 375 acres in size, and a total of 129.3 acres of combined floating-leaf and emergent aquatic plants were mapped in the lake in 2019. This equals just over 1/3 of the lake being covered by these communities, which is a high proportion in relation to other lakes, especially being one that is used for recreational opportunities. These floating-leaf and emergent species provide valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft. Despite these benefits, the overabundance of aquatic vegetation in some areas was one of the common concerns listed in the stakeholder survey, as they can cause navigability issues for boaters as well as appear aesthetically unpleasant to lake users.

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

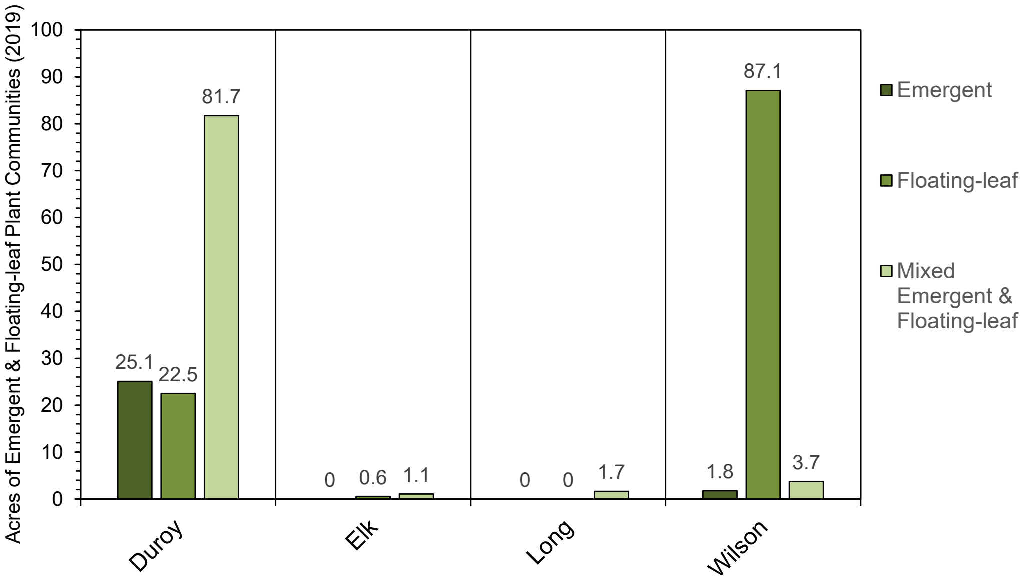


Figure 3.4-11. Phillips Chain acreage of plant community types. Created from 2019 community mapping survey data.

During the 2019 point-intercept survey on Wilson Lake, Onterra crews observed an algal bloom and what appeared to be surface-matted *Cladophora* spp. (Photograph 3.4-10), a type of filamentous algae. High nutrient conditions in a lake can result in extensive growth of *Cladophora* spp. which can grow in dense communities among vegetation in shallow water and can break off and form floating mats, causing further navigability and aesthetic issues.

Photograph 3.4-10. *Cladophora* spp. among submergent and floating-leaf vegetation.

Eurasian watermilfoil

Eurasian watermilfoil (EWM) was first located in Duroy Lake in 2000, and by 2002, was located in Elk, Long, and Wilson Lakes as well. PCOLA has sponsored a number of AIS control projects aimed at managing the EWM population on the Phillips Chain, starting in 2011. Some of the results of these earlier surveys will be integrated and displayed in the lake-specific sections of this report.

On August 27-28, 2019, the Late-Season AIS survey was completed, targeting occurrences of EWM within the Phillips Chain. During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques are applied to AIS locations considered to be *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*.

A total of 101.6 acres of EWM was mapped during the 2019 Late-Season AIS survey on the Phillips Chain (Figure 3.4-12). Note that the acreage values only reflect contiguous colonies of EWM mapped using polygons and does not include point-based occurrences. The last Late-Season AIS survey completed on the chain was in 2016. When comparing the acreage mapped between the 2016 and 2019 surveys, the 2019 survey showed a decrease of EWM in Duroy and Long Lakes, but a large increase in Wilson Lake (2016: 14.8 acres). No contiguous colonies of EWM have been mapped in Elk Lake to date. More specific details showing all available years of EWM acreage as well as maps showing EWM locations is referenced in each lake-specific section.

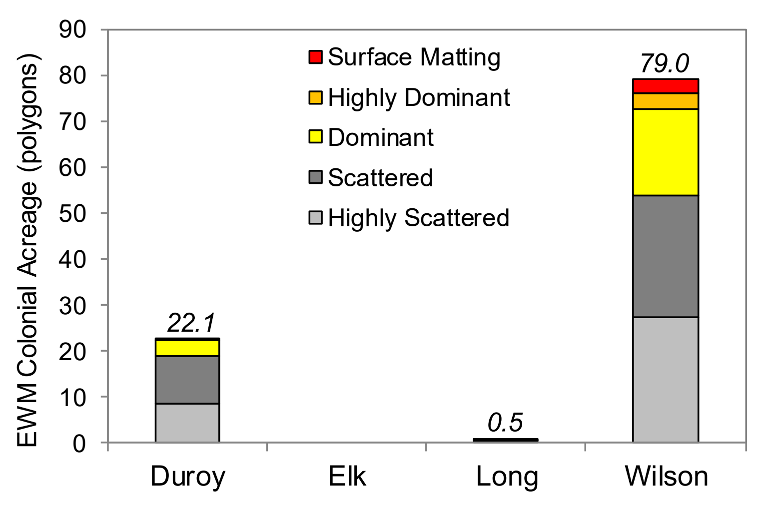


Figure 3.4-12. EWM acreage mapped in the Phillips Chain during 2019.

Using data from the point-intercept surveys that have been completed over the years, the littoral frequency of occurrence of EWM can be compared for each of the lakes (Figure 3.4-13). The pink shading in Figure 3.4-13 indicates the year of the whole-lake herbicide treatment that occurred on Wilson Lake in 2012. During this year, smaller scale spot-treatments also took place on Long and Duroy lakes. More in-depth information regarding the herbicide treatments that have taken place on each lake can be found in their respective lake-specific sections. Figure 3.4-14 appears to indicate that the EWM in Wilson Lake is rebounding to near-pre-treatment levels.

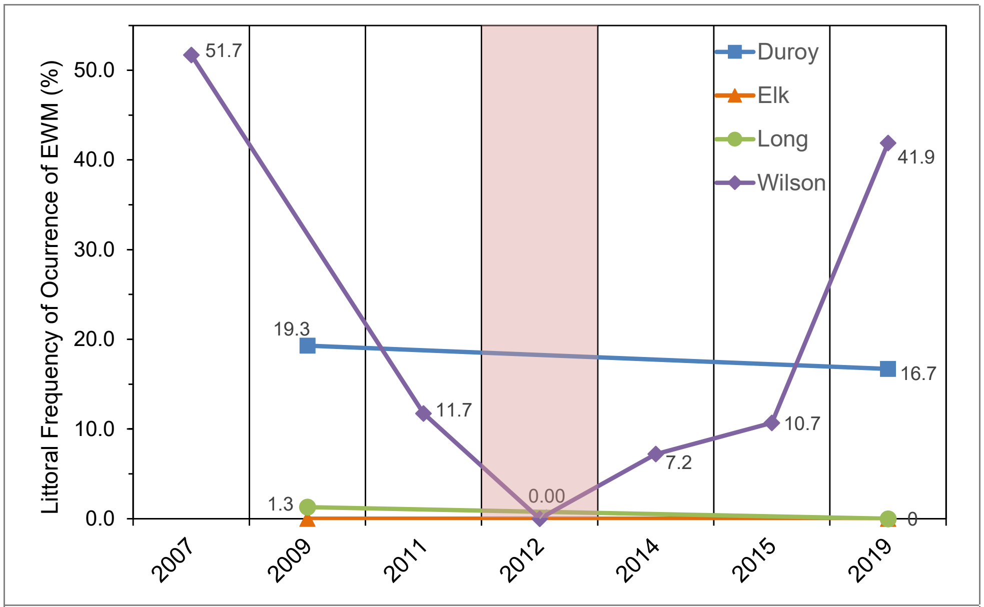


Figure 3.4-13. EWM littoral frequency of occurrence. Pink shading is year of Wilson Lake whole-lake 2,4-D treatment.

WDNR Long-Term EWM Trends Monitoring Research Project

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

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). The point-intercept data are most clear for unmanaged lakes in the Northern Lakes and Forests Ecoregion (Figure 3.4-14). The upper frame of Figure 3.4-14 shows the EWM littoral frequency of occurrence for these unmanaged systems by year, and the lower frame shows the same data based on the number years the survey was conducted following the year of initial detection of EWM listed on the WDNR website. During this study, six of the originally selected “unmanaged lakes” were moved into the “managed” category as the EWM populations were targeted for control by the local lake organization as populations increased.

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

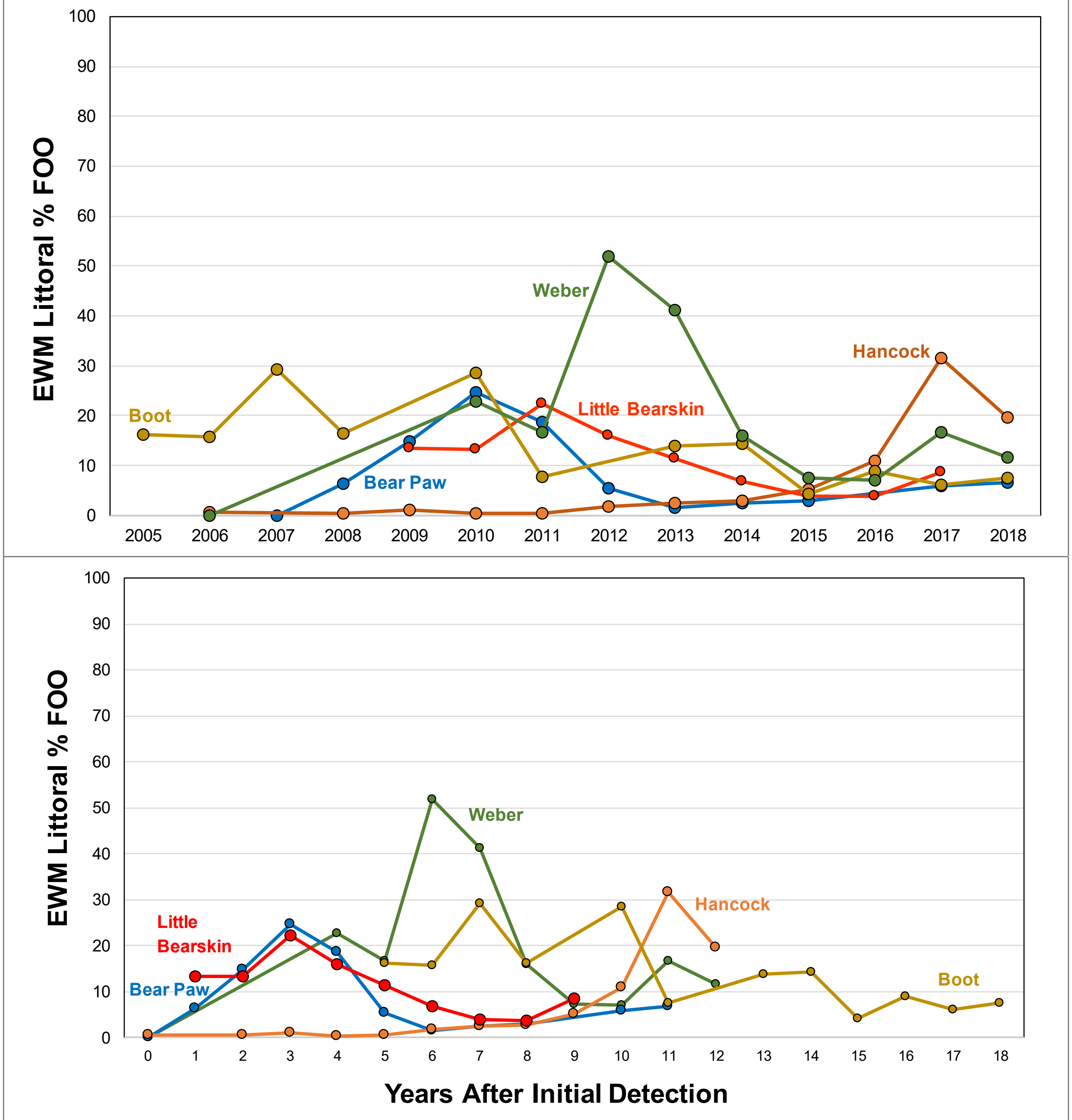


Figure 3.4-14. Littoral frequency of occurrence of EWM in the Northern Lakes and Forests Ecoregion without management. Data provided by and used with permission from WDNR.

The Science Behind the "So-Called" Super Weed (Nault 2016)

In 2015, the WDNR investigated the most recent point-intercept data from almost 400 Wisconsin Lakes that had confirmed EWM populations. These data show that approximately 65% of these lakes had EWM populations of 10% or less (Figure 3.4-15). At these low population levels, there is not likely to be impacts to recreation and navigation, nor changes in ecological function. At the time of this writing, Wilson Lake's most recent point-intercept survey (2019) yielded EWM at just under 42% of the littoral sampling locations. Within this dataset, 94.7% of lakes contained EWM populations less than 50%. This indicates that Wilson Lake's 2019 EWM population is roughly within the top 5% of Wisconsin lakes that have EWM populations. This may be due to the fact that the EWM population on some lakes may never reach that level or that management activities may have been enacted to suppress the EWM population to lower levels.

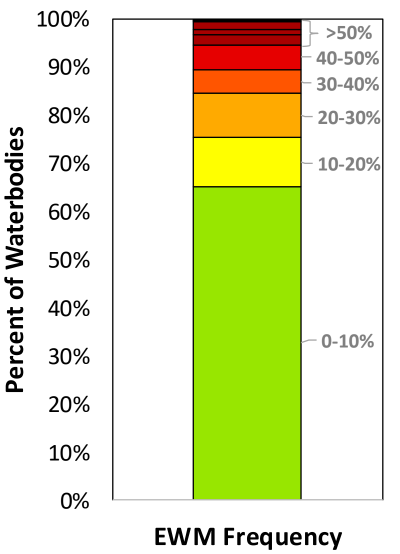


Figure 3.4-15. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

Large-Scale Aquatic Plant Management on the Phillips Chain

EWM has been shown to be impacted greatly by winter drawdowns when the system can be dewatered to a sufficient depth to desiccate (i.e. dry out) and freeze the EWM's root crown. In order to achieve sediment desiccation and freezing, the drawdown must be implemented during a cold and dry winter. If the exposed sediment is kept hydrated by deep snow, winter rains, or hydrologic springs; the impacts to EWM will likely not meet expectations. In fact, an incomplete or poor winter drawdown has been shown to exasperate the EWM problem in some cases.

Drawdowns are typically started after Labor Day to limit the effects on seasonal tourism. Drawing a system down slowly at a rate of 6 inches per day or less allows the lake's amphibians and reptiles to migrate with the receding water level and have time to burrow into the lake sediments and hibernate (Personal Comm. Scott Provost, WDNR). Once the drawdown is complete, further altering the water level either up or down at that time of year would be detrimental to these organisms and is one of the reasons why the lake is not brought back up until April of the following year. If the system is brought to full pool before the middle of May, the effects on fish spawning is greatly reduced.

Concerned over the increase in native plants in the chain, a 4-foot drawdown was planned in 1996. The 1996 drawdown began on September 23 and by October 23, the lake was down 48 inches. Numerous complaints were raised by riparians that noticed problems with their private wells. The flowage creates a mounding of the water table, artificially elevating the height of the water table above what it would be if the dam was removed and the system was returned to its original state as a flowing river. With the flowage being partially de-watered during the drawdown, the water table was also lowered and shallow wells (i.e. non-conforming sand point wells) were inadvertently dewatered as well.

The City of Phillips water supply is fed by three high-capacity wells. During the 1996 drawdown, these wells began to cavitate (draw air) when dewatered 36 inches. Under these conditions, the wells cannot operate at their normal capacity. Terry Stroba, former Director of Public Works for Phillips, indicated that while it was likely that the wells could probably meet the needs of the community's water supply under the reduced operation, the city would be vulnerable during an extreme demand situation like a major fire. Bill Dobbins, WDNR Regional Drinking Water Engineer, also investigated this issue and came to a similar conclusion.

On October 31, 1996, efforts to refill the system began and were brought back to winter operating level (8 inches lower than summer level) by November 8, 1996. Many people expressed concerns about the reliance of a municipal water source on a dam owned and operated by a separate unit of government (Price County). It also became apparent that if the Jobes Dam was to fail; the water supply for the City of Phillips would be greatly affected. Due to this fact, the City of Phillips may want to evaluate their water supplies.

Concerned over the amount of Eurasian water milfoil in the chain, the PCOLA began planning a 2-foot drawdown during the winter of 2005-2006. At this level, many of the issues that halted the 1996 drawdown would not develop. In preparation for this management action, Craig Roesler, WDNR biologist, and PCOLA volunteers assessed the system. The assessment seemed to indicate that EWM populations had declined since the 2002 survey and a drawdown was not warranted.

Mr. Roesler visited the system again in 2007 and performed a point-intercept survey on Wilson Lake. The results of the 2007 point-intercept survey indicate that EWM exists in approximately 52% of the littoral zone (area of the lake where plants grow). A WDNR Aquatic Invasive Species Education, Prevention and Planning Grant was successfully applied for during February 2008 with the intentions of monitoring a winter 2008-2009 drawdown. After the funds were secured, a public information meeting was held on April 9, 2008 to discuss the control project with the general public. Planners of the drawdown were optimistic that the past issues involving the private and municipal wells could be resolved. New issues were also brought forth including the fact that the outfall pipe for the wastewater treatment plant that empties into Elk Lake would no longer be submersed during a 5-foot drawdown. This pipe needs to remain submerged to properly allow mixing. However, Lonn Franson, City of Phillips Wastewater Engineer, indicated that the outfall pipe could be extended.

As with most drawdowns, fisheries impacts were also of concern to riparians. Two aeration systems were proposed to be implemented during the drawdown to aid in oxygenating the water. Many also felt that special fisheries regulations would need to be implemented in order to protect the concentrated fish that may be overexploited by anglers. The WDNR would implement emergency regulations if an emergency condition became apparent, but thought that having the association promote voluntary compliance with reduced bag limits during the drawdown would be the best first step.

During the winter of 2008-2009, it became apparent that a drawdown was not in the near future and the PCOLA was encouraged by the WDNR to undergo a management planning project in which baseline studies and specific management goals and associated actions would be constructed to help protect and enhance the Phillips Chain. The PCOLA hired Onterra and amended their existing WDNR grant to reallocate finances for the planning process.

A water level drawdown was seriously considered as a management tool because it is likely the best way to control a significant EWM population on a system the size of the Phillips Chain. Serious and productive discussions were held with various members of the City of Phillips, Price County, and the WDNR, but the same roadblocks that were encountered in 1996 made this alternative infeasible.

In 2011, the PCOLA began planning a whole-lake 2,4-D treatment of Wilson Lake. 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 (of the lake or a lake basin); it is at a concentration that is sufficient to cause mortality to the target plant within that entire lake or basin. Although the herbicide is applied over the areas containing the densest levels of the target species, the application rate is dictated by the entire volume of water in which the herbicide is theorized to reach equilibrium. The target herbicide concentration is typically between 0.225 and 0.350 ppm acid equivalent (ae) when exposed to the target plants for 14-35 or more days. However, these same concentration and exposure times have been shown to impact some native plant species, particularly dicot species, some thin-leaved pondweeds, and naiad species.

Significant concerns exist about the likelihood of success from an herbicide control program on Wilson Lake because the flow of water through the lake may be too high to achieve the necessary herbicide concentrations and exposure times required. Based upon modeling conducted during the 2011 management planning project, Wilson Lake has an average residence time of approximately 78 days, but likely shorter during the spring when runoff events are greater. An updated modeling exercise as part of this process indicated the residence time is closer to 51 days. The uncertainty of being able to maintain sufficient herbicide exposure times resulted in concerns about the efficacy and longevity of a whole-lake 2,4-D treatment of Wilson Lake.

In spring of 212, Wilson Lake was targeted with a whole-lake 2,4-D treatment to achieve an approximate 0.325 ppm ae lake-wide concentration. Volunteer-based water testing indicated that the mean concentration of the lake was only slightly below target (0.315 ppm ae), with concentrations exceeding targets in the southern half of Wilson Lake, and being lower than targets in the northern half. Herbicide concentrations were below detection by 28 days after treatment. While no EWM was recorded during 2012 on the point-intercept survey, remnant populations were identified in the northern half of the lake where concentrations were lower. As discussed above, EWM populations were reduced for approximately three years following this management action.

Four native aquatic plant species saw a statistically valid decrease in LFOO from 2011-2012 following the herbicide treatment; coontail, fern pondweed, flat-stem pondweed, and small pondweed. Some population rebound of these species occurred soon after treatment, whereas others were slower to recover.

Future EWM Management Discussions

During the upcoming Planning Committee meetings, Onterra will outline three broad EWM population management perspectives for consideration, including a generic potential action plan for each (Figure 3.4-16). Onterra has extracted relevant chapters from the WDNR's *APM Strategic Analysis Document* to serve as an objective baseline for PCOLA to weigh the benefits of the management strategy with the collateral impacts each management action may have on the Phillips Chain ecosystem. These chapters are included as Appendix E. The PCOLA Planning Committee will also review these management perspectives in the context of perceived riparian stakeholder support, which is discussed in the subsequent sub-section.

1. **No Coordinated Active Management**
   (Let Nature Take its Course)
   - Focus on education of manual removal methods for property owners
2. **Reduce EWM Population on a lake-wide level**
   (Lake-Wide Population Management)
   - Would likely rely on herbicide treatment and/or winter drawdown (risk assessment)
   - Will not "eradicate" EWM
   - Set triggers (thresholds) of implementation and tolerance
3. **Minimize navigation and recreation impediment**
   (Nuisance Control)
   - May be accomplished through mechanical harvesting of areas or lanes

Figure 3.4-16. Potential EWM Management Perspectives.

Let Nature Take its Course: In some instances, the EWM population of a lake may plateau or reduce without conducting active management, as shown in the WDNR Long-Term EWM Trends Monitoring Research Project on Figure 3.5-19. Some lake groups decide to periodically monitor the EWM population, typically through a semi-annual point-intercept survey, but do not coordinate active management (e.g. hand-harvesting or herbicide treatments). This requires that the riparians tolerate the conditions caused by the EWM, acknowledging that some years may be problematic to recreation, navigation, and aesthetics. Individual riparians may choose to hand-remove the EWM within their recreational footprint, but most often the lake group chooses not to assist financially or with securing permits (only necessary if Diver Assisted Suction Harvest [DASH] is used). In some instances, the lake group may select this management goal, but also set an EWM population threshold or "trigger" where they would revisit their management strategy if the population reached that level. Said another way, the lake group would let nature take its course up until populations reached a certain level. At that time, the lake group would investigate whether active management measures may be justified.

Lake-Wide Population Management: Some believe that there is an intrinsic responsibility to correct for changes in the environment that are caused by humans. For lakes with EWM populations, that may be to manage the EWM population at a reduced level with the perceived goal to allow the lake to function as it had prior to EWM establishment. It must also be acknowledged that some lake managers and natural resource regulators question whether that is an achievable goal,

In early EWM populations, the entire population may be targeted through hand-harvesting or spot treatments. On more advanced or established populations, this may be accomplished through large-scale control efforts such as water-level drawdowns or whole-lake herbicide treatment strategies. If conducted properly, large-scale management can reduce EWM populations for several years, but will not eradicate it from the lake. Subsequent smaller scale management (e.g. hand-harvesting or spot treatments) is typically employed to slow the rebound of the population until another large-scale effort is likely required again. Typically, complete rebound of an EWM population following a large-scale control action is 4-6 years, with quicker rebound on some lakes and longer control observed on others. Wilson Lake received approximately 3 years of reduced EWM from the 2012 whole-lake 2,4-D treatment. Downstream Lac Sault Dore (Soo) Lake conducted a winter drawdown in winter of 2010-2011 with lowered EWM populations for nine years and counting. Large-scale control efforts, especially using herbicide treatments, can have adverse effects on some native plant species as well as carry a risk of environmental toxicity. Some argue that the impacts of large-scale control actions may have greater negative impacts to the ecology of the system than if the EWM population was not managed.

Nuisance Control: The concept of ecosystem services is that the natural world provides a multitude of services to humans, such as the production of food and water (provisioning), control of climate and disease (regulating), nutrient cycles and pollination (supporting), and spiritual and recreational benefits (cultural). Some lake groups acknowledge that the most pressing issues with the EWM population on their lake is the reduced recreation, navigation, and aesthetics compared to before EWM became established in their lake. Particularly on lakes with large EWM populations that may be impractical or unpopular to target on a lake-wide basis, the lake group would coordinate (secure permits and financially support the effort) a strategy to improve these cultural ecosystem services.

A nuisance control strategy typically involves creating a strategic network of common use lanes and riparian spokes through EWM colonies, maintained by mechanical harvesting (i.e. weed cutting machine). As a part of the *Phillips Chain Comprehensive Management Plan* (June 2011), the PCOLA considered mechanical harvesting and developed a skeletal plan that was not implemented.

The PCOLOA believes the current EWM population in the Phillips Chain, particularly in Wilson Lake warrants consideration for another large-scale management action. Explored below are a future winter-drawdown of the chain and whole-lake herbicide treatment of Wilson Lake.

Using the 2019 point-intercept survey results, it was concluded that EWM was not found growing any deeper than six feet within the Phillips Chain. Therefore, a potential future six-foot water level drawdown would be sufficient to have impacts on all of the EWM within the system. Figure 3.4-17 shows the number of point-intercept locations which contained EWM, along with their respective depths. Based upon prior road blocks to implementing a 6-foot winter drawdown, it is unclear if that is a realistic management action moving forward.

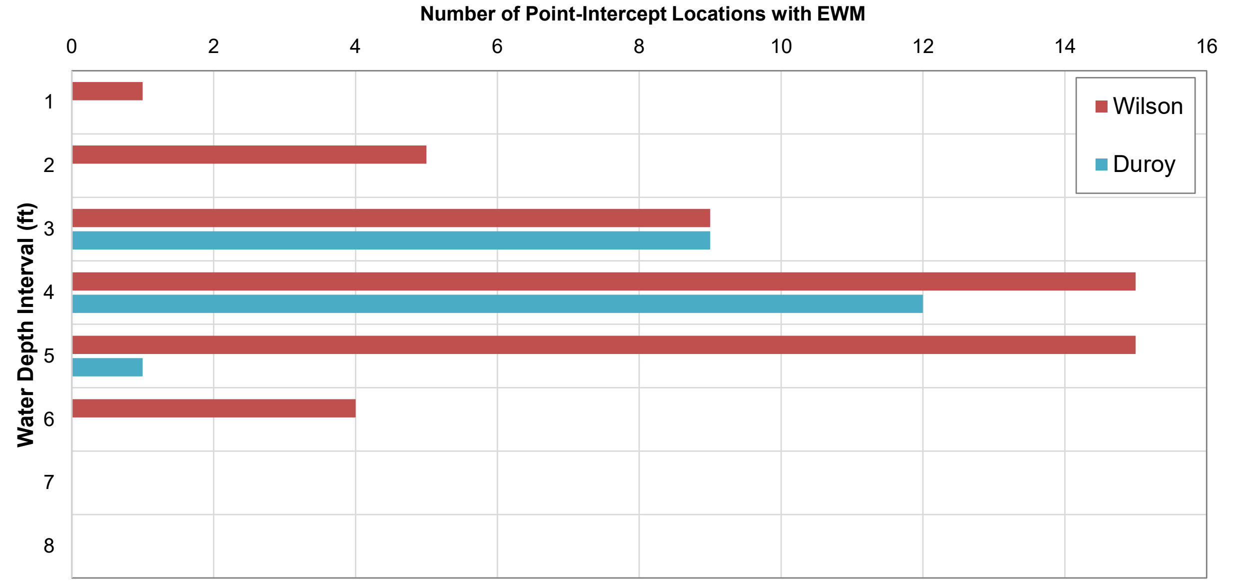


Figure 3.4-17. EWM depths chart from 2019 point-intercept surveys.

In 2014, a couple of samples of EWM were sent to Annis Water Resource Institute for DNA analysis to determine whether the EWM in Wilson Lake was of a hybrid variety (a cross between EWM and native northern watermilfoil, *M. spicatum* x *sibiricum*). Both samples came back as pure-strain EWM. It is recommended that this hybridity testing be repeated in the future, as pure-strain EWM and hybrid watermilfoil (HWM) have been shown to respond differently to management actions. Some strains of HWM have proven to be more robust and less susceptible to certain herbicide control strategies (including 2,4-D). Knowing which type is being dealt with will increase the likelihood of successful EWM management.

While understood in terrestrial herbicide applications for years, tolerance evolution is an emerging topic amongst aquatic herbicide applicators, lake management planners, and researchers. Herbicide tolerance is when a population of a given species develops reduced susceptibility to an herbicide over time. This occurs in a population when some of the targeted plants have an innate tolerance to the herbicide and some do not. Following an herbicide treatment, the more tolerant strains will rebound whereas the more sensitive strains will be controlled. Thus, the plants that re-populate the lake will be those that are more tolerant to that herbicide resulting in a more tolerant population. If genetic variation in the target population exists, particularly the presence of hybrid watermilfoils, repetitive treatments with the same herbicide may cause a shift towards increased herbicide tolerance in the population. Rotating herbicide use-patterns can help avoid population-level herbicide tolerance evolution from occurring. Concern exists that the past use-history of 2,4-D on Wilson Lake may have resulted in a population of more-tolerant invasive watermilfoils to auxin hormone mimic herbicides, which also includes triclopyr.

To gain multi-year EWM suppression, future spot herbicide treatments would likely need to consider herbicides (diquat, florpyrauxifen-benzyl, etc.) or herbicide combinations (2,4-D/endothall, diquat/endothall, etc.) thought to be more effective under short exposure situations than with traditional weak-acid auxin herbicides (e.g., 2,4-D, triclopyr). At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike ™) are examples of herbicides with reported short exposure time requirements.

ProcellaCOR™ is currently the region's most popular spot-treatment strategy. Onterra's experience monitoring approximately a few dozen ProcellaCOR™ treatments within the state during 2019-2021, EWM control has been high with almost no EWM being located during the summer post treatment. Within these treatments, native plant impacts have been minimal outside of some sensitive dicot species. Specific to Wilson Lake, non-target impacts are likely to be limited to coontail. Northern watermilfoil was found during a historic point-intercept survey, however not located since 2014. This species has been found to be extremely sensitive to this chemistry. ProcellaCOR™ has a high sediment/organic binding affinity (Koc) and relatively short persistence (half-life of > 6 days), so it is thought to stay where applied better than other chemistries. In many of the treatment Onterra has monitored, EWM impacts have been observed extending outside of the application area, as this chemical has shown activity at even low concentrations and exposure times as it dissipates.

Stakeholder Survey Responses to EWM Management within the Phillips Chain

As discussed in Section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. The return rate of the 2020 survey was 35% and a 2010 survey was 55%. In instances where stakeholder survey response rates are 60% or above, the results can generally be interpreted as being a statistical representation of the population. While the survey response rate of both these surveys may not be sufficient to be a statistical representation of the Phillip Chain property owners, the PCOLA believe the sentiments of the respondents is sufficient to provide a loose indication of riparian preferences and concerns. Said another way, these are the best quantitative data the PCOLA has to help understand stakeholder's opinions and will couple the results with other communications to determine which management actions to pursue moving forward.

In 2019, riparian stakeholders were asked whether EWM populations have decreased their recreation time on the lake, with approximately 60% of respondents indicating "yes" (Appendix B, Question 31), with reduced time on Wilson Lake being an overwhelming response (Appendix B, Question 32).

Question 34. How do you feel about the past use of herbicides to treat EWM in previous years?

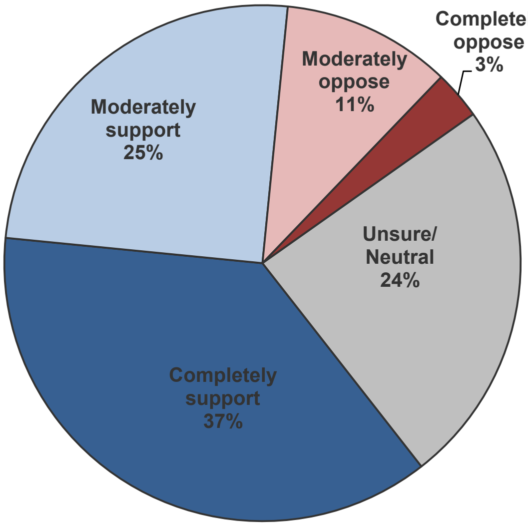


Figure 3.4-18. Select survey responses from the Phillips Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 35. What concerns, if any, do you have for the future use of the following techniques to target EWM in the Phillips Chain

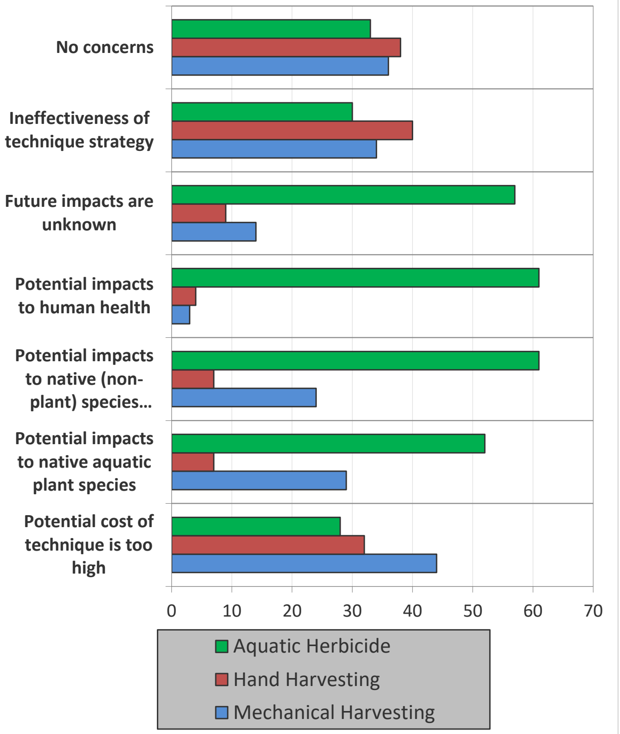
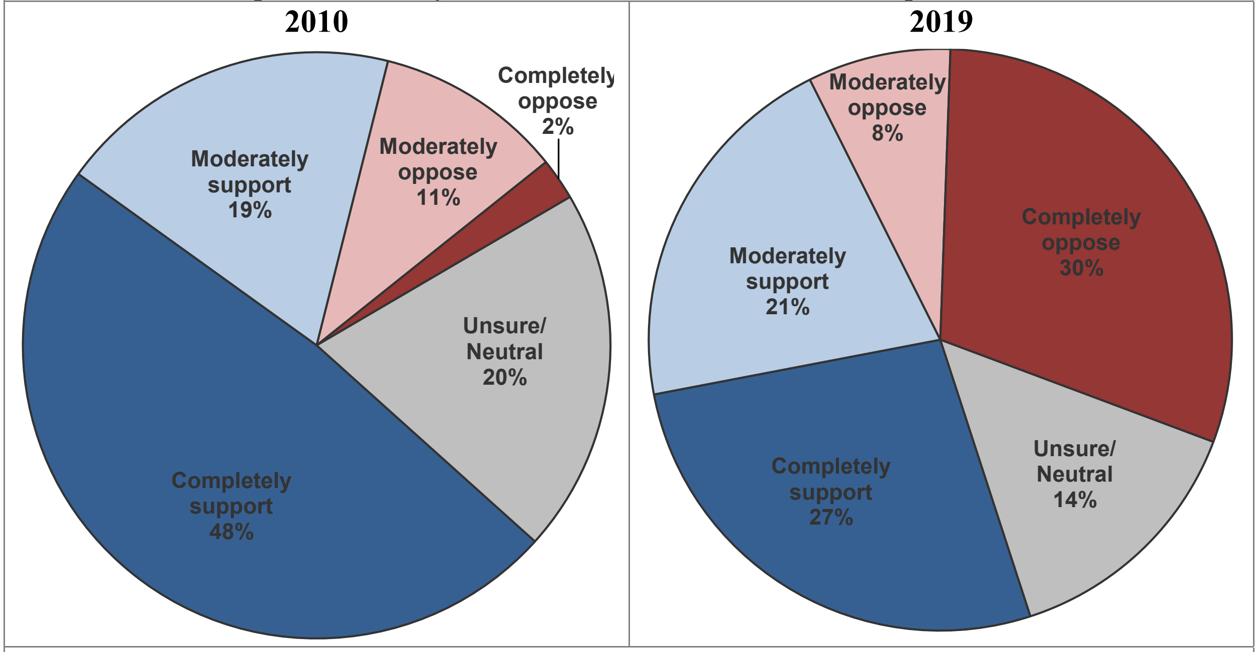


Figure 3.4-19. Select survey responses from the Phillips Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Approximately 62% of respondents indicated support (pooled *moderately support* and *strongly support*) for herbicide management, 15% opposed (pooled *moderately oppose* and *completely oppose*), and 24% where *unsure/neutral* (Figure 3.4-18). The majority of concerns using herbicides to manage EWM related to *future impacts are unknown*, *potential impacts to human health*, *potential impact to non-plant species*, and *potential impacts to native plants* (Figure 3.4-19). Respondents largely did not have these same concerns when asked about hand-harvesting or mechanical harvesting, although were more concerned with the *ineffectiveness of the technique* and *cost of technique* compared with aquatic herbicide use.

Both the 2010 and 2019 stakeholder survey asked riparians what their level of support or opposition for a water level drawdown (Figure 3.4-20). Support for a drawdown was over two-thirds of respondents in 2010 and was less than half of respondents in 2019. The 2019 survey contained a specific question about support for a 6-foot winter drawdown for EWM starting after Labor Day and refilling by Memorial Day. Approximately 43% of respondents indicated they supported this action, 19% indicated [they] *think so but can't say for certain*, and 38% opposed.

Question 34 (2010) & 36 (2019). What is your level of support or opposition for the responsible use of water level drawdown on the Phillips Chain?



	2010	2019
Support	67.2%	47.6%
Opposition	12.6%	38.1%
Unsure/Neutral	20.1%	14.3%

Figure 3.4-20. Select survey responses from the Phillips Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.5 Aquatic Invasive Species in Phillips Chain

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

Table 3.5-1. AIS present within Phillips Chain.

Type	Common name	Scientific name	Lake	Location within the report
Plants	Eurasian watermilfoil	*Myriophyllum spicatum*	Duroy, Elk, Long, Wilson	Section 3.4 – Aquatic Plants
	Curly-leaf pondweed	*Potamogeton crispus*	Duroy	Section 3.4 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Duroy, Wilson	Sections 8.1.4 & 8.4.4
	Reed canary grass	*Phalaris arundinacea*	Duroy, Long, Wilson	Section 3.5 – AIS (below)
	Narrow-leaved cattail	*Typha angustifolia*	Wilson	Section 3.5 – AIS (below)
Invertebrates	Rusty crayfish	*Orconectes rusticus*	Duroy, Elk, Wilson	Section 3.5 – AIS (below)
	Banded mystery snail	*Viviparus georgianus*	Elk, Wilson	Section 3.5 – AIS (below)

Reed Canary Grass

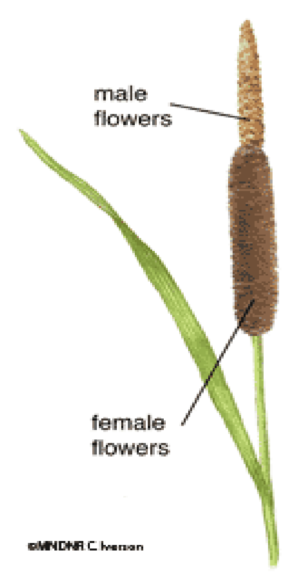
Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach three to six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines.

Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic. Often reed canary grass is simply tolerated unless it is found disrupting beneficial habitats.

Narrow-leaved cattail

Two species of cattail can be found in Wisconsin, broad-leaved cattail (*Typha latifolia*) and narrow-leaved cattail (*Typha angustifolia*). Broad-leaved cattail is considered to be indigenous to North America while narrow-leaved cattail is believed to have been introduced from Europe and is considered to be ecologically invasive. Both species have been identified from the Phillips Chain

The easiest way to tell this narrow-leaved cattail apart from the native variety (broad-leaved cattail) is the space between the male and female portions of the flowers which is not usually visible on the native cattail (Figure 3.5-1). Narrow-leaved cattail often hybridizes with native broad-leaved cattail (*T. latifolia*) making field identification difficult. The best method of control for invasive narrow-leaved cattail is manual removal although water level manipulation and herbicide application may be required for larger populations.



Photograph 3.5-1. Cattail identification aid. Broad-leaved cattail shown, as there is no gap between male and female flowers. Photo credit Minnesota DNR.

Property owners are allowed to manually remove cattails in a 30-foot wide area extending out from their property so long as removed materials are disposed of outside the lake. Cattail management can involve cutting plants below the waterline, where they will subsequently drown. This can be labor intensive and requires annual maintenance.

Aquatic Animals

Rusty Crayfish

Photograph 3.5-2. Rusty crayfish. Photo credit: GLIFWC.

Rusty crayfish (*Orconectes rusticus*) are originally from the Ohio River basin and are thought to have been transferred to Wisconsin through bait buckets. These crayfish displace native crayfish and reduce aquatic plant abundance and diversity. Rusty crayfish can be identified by their large, smooth claws, varying in color from grayish-green to reddish-brown, and sometimes visible rusty spots on the sides of their shell (Photograph 3.5-2). They are not eaten by fish that typically eat crayfish because they are more aggressive than the native crayfish. Rusty crayfish reproduce quickly but with intensive harvesting their populations can be greatly reduced within a lake.

Mystery snails

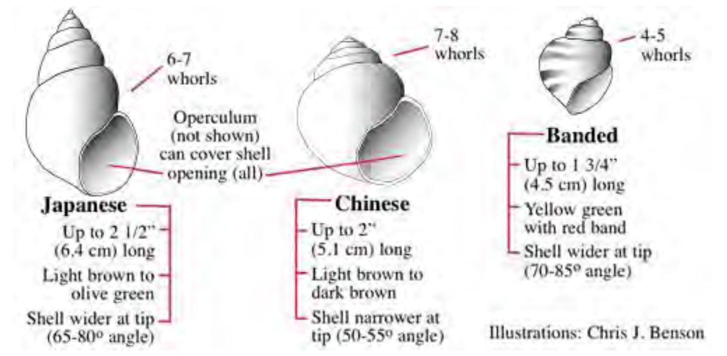


Figure 3.5-1. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (http://www.seagrant.umn.edu/ais/mysterysnail).

There are four types of mystery snails found within Wisconsin waters, with the brown mystery snail (*Campleoma decisum*) being the only species native. They are called mystery snails because the give birth to fully developed snails that mysteriously appear in spring. The two primary non-native mystery snails in Wisconsin are the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009). Currently the Japanese mystery snail (*Cipangopaludina japonica*) has only been documented from a handful of waterbodies in northwestern Wisconsin. Chinese and banded mystery snails are common throughout WI and likely the number of waters they inhabit is underreported.

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

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

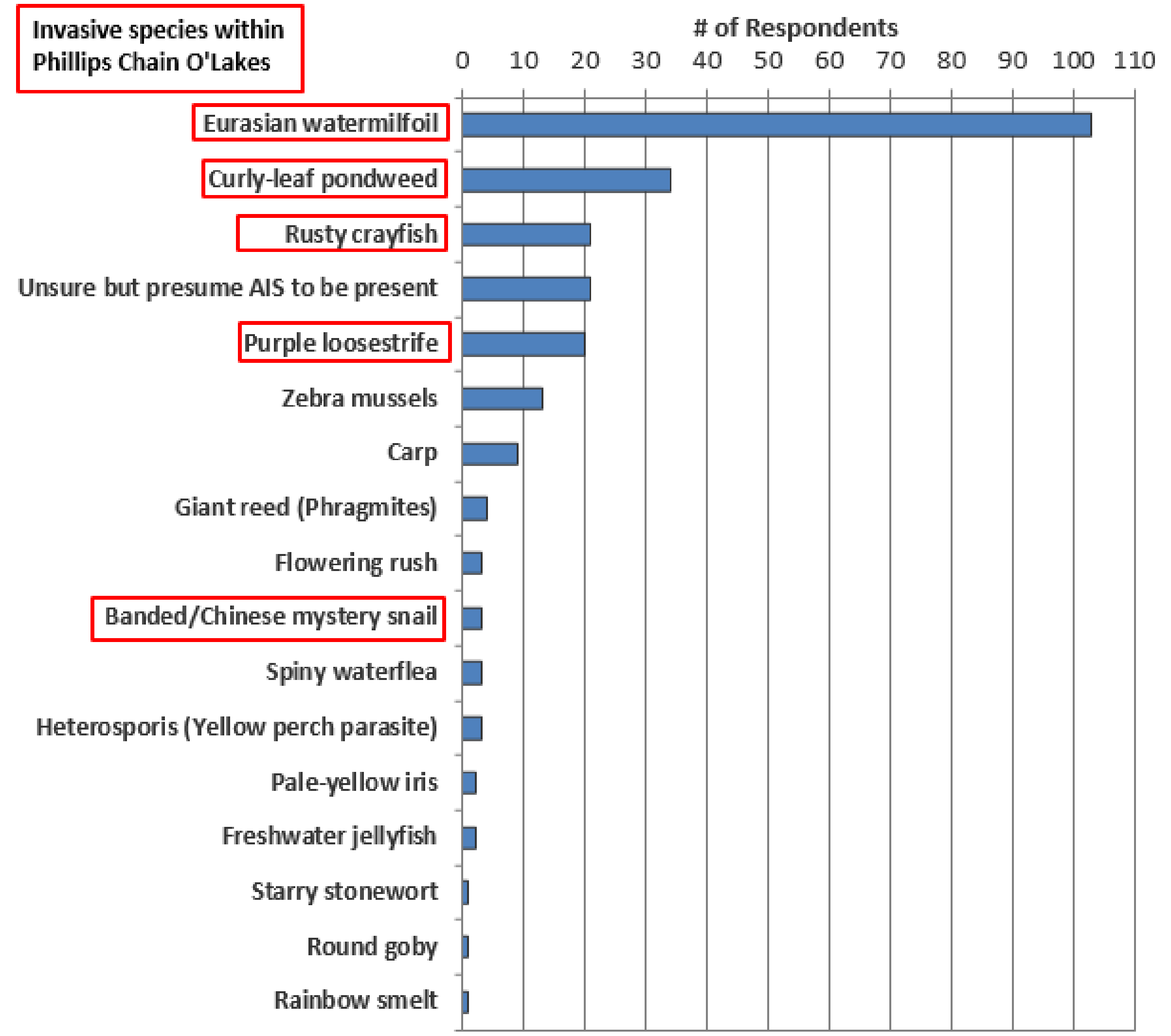


Figure 3.5-2. Stakeholder survey response Question #28. Which aquatic invasive species do you believe are in the Phillips Chain?

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing the Phillips Chain. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Jeff Scheirer (WDNR 2020 & GLIFWC 2019).

Phillips Chain of Lake's Fishery

Energy Flow of a Fishery

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

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

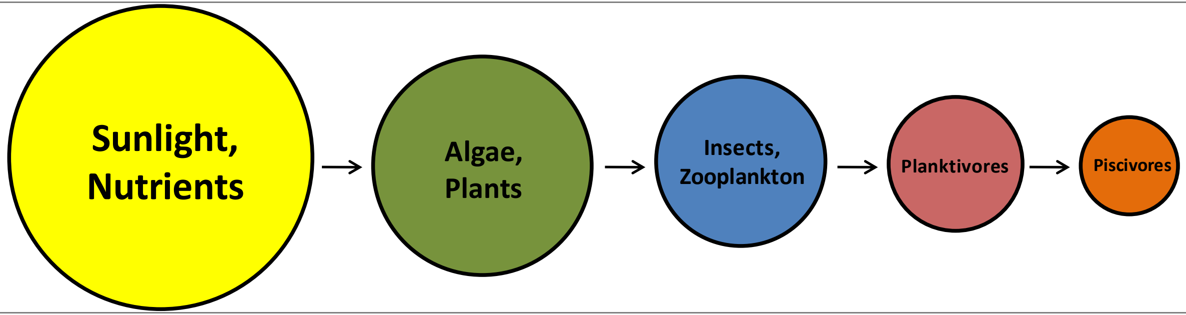


Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, all lakes within the Phillips Chain are eutrophic systems, meaning there is higher nutrient content and thus relatively high primary productivity. Simply put, this means the Phillips Chain should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past WDNR surveys of the Phillips Chain include white sucker (*Catostomus commersonii*), northern hog sucker (*Hypentelium nigricans),* shorthead redhorse (*Moxostoma macrolepidotum)*, silver redhorse (*Moxostoma anisurum)* and the golden redhorse (*Moxostoma erythrurum*). Table 3.6-1 shows the popular game fish present in the system.

Table 3.6-1. Gamefish present in the Phillip Chain of Lakes with corresponding 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
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
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
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

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

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

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

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

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. The Phillips Chain has been stocked from 1972 to 2019 with muskellunge, walleye and northern pike X muskellunge hybrids (Tables 3.6-2 and 3.6-3). For a complete list of stocking history refer to Appendix F.

Photograph 3.6-2. Muskellunge fingerling.

Table 3.6-2. Stocking data available for Walleye in the Phillips Chain (1994-2004).

Lake	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Duroy Lake	1994	Walleye	Unspecified	Fingerling	9,545	3
Duroy Lake	1995	Walleye	Unspecified	Fingerling	9,800	2.6
Duroy Lake	1996	Walleye	Unspecified	Fingerling	18,950	1.5
Duroy Lake	1997	Walleye	Unspecified	Large Fingerling	10,000	2.7
Duroy Lake	2000	Walleye	Unspecified	Small Fingerling	22,950	2.25
Duroy Lake	2002	Walleye	Mississippi Headwaters	Small Fingerling	18,950	1.7
Duroy Lake	2004	Walleye	Mississippi Headwaters	Small Fingerling	19,125	1.2
Elk Lake	1996	Walleye	Unspecified	Fingerling	4400	1.5
Elk Lake	1994	Walleye	Unspecified	Fingerling	2275	3
Elk Lake	1995	Walleye	Unspecified	Fingerling	2400	2.6
Elk Lake	1997	Walleye	Unspecified	Large Fingerling	2000	2.7
Elk Lake	2002	Walleye	Mississippi Headwaters	Small Fingerling	4390	1.3
Elk Lake	2004	Walleye	Mississippi Headwaters	Small Fingerling	4400	1.2
Long Lake	1994	Walleye	Unspecified	Fingerling	10525	3
Long Lake	1995	Walleye	Unspecified	Fingerling	10000	2.6
Long Lake	1996	Walleye	Unspecified	Fingerling	20900	1.5
Long Lake	1997	Walleye	Unspecified	Large Fingerling	10000	2.7
Long Lake	2000	Walleye	Unspecified	Small Fingerling	20900	1.7
Long Lake	2002	Walleye	Mississippi Headwaters	Small Fingerling	20900	1.7
Long Lake	2004	Walleye	Mississippi Headwaters	Small Fingerling	20898	1.2
Wilson Lake	1994	Walleye	Unspecified	Fingerling	8840	3
Wilson Lake	1995	Walleye	Unspecified	Fingerling	9000	2.6
Wilson Lake	1996	Walleye	Unspecified	Fingerling	17550	1.5
Wilson Lake	1997	Walleye	Unspecified	Large Fingerling	9000	2.7
Wilson Lake	2000	Walleye	Unspecified	Small Fingerling	17299	2.7
Wilson Lake	2002	Walleye	Mississippi Headwaters	Small Fingerling	17500	1.4

Table 3.6-3. Stocking data available for Muskellunge in the Phillips Chain (2003-2019).

Lake	Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Duroy Lake	2003	Muskellunge	Unspecified	Large Fingerling	379	10.9
Duroy Lake	2005	Muskellunge	Unspecified	Large Fingerling	379	10.6
Duroy Lake	2007	Muskellunge	Upper Chippewa River	Large Fingerling	252	12.3
Duroy Lake	2009	Muskellunge	Upper Chippewa River	Large Fingerling	379	10
Duroy Lake	2011	Muskellunge	Upper Chippewa River	Large Fingerling	379	9.9
Duroy Lake	2013	Muskellunge	Upper Chippewa River	Large Fingerling	190	11.2
Duroy Lake	2014	Muskellunge	Upper Chippewa River	Large Fingerling	190	11.3
Duroy Lake	2015	Muskellunge	Upper Chippewa River	Large Fingerling	379	12.25
Duroy Lake	2017	Muskellunge	Upper Chippewa River	Large Fingerling	37	11.5
Duroy Lake	2019	Muskellunge	Upper Chippewa River	Large Fingerling	88	12.6
Elk Lake	2003	Muskellunge	Unspecified	Large Fingerling	88	10.9
Elk Lake	2005	Muskellunge	Unspecified	Large Fingerling	88	10.6
Elk Lake	2007	Muskellunge	Upper Chippewa River	Large Fingerling	59	12.3
Elk Lake	2009	Muskellunge	Upper Chippewa River	Large Fingerling	88	10
Elk Lake	2011	Muskellunge	Upper Chippewa River	Large Fingerling	88	9.9
Elk Lake	2013	Muskellunge	Upper Chippewa River	Large Fingerling	44	11.2
Elk Lake	2014	Muskellunge	Upper Chippewa River	Large Fingerling	44	11.3
Elk Lake	2015	Muskellunge	Upper Chippewa River	Large Fingerling	88	12.25
Elk Lake	2017	Muskellunge	Upper Chippewa River	Large Fingerling	11	11.5
Elk Lake	2019	Muskellunge	Upper Chippewa River	Large Fingerling	22	12.6
Long Lake	2003	Muskellunge	Unspecified	Large Fingerling	418	10.9
Long Lake	2005	Muskellunge	Unspecified	Large Fingerling	418	10.6
Long Lake	2007	Muskellunge	Upper Chippewa River	Large Fingerling	278	12.3
Long Lake	2009	Muskellunge	Upper Chippewa River	Large Fingerling	418	10
Long Lake	2011	Muskellunge	Upper Chippewa River	Large Fingerling	418	9.8
Long Lake	2013	Muskellunge	Upper Chippewa River	Large Fingerling	209	11.2
Long Lake	2014	Muskellunge	Upper Chippewa River	Large Fingerling	209	11.3
Long Lake	2015	Muskellunge	Upper Chippewa River	Large Fingerling	418	12.25
Long Lake	2017	Muskellunge	Upper Chippewa River	Large Fingerling	44	11.5
Long Lake	2019	Muskellunge	Upper Chippewa River	Large Fingerling	105	12.6
Wilson Lake	2003	Muskellunge	Unspecified	Large Fingerling	175	10.9
Wilson Lake	2007	Muskellunge	Upper Chippewa River	Large Fingerling	115	12.3
Wilson Lake	2009	Muskellunge	Upper Chippewa River	Large Fingerling	176	10
Wilson Lake	2011	Muskellunge	Upper Chippewa River	Large Fingerling	175	9.9
Wilson Lake	2013	Muskellunge	Upper Chippewa River	Large Fingerling	88	11.2
Wilson Lake	2015	Muskellunge	Upper Chippewa River	Large Fingerling	175	12.4
Wilson Lake	2017	Muskellunge	Upper Chippewa River	Large Fingerling	37	11.5
Wilson Lake	2019	Muskellunge	Upper Chippewa River	Large Fingerling	141	12.6

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the first most important reason for owning property on the Phillips Chain O'Lakes (Question #18). The most popular lake to fish by stakeholders was considered to be Long Lake (Figure 3.6-5). Figure 3.6-2 displays the fish that the Phillips Chain O'Lakes stakeholders enjoy catching the most, with bluegill/sunfish, walleye and crappie being the most popular. Approximately 69% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.6-3). Approximately 65% of respondents who fish the Phillips Chain believe the quality of fishing is worse since they first started to fish the lake (Figure 3.6-4).

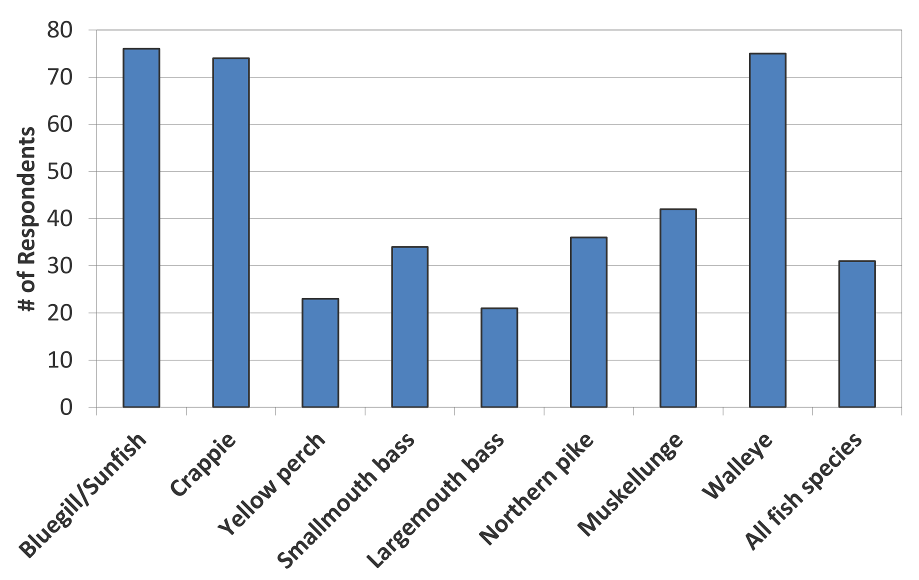


Figure 3.6-2. Stakeholder survey response Question #12. What species of fish do you like to catch on the Phillips Chain O'Lakes?

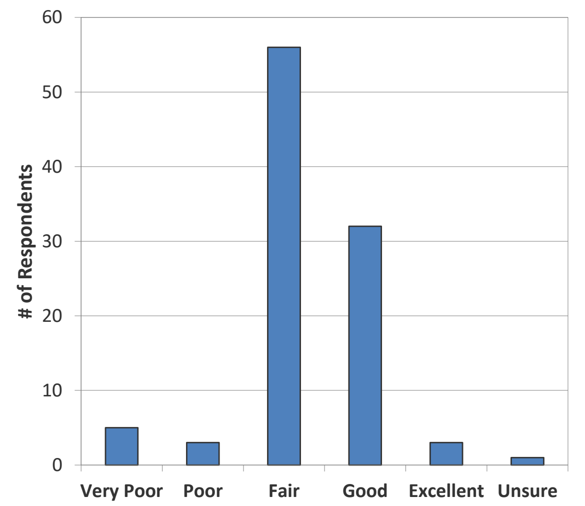


Figure 3.6-3. Stakeholder survey response Question #13. How would you describe the current quality of fishing on the Phillips Chain?

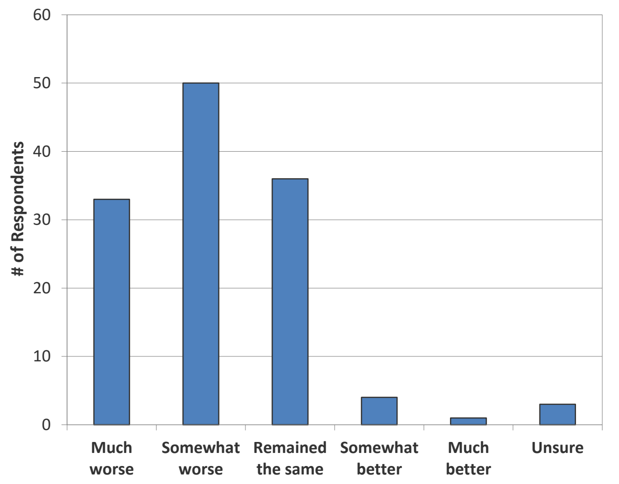


Figure 3.6-4. Stakeholder survey response Question #14. How has the quality of fishing changed on the Phillips Chain since you started fishing the lake?

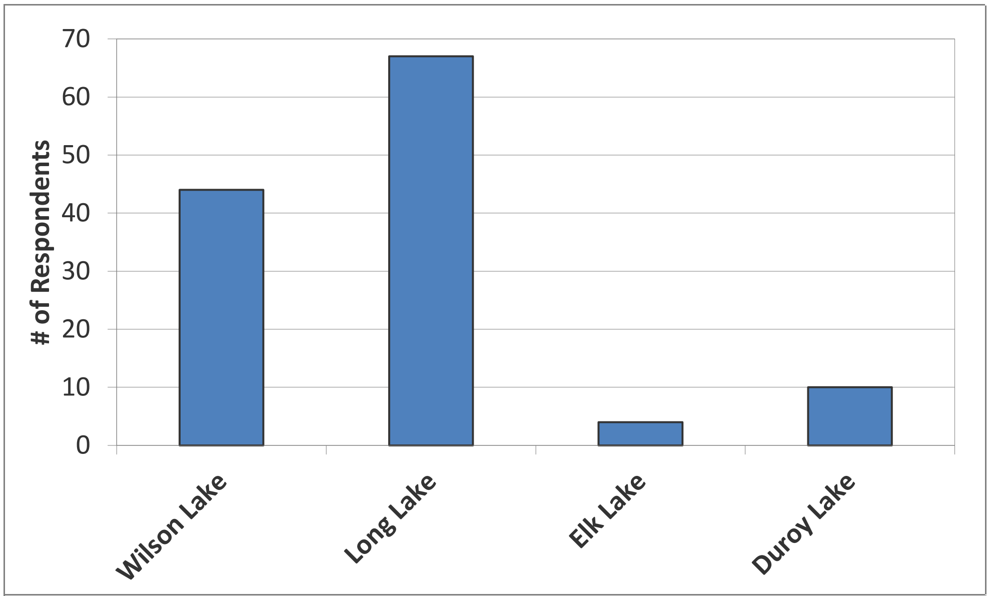


Figure 3.6-5. Stakeholder survey response Question #11. Which chain lake do you fish on the most?

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on the Phillips Chain represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on the Phillips Chain (Figure 3.6-2). The Phillips Chain contains a wide variety of species which can be attributed to the diversity of habitat and connecting tributaries (WDNR 2014).

Walleyes are a valued sportfish in Wisconsin. The Phillips Chain were surveyed in 2008 and 2014 to assess the walleye population. Overall the Duroy Lake population increased, Elk Lake remained unchanged, Wilson Lake declined and Long Lake saw a decline in the walleye population. For Wilson Lake, the data showed a steep decline in capture rates along with an increase in walleye 15 inches and longer. This showed WDNR Fishery Biologists there is low recruitment occurring within Wilson Lake. This is likely due to inadequate spawning habitat and the narrow shallow culvert connecting Wilson Lake to Long Lake limiting fish movement. If 2020 surveys indicate similar results the WDNR may consider supplementing Wilson Lake with walleye stocking (WDNR 2014).

Northern Pike are considered common in the Phillips Chain. The 2014 WDNR survey showed an increase in both distribution and size since the 2008 survey. No management goals were planned for this species due to a lack of stakeholder interest in most fishing stakeholders (WDNR 2014).

Muskellunge are considered a valued sportfish of the Phillips Chain. Muskellunge have been regularly stocked by the WDNR since 1972, occurring mainly in odd years (Table 3.6-3). The Phillips Chain are considered by the WDNR as an A2 chain which means the waterbody has the capabilities of producing consistent angling action and the potential to harbor trophy sized fish (WDNR 2014).

Smallmouth bass are present in the Phillips Chain but in lower numbers which is similar to other area lakes. The 2008 management goal was to attain a population of moderate density with a high proportion of preferred-size fish and a moderate proportion of memorable-size fish which was not met in the 2014 survey data. If future WDNR fishery surveys show similar results this goal may be adjusted to be more realistic for the area (WDNR 2014).

Panfish

The results for the stakeholder survey show anglers prefer to catch crappie and bluegill on Phillips Chain (Figure 3.6-2). Yellow perch, black crappie and bluegill populations were varied during the 2014 WDNR fisheries survey depending on the species (WDNR 2014).

Bluegill management objectives in 2008 were to attain a population of moderate density with a low to moderate proportion of preferred-size fish. Capture rates during 2014 were near the objective range in Elk, Duroy and Long Lakes. Wilson Lakes results indicates very high bluegill abundance. Differences between the lakes may be due to the weedy habitat in Wilson Lake which also may also alter the predator effectiveness on bluegill density.

Black crappie overall saw higher capture rates in all lakes within the Chain with the exception of Long Lake which saw similar catches rates between the survey years. The WDNR set a management goal for black crappie to reach a population of moderate density with a moderate proportion of preferred-size fish.

Yellow perch were varied in populations throughout the chain. Wilson Lake populations were gauged as moderately abundant. No management goals were set for yellow perch in the 2008 plan.

Phillips Chain Spear Harvest Records

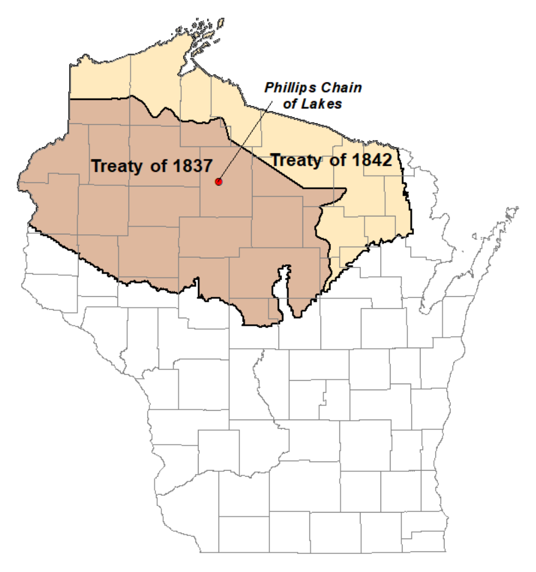


Figure 3.6-6. Location of the Phillips Chain within the Native American Ceded Territory (GLIFWC 2019). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-5). The Phillips Chain falls within the ceded territory based on the Treaty of 1837. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods. By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2017). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIFWC 2017). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake.

Walleye open water spear harvest on Long Lake are provided in Figure 3.6-6 from 2000 to 2019. As many as 30 walleye have been harvested from the lake in the past (2012), but the average harvest is roughly four fish in a given year. Spear harvesters on average have taken 4% of the declared quota.

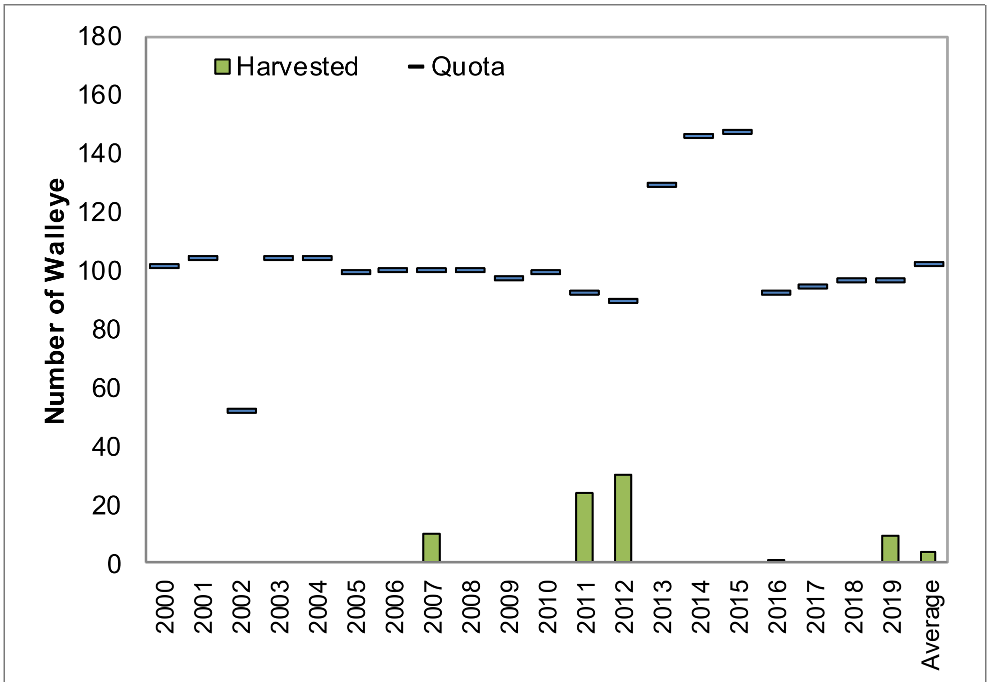


Figure 3.6-7. Long Lake walleye spear harvest data. (GLIFWC 2000-2019).

Walleye open water spear harvest on Wilson Lake are provided in Figure 3.6-7 from 2005 to 2019. A quota for Wilson Lake was first documented in 2005. As many as 75 walleye have been harvested from the lake in the past (2009 and 2012), but the average harvest is roughly 20 fish in a given year. Spear harvesters on average have taken 25% of the declared quota.

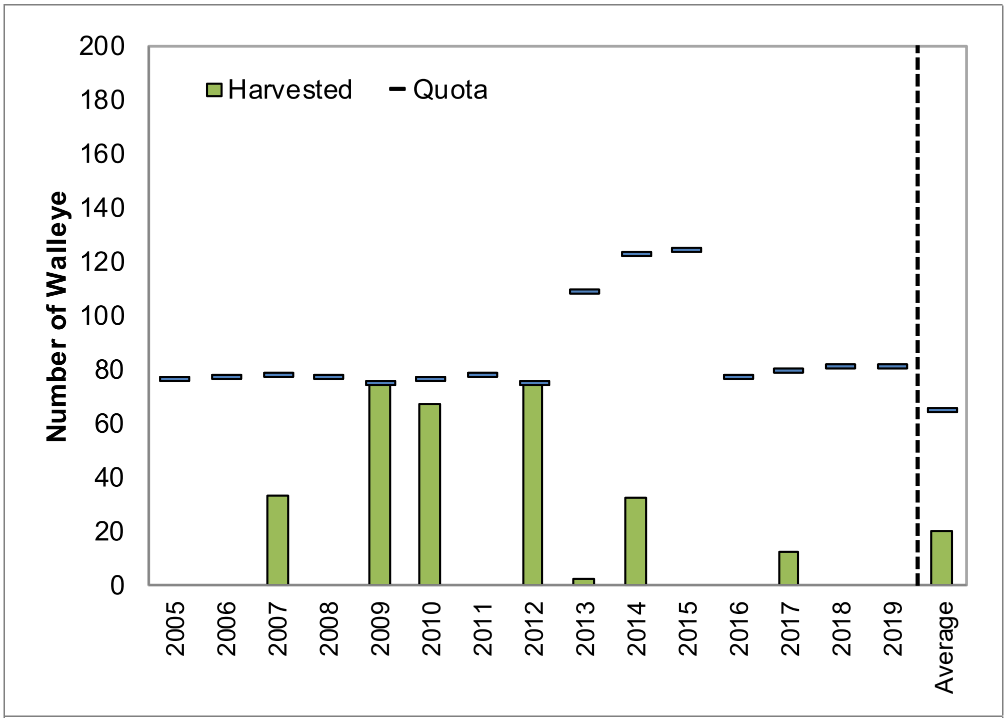


Figure 3.6-8. Wilson Lake walleye spear harvest data. (GLIFWC 2005-2019).

While within the ceded territory, the Phillips Chain have not experienced a spearfishing harvest for muskellunge. A small quota for muskellunge harvest has been listed for the chain in recent years; however, no spearing efforts have been undertaken. It is possible that spearing efforts have been concentrated on other larger lakes in the region, which would potentially have a higher estimated safe harvest for muskellunge. Additionally, Elk and Duroy Lakes have not experienced a walleye harvest perhaps for similar reasons as described above.

Phillips Chain Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2019, 87% of the substrate sampled in the littoral zone of Duroy Lake were soft sediments, 13% was composed of sand and 0% were composed of rock.

According to the point-intercept survey conducted by Onterra in 2019, 56% of the substrate sampled in the littoral zone of Elk Lake were sand sediments, 25% was composed of soft and 19% were composed of rock.

According to the point-intercept survey conducted by Onterra in 2019, 59% of the substrate sampled in the littoral zone of Long Lake were soft sediments, 33% was composed of sand and 8% were composed of rock.

According to the point-intercept survey conducted by Onterra in 2019, 84% of the substrate sampled in the littoral zone of Wilson Lake were soft sediments, 13% was composed of sand and 3% were composed of rock.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish’s life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2009). A Fall 2019 survey documented 788 pieces of coarse woody along the shores of the Phillips Chain, resulting in a ratio of approximately 25 pieces per mile of shoreline. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how the Phillips Chain of Lake’s coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

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

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

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

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

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

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

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

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

If interested, the Phillips Chain O'Lakes Association, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for the Phillips Chain.

Fishing Regulations

Regulations for the Phillips Chain fish species as of March 2020 are displayed in Table 3.6-4. For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-4. WDNR fishing regulations for the Phillips Chain (As of March 2020).

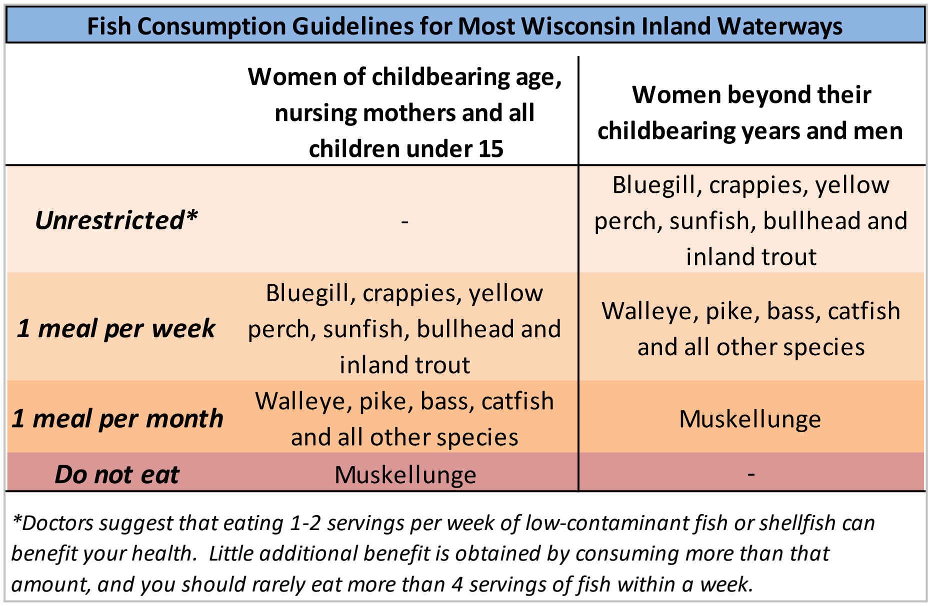
Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Largemouth bass and smallmouth bass	5	14"	June 20, 2020 to March 7, 2021
Smallmouth bass	5	14"	June 20, 2020 to March 7, 2021
Largemouth bass	5	14"	May 2, 2020 to March 7, 2021
Muskellunge and hybrids	1	40"	May 23, 2020 to December 31, 2020
Northern pike	5	None	May 2, 2020 to March 7, 2021
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 2, 2020 to March 7, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or lures

Mercury Contamination and Fish Consumption Advisories

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

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.6-8. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.



Fish Consumption Guidelines for Most Wisconsin Inland Waterways

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

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

Figure 3.6-9. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/).

Fishery Management & Conclusions

The WDNR have six main goals for the Phillips Chain which are described in detail in the 2008 fishery summery (Appendix F) and briefly outlined below.

Goal 1: Black crappie – a population of moderate density with a moderate proportion of preferred-size fish.

Goal 2: Bluegill – a population of moderate density with a low to moderate proportion of preferred-size fish.

Goal 3: Walleye – a population of moderate density with a moderate proportion of quality-size fish.

Goal 4: Smallmouth bass – a population of moderate density with a high proportion of preferred-size fish and a moderate proportion of memorable-size fish.

Goal 5: Muskellunge – a muskellunge population of moderate density with a moderate proportion of memorable-size fish.

Goal 6: Biodiversity – a diverse native fish community that fluctuates in species composition but generally experiences no net loss of native fish species and provides adequate forage for sport fish populations.

The WDNR tentatively plans to next survey the Phillips Chain in 2020. This survey will estimate the adult walleye population density, walleye recruitment, and bluegill population assessment (Scheirer 2020).

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 Phillips Chain ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil.
3) Collect sociological information from Phillips Chain 'O Lakes Association stakeholders regarding their use of the system and their thoughts pertaining to the past and current condition of the chain and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Phillips Chain ecosystem, the folks that care about the lakes, and what steps can be taken by the PCOLA to protect and enhance the system.

Almost 200 square miles of land drains into the Phillips Chain and ultimately flows over the Jobes Dam. Lakes that turn-over their entire volume of water in less than 14 days are actually considered *impounded flowing waters* and not true lakes. The hydraulic residence time of Wilson Lake is around 51 days based upon current modeling, and all the other lakes have a residence time of less than 4 days. The short residence time means that in-lake processes have little impact on the lake's water quality and the water quality of the system is mostly driven by the water quality of the incoming Elk River, Little Elk River, and Squaw Creek. Wilson Lake acts more like a traditional shallow lowland drainage lake that does not thermally stratify during the summer. Duroy also does not stratify, whereas Elk and Long lakes thermally stratify during the summer. Lakes that thermally stratify have more complex drivers of water quality as the deep areas can be a source of internal nutrient loading to the system during turnover events.

The water clarity of the Phillips Chain is largely impacted by staining compounds called organic acids, which gives the lake a tea-color, restricting sunlight penetration and plant growth to shallower areas up to about six feet deep. Increases in precipitation can flush more of these tannins into the lake, decreasing water clarity. Lake water pH is around 7.5/7.7 in July, being considered a little more *alkaline* than *neutral*. While this is the preferred pH for zebra mussels (an invasive species), the low amount of calcium within the flowage suggests *very low susceptibility* for zebra mussel establishment.

Based upon each lake's phosphorus concentrations and closely-related free-floating algal content (chlorophyll-*a*), the entire system is classified as eutrophic. This generally means the lakes can support a high amount of primary production, with high amounts of plant biomass or algae. By having a strong base of the food web, the system can support high amounts of animal life including fish and the critters the fish feed on. With the short residence times discussed earlier, much of the nutrients are flushed downstream before they are able to be used by plants or algae.

The Phillips Chain is a regionally popular destination for anglers that target plentiful gamefish, including trophy-sized muskellunge. Walleye and panfish are also heavily targeted. Riparian stakeholder respondents believe the fishery is currently *fair* to *good* and that the fishery has *remained the same* or has become *somewhat* worse since they first started fishing the lake. It is common for stakeholder survey respondents to indicate the quality of fishing has gotten worse in an effort to persuade managers to increase its potential. The next comprehensive fisheries survey is planned by the WDNR to occur in 2021.

The Phillips Chain is known for its natural scenic beauty. The shoreland condition assessment found that 69% of the chain's shoreline consisted of shorelines in the two most ecologically beneficial categories (*developed–natural* and *undeveloped*), whereas only 17% were categorized as being within the two most impactful categories (*urbanize*d and *developed–unnatural*). As a part of this management planning process, the PCOLA has outlined management actions aimed at protecting the valuable habitat and nutrient buffering capacity of the near-shore zone, as well as outlined actions to shift some of the urbanized properties into being more natural. The system also contains a moderately high about of coarse woody habitat. These downed trees, stumps, and other woody debris provide extremely valuable habitat for many organisms including larval fish. The PCOLA has supported an extraordinary and commendable effort of placing 69 *fish-stick* structures across 20 sperate properties in the past decade.

During 2019 alone, over 50 different species of plants were located within and along the margins of the Phillips Chain, much higher than most Wisconsin systems. The Phillips Chain contains a wide range of habitats, including sandy shoals, sediment-rich backwater bays, and riverine areas. Different aquatic plant species favor these habits and results in the high species richness. A statistical measurement of aquatic plant diversity indicates that there is a 90% chance of the next plant species encountered being different from the previous one. The Phillips Chain also harbors two species listed by the Natural Heritage Inventory as being species of special concern: vasey's pondweed and autumnal starwort. In the past decade, Long Lake's aquatic plant community has remained relatively stable with only one species having a statistically valid change in frequency – an increase in slender naiad populations. Six species on Elk Lake and six species on Duroy Lake had statistically valid population increases and no statistically valid population decreases. Wilson Lake had more dynamic aquatic plant populations, potentially in response to EWM management activities (i.e. herbicide treatments) and overall more conducive environment of aquatic plants. Continued monitoring of these populations will be important to continue to understand this valuable component of the system's health.

Two primary non-native submergent aquatic plant species are known to exist in the Phillips Chain: Eurasian watermilfoil (EWM) and curly-leaf pondweed (CLP). Curly-leaf pondweed was found in a 2013 survey in the upstream portions of Duroy Lake and have not expanded or become problematic. The PCOLA will continue to periodically monitor the CLP population, with no management actions being warranted at this time.

Eurasian watermilfoil populations continue to be high in Wilson Lake and parts of Duroy Lake. These are the two lakes most conducive to high populations of EWM. The PCOLA believes that implementing a winter-long water level reduction is the most effective, ecological, and lowest cost management approach for reducing nuisance levels of aquatic plants, particularly EWM in the chain. Based upon the results of the stakeholder survey, approximately 48% of respondents support (pooled *highly supportive* and *moderately supportive*) a winter drawdown and 38% oppose (pooled *completely oppose* and *moderately oppose*) (Appendix B, Question #36). Based upon current community opposition to this management activity forces PCOLA to consider mechanical harvesting and herbicide treatment as short-term alternatives, as discussed in the Implementation Plan Section (5.0, Management Goal #5). The PCOLA will continue to investigate and determine ways to overcome implementation challenges of a winter drawdown.

When large-scale management activities are not practical or unsupported by the community, smaller-scale and focused actions are considered. In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to targeting established aquatic invasive species populations with these methods. Instead of chasing the entire EWM population with management, perhaps focusing on targeting only the areas that are causing the largest impacts can be more economical and cause less ecological stress to the lake. To that end, the PCOLA created two distinct plans for aquatic plant management.

One management action is to continue investigating mechanical harvesting potential, particularly on Wilson Lake. Based upon the results of the stakeholder survey, approximately 60% of respondents support (pooled *highly supportive* and *moderately supportive*) mechanical harvesting (Appendix B, Question #36). The PCOLA acknowledges that the first step in this process is to understand what can logistically and legally be conducted and then confer that reality to its stakeholders. While many folks believe that they will be able to instruct the harvester operator to clear cut large areas of the lake, a more realistic mechanical harvesting plan would likely consist of a 20- or 30-foot wide common use lane around Wilson Lake. Areas that are less than 3-feet deep or contain stumps or other obstructions will need to be avoided. While a number of advantages and disadvantages are discussed within this management action, the main advantage is that this technique will immediately resolve nuisance conditions allowing navigation. The main disadvantage is that it is a temporary improvement in a predefined path around the lake.

The PCOLA also created a plan for EWM management with aquatic herbicides when navigation and recreation are impeded. Approximately 62% of respondents to the stakeholder survey indicated support (pooled *moderately support* and *strongly support*) for herbicide management, 14% opposed (pooled *moderately oppose* and *completely oppose*), and 24% where *unsure/neutral*. The herbicide strategies the PCLOA has employed to date were considered the *Best Management Practice (BMPs*) of the time, but advancements in management strategies have occurred since this time. Onterra believes some of the largest advances in BMPs in regards to EWM management was gained as a part of a cooperative research project between the WDNR, US Army Corps of Engineers Research and Development Center (USACE), and private consultants. This program took place roughly from 2009 to 2016. The PCOLA involved with this research project and should be commended for their valuable role in improving herbicide management across the Midwest.

As a part of this management planning project, the PCOLA has been educated on the updated BMPs of managing EWM with herbicides. This includes using newer herbicides that are more effective under short concentration and exposure time scenarios. This also includes understanding the area of potential impact (AOPI) that the herbicide will ultimately dilute into and designing a strategy that includes a purposeful AOPI target concentration. Through numerous conversations with the WDNR, the PCOLA has developed a trial strategy for potential implementation during the spring of 2022.

Through the process of this lake management planning effort, the PCOLA has learned much about their system, both in terms of its positive and negative attributes. The PCOLOA continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Phillips Chain ecosystem.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the PCOLA Planning Committee and ecologist/planners from Onterra. It represents the path PCOLA 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 Phillips Chain stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

While the PCOLA Board of Directors is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee or an individual director/coordinator. The PCOLA Board of Directors will be responsible for deciding whether the formation of sub-committees and or directors is needed to achieve the various management goals.

The APM-related Implementation Plan provided here outlines separate management goals and actions that together form the PCOLA's Integrated Pest Management strategy for EWM on the Phillips Chain. Integrated Pest Management (IPM) is an approach to manage a species that utilizes a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately. This long-term vision considers all available control practices such as:

- Prevention
- Biological control
- Biomanipulation
- Nutrient management
- Habitat manipulation
- Pesticide application
- Water level manipulation
- Mechanical removal
- Feasibility planning
- Population monitoring
- Substantial modification of cultural practices

The PCOLA's IPM plan includes winter water level drawdown, mechanical harvesting, herbicide application, hand-harvesting, monitoring, planning, and prevention. The monitoring data will help the PCOLA understand the EWM population as it relates to the triggers outlined within this Plan. Proper planning will determine appropriate scale-appropriate and stakeholder-supported active management approaches. Following active management, subsequent smaller-scale actions, such as hand-harvesting, may be implemented to preserve the gains made.

Management Goal 1: **Increase the PCOLA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities**

Management Action:	Bolster communication abilities and pursue additional communication avenues
Timeframe:	In Progress
Facilitator:	PCOLA Board of Directors
Description:	Education represents an effective tool to address many lake issues. The PCOLA aims to send out regularly distributed newsletters (at least one per year) and maintain an updated website (phillipschain.org). The webpage is a useful repository for association information; including meeting minutes and announcement, general association information, and educational materials. The committee would also investigate creating and moderating a dedicated PCOLA Facebook Page, allowing another resource for building a sense of community, as well as providing information on upcoming events or providing links to educational pieces posted on the website. This can include announcements, pictures, short videos, and links to websites. Links to websites are useful because they allow the association to keep their followers informed regarding updates and additions made to the PCOLA webpage. The disadvantage to utilizing Facebook is that it requires users to have a subscription, which is free, and check their newsfeed regularly. As social media platforms and use evolves, investigate opportunities for the PCOLA to use additional and/or alternative platforms to provided content to its audience. Email is another useful form of electronic communication that allows the association to disseminate news quickly at low cost. Emails can contain short informational pieces, pictures, and links to information on the web. The PCOLA strives to maintain a complete and updated email list, which will allow more rapid and cost-effective means of providing information to association members. These mediums allow for exceptional communication with association members. This level of communication is important within a management group because it facilitates the spread of important association news, educational topics, and even social happenings.
Action Steps:	
	See description above

Management Action:	Participate in Wisconsin Lakes and Rivers Convention
Timeframe:	Annually or as often as feasible
Facilitator:	PCOLA Board of Directors
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and associations. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/association. The PCOLA will consider sponsoring the attendance of association representative(s) at the convention. Following the attendance of the convention, the members will report specifics to the Board of Directors regarding topics that may be applicable to the management of Phillips Chain and operations of the PCOLA. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the association membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/default.aspx In addition to the state-wide conference, local counties occasionally hold more focused conferences where PCOLA would attempt to have representation present. The North American Lake Management Society (NALMS) also holds regular conferences that may be beneficial for PCOLA members to attend portions of when it is located geographically close to the Phillips Chain. In addition, NALMS provides valuable research and educational materials that may be of interest to the PCOLA. More information can be found at: https://www.nalms.org/
Action Steps:	
	See description above.

Management Action:	Routinely educate and communicate with all lake stakeholders
Timeframe:	In progress
Facilitator:	PCOLA Board of Directors
Description:	The PCOLA will make the education of lake-related issues a priority. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan*, allowing it to be better understood by association members. To accomplish this task, the PCOLA plans to highlight key topics from the plan and share educational materials on the subjects over time. The PCOLA believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative. As a part of the planning process, the PCOLA identified key topics which they believe the association members would appreciate additional educational opportunities. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • Importance of natural landscapes • Development of a courtesy code • General lake ecology • Benefits and uses of wild rice • Aquatic invasive species identification • Septic system maintenance • Shoreline habitat restoration and protection • Litter • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Shoreline erosion – individuals, wildlife • Bluegreen algae
Action Steps:	
	See description above.

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	During updated planning project or when prompted.
Facilitator:	PCOLA Board of Directors
Description:	Formal riparian stakeholder user surveys have been performed by the association in 2010 and 2019 as part of management planning projects.

	During the next management planning project, or if prompted by a specific rationale, an updated stakeholder survey would be distributed to the Phillips Chain riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2019, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.
Action Steps:	
	See description above

<u>Management Action:</u>	Continue PCOLA's involvement with other entities that have responsibilities in managing (management units) Phillips Chain
Timeframe:	Continuation of current efforts
Facilitator:	PCOLA Board of Directors
Description:	The purpose of the PCOLA is to maintain, protect, and improve the quality of lakes for the landowners and those that use the lake for recreation purposes. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the PCOLA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page.
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (Jeff Scheirer– 715.762.1354)	Manages the fishery of the system.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier – 715-356-5211)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants r permits, and to seek advice on other lake issues.
	Warden (Joe Paul – 715.416.0086)	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.	As needed	Contact to arrange for training as needed, in addition to planning out monitoring and reporting of data.
	AIS Regional Coordinator (Alan Wirt - 715-365-8905)	Oversees AIS monitoring and prevention activities locally.	As needed.	AIS training and ID, AIS monitoring techniques
Price County Land Conservation	Administrator (Evan Lund – 715.339.3272)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements, and zoning.
Price County Dams	Dams Keeper (Adam Nelson – 715.339.3081)	Operates Jobes Dam	As needed	
City of Phillips	Clerk/Zoning (Shelby Prochnow 715.339.3125)	Local unit of government	As needed: (cityofphillips.com)	Aspects that involve the government such as building and zoning, municipal sewer, funding opportunities, grant applications, CBCW, events, ordinances etc. PCOLA provides regular updates to these municipalities on the health of the lake and efforts to maintain it.
Town of Elk	Treasurer (Joseph Neerdaels - 715.820.1123)		As needed: (co.price.wi.us/337/ Town-of-Elk)	
Town of Worcester	Clerk/Treasurer (Marcie Bogdanovic- (715.339.3430)		As needed: (co.price.wi.us/325/ Town-of-Worcester)	
Phillips Area Chamber of Commerce	715.339.4100	Membership organization	As needed: (phillipswisconsin.net)	Promoting local businesses, tourism, and community.
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 (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 2: Ensure the PCOLA has a Functioning and Up-to-Date Management Plan

Management Action:	Periodically update lake management plan
Timeframe:	Periodic
Facilitator:	PCOLA Board of Directors
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. The WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years. This allows a review of the available data from the lake, as well as to consider changing BMPs for water quality, watershed, and shoreland management. The PCOLA has generally followed this timeframe in the past. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. Therefore, the WDNR requires those aspects of the plan to be updated every 5 years in order to be eligible for grants and permits. For example, if herbicide management of EWM is occurring, the WDNR will require the PCOLA revisit their aquatic plant management-related goals and actions approximately once every 5 years. It is important to work with the regional WDNR Lakes Biologist to understand what is required at this time, as it is more subjective in comparison to the requirements of a *Comprehensive Lake Management Plan* as it relates to the specific management actions being considered. It is important to note that the management plan provides a framework to guide the management action, but does not include the specific control plan for a given year. A written control plan, consistent with the *Management Plan*, would be produced prior to the action outlining the management and monitoring strategy. The control plan is useful for WDNR and tribal regulators when considering approval of the action, as well as to convey the control plan to PCOLA members for their understanding. Historically, the PCOLA has conveyed their control plan within annual reporting, which are distributed in late winter of each year.
Action Steps:	
	See description above.

Management Goal 3: Monitor Aquatic Vegetation in the Phillips Chain

Management Action:	Coordinate periodic point-intercept surveys
Timeframe:	Periodic: every 5 years
Facilitator:	PCOLA Board of Directors
Description:	The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) has been conducted on Duroy, Elk, and Long lakes in 2009 and 2019 and Wilson Lake in 2007, 2011, 2012, 2014, 2015, and 2019. The more frequent surveys on Wilson Lake were prompted by high Eurasian watermilfoil populations and associated management actions directed towards this species. At each point-intercept location within the *littoral zone,* information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR generally indicates that repeating a point-intercept survey every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. The five-year-interval corresponds with the interval of an updated *Aquatic Plant Management Plan.* Please note that eligibility for a WDNR control grant requires that the most recent point-intercept survey be no more than 5 years ago in order to be eligible to apply. The PCOLA will also investigate grant funding opportunities to help fund this survey in the future. This will likely consist of a Surface Water Grant, which offers a WDNR cost share. Grant applications are due on November 1 of each year, with intent materials being due 60 days prior (September 2).
Action Steps:	
	See description above.

<u>Management Action:</u>	Periodically monitor the EWM population
Timeframe:	Periodic: Every 5 years or when prompted
Facilitator:	PCOLA Board of Directors
Description:	As the name implies, the Late-Season EWM Mapping Survey is completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For the Phillips Chain, this survey would likely take place in mid-August to the end of September, dependent on the growing conditions of the particular year. This survey would include a complete meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late- Season EWM Mapping Surveys have been conducted semi-annually on the Phillips Chain since 2009, allowing for lake stakeholders to understand EWM population dynamics. These surveys are used as the trigger within subsequent EWM management goals. Unless prompted by a specific rationale, such as areas suspected to have reached the trigger for management discussed above, PCOLA will conduct this mapping survey at approximately 5-year intervals on the entirety of the Phillips Chain. This will allow the dataset to stay current but balances the financial costs of the effort. Further, the PCOLA may choose to surveys a focused part of the system that may be considered for management in a subsequent season, such as Wilson Lake. The PCOLA will also investigate grant funding opportunities to help fund this survey in the future. This will likely consist of a Surface Water Grant, which offers a WDNR cost share. Grant applications are due on November 1 of each year, with intent materials being due 60 days prior (September 2).
Action Steps:	
	See description above.

Management Action:	Coordinate Periodic Community Mapping (floating-leaf and emergent) Surveys
Timeframe:	Period: every 10-15 years or when prompted
Facilitator:	PCOLA Board of Directors
Description:	This survey would delineate the margins of floating-leaf (e.g. water lilies) and emergent (e.g. cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. This survey has been conducted on the Phillips Chain in 2009 and 2019, with a few additional survey years on Duroy documenting wild rice population fluctuations. In order to understand the dynamics of the emergent and floating-leaf aquatic plant communities in the Phillips Chain, a community mapping survey would be conducted approximately every 10-15 years unless a specific rationale prompts a shorter interval. The PCOLRA would consider new techniques, such as drone technology, if the data generated are at least as accurate as the existing methodologies and if the costs are less. This survey would also identify non-native emergent shoreline plants, such as purple loosestrife, narrow-leaved cattail, reed manna grass and pale-yellow iris, all of which are known or suspected from around the Phillips Chain.
Action Steps:	
	See description above.

Management Goal 4: Manage Aquatic Invasive Species and Prevent Establishment of New Aquatic Invasive Species

Management Action:	Monitor Phillips Chain entry points for aquatic invasive species
Timeframe:	Ongoing
Facilitator:	Board of Directors with an appointed coordinator
Description:	The intent of this program is not only be to prevent additional invasive species from entering the Phillips Chain through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the system. The PCOLA would ensure that all landings have updated signage as it relates to aquatic invasive species. The PCOLA will promote watercraft inspection programs (Clean Boat Clean Waters program), through interested riparian volunteers. During 2019 and 2020, an average of over 200 hours of volunteer inspections occurred. The PCOLA has made it a point to acknowledge those volunteers within association meetings and newsletters. It is most helpful to have watercraft monitors at the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of its spread. The PCOLOA will also engage with local fishing clubs and strive to be present at fishing tournaments occurring on the system. The PCOLA may consider paid watercraft inspections in the future, with cost share assistance to fund this program through the WDNR's streamline CBCW Grant Program. More information can be found by clicking here: https://dnr.wisconsin.gov/topic/lakes/cbcw
Action Steps:	
	See description above.

Management Action:	Continue to investigate winter drawdown feasibility
Timeframe:	Ongoing
Facilitator:	PCOLA Board of Directors
Description:	Water drawdowns are unique to flowage systems as it is infeasible to significantly dewater natural lakes. Many flowages have used water-level drawdowns to assist in controlling nuisance aquatic plants as well as to specifically target certain aquatic invasive species. As briefly

mentioned in the Primer subsection of the of the Aquatic Plant section, the primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation (drying out) and either heating or freezing depending on the timing of the treatment.

It is believed that a winter drawdown could be ecologically beneficial for the Phillips Chain, specifically Wilson Lake, by reducing the EWM population. Greenhouse studies conducted by Stanley (1976) found that the biomass of dewatered EWM shoots and roots decreased by 99% when exposed to temperatures just below freezing for 96 hours. In addition, EWM plants that were left submersed (10 cm of water) and exposed to subfreezing temperatures for 96 hours saw a 35% decrease in biomass (Stanley 1976). Compared to many of Wisconsin's native aquatic plants which overwinter via turions (vegetative reproductive structures), seeds, or tubers, EWM generally overwinters as a whole plant. Because of this, it is believed that winter drawdowns would have a greater impact on EWM, especially in dewatered and shallow areas (Olson et al. 2012). Nearby Lac Sault Dore (Soo) Lake conducted a drawdown during the winter of 2010-2011 resulting in lowered EWM populations for nine years and counting.

While there are many benefits to water-level drawdowns, there are disadvantages as well. Drawdowns can have negative ecological consequences, such as impacts to the valuable native plant community. As discussed in the Fisheries Data Integration Section (3.6), drawdowns can also greatly decrease fish populations, as many fish will leave the lake if possible or be aggregated in small pools that are vulnerable to predation and overfishing. In the case of Wilson Lake, the short-term fisheries impacts may reset the fish community and actually be beneficial to the long-term health of the fishery. However, the ability to fish on Wilson Lakes is important to many people in the community, especially during the winter. Based upon the results of the stakeholder survey, respondents were not overly supportive of a drawdown, with approximately 48% support (pooled *highly supportive* and *moderately supportive*) (Figure 3.4-20, right frame).

The PCOLA believes that implementing a winter-long water level reduction is the most effective, ecological, and lowest cost management approach for reducing nuisance levels of aquatic plants, particularly EWM in Wilson Lake. However, current community opposition to this management activity forces PCOLA to consider mechanical harvesting and herbicide treatment as short-term alternatives, as discussed in the following management actions. The PCOLA will continue to investigate and determine ways to overcome implementation challenges like those identified below and investigated as part of the stakeholder riparian survey (Figure 5.0-1):

- Increased public support
- Impacts on municipal water supply wells
- Impacts to non-complying private landowner wells
- Needed extension of wastewater treatment outfall pipe
- Impacts to the fisheries
- Impacts to business revenue during dewatered period (i.e. tourism)
- Impacts to recreation during dewatered period
- Potential environmental impacts

Question 38: What is the reason or reasons you would oppose a water level drawdown?

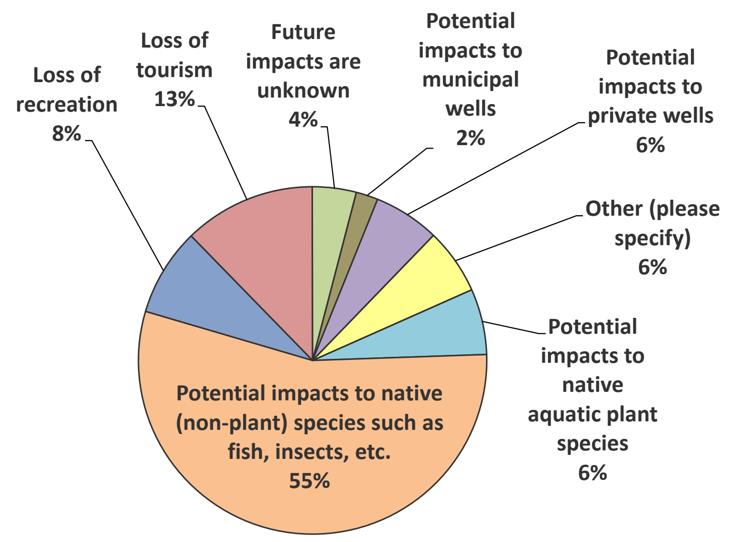


Figure 5.0-1. Select survey responses from the Phillips Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Action Steps:

See description above.

<u>Management Action:</u>	Continue to investigate mechanical harvesting potential
Timeframe:	Ongoing
Facilitator:	PCOLA Board of Directors
Description:	Within the previous lake management plan (June 2011), the PCOLA investigated mechanical harvesting as an option if herbicide management of EWM was unsuccessful and/or if native plants continue to cause nuisance conditions. As with all aquatic plant management techniques, harvesting has its advantages and disadvantages. Advantages include the removal of

plants and associated nutrients from the waterbody, immediate relief of nuisance plants, harvesting is less controversial than chemical use, and specific areas can be targeted accurately. Disadvantages include sediment re-suspension, fragmentation of plants, need for repeated events within a single year, and no ability to select specific plant species for treatment. Mechanical harvesting in areas that contain aquatic invasive species may increase the rate of spread of these species as it increases cut fragments to other parts of the system. With EWM occurring in almost all areas of Wilson Lake, this concern is not substantiated as natural auto-fragmentation of this species is likely a much greater contributor to its spread about the lake.

Aside from some specific areas on Elk and Long lakes, nuisance levels of aquatic plants from the chain are confined to Duroy and Wilson Lake. Duroy Lake is relatively unpopulated and users are often able to avoid these areas. On the opposite end of the spectrum, Wilson Lake is fairly well-developed and contains numerous resorts. A map of potential mechanical harvesting lanes was included within the previous lake management plan (June 2011). This included approximately 33,000 linear feet of a 20-ft wide lane which equates to about 15 acres.

Based upon the results of the stakeholder survey, approximately 60% of respondents support (pooled *highly supportive* and *moderately supportive*) mechanical harvesting (Appendix B, Question #36). The PCOLA supports reasonable and environmentally sound actions to facilitate navigability on Wilson Lake. These actions target nuisance levels of aquatic plants in order to benefit watercraft navigation patterns. Reasonable and environmentally sound actions are those which meet WDNR regulatory and permitting requirements and do not impact any more shoreland or lake surface area than absolutely necessary.

The PCOLA will continue to investigate mechanical harvesting as an aquatic plant management tool on the system, particularly Wilson Lake. Mechanical harvesting services can be contracted, or the equipment can be owned and operated by the association. Unfortunately, there are few contracting firms in this part of Wisconsin and many contain equipment that may be too large for use on Wilson Lake. The PCOLA will conduct a feasibility study where they will investigate contracted vs purchased mechanical harvesting options.

The bulleted list below outlines the WDNR's Mechanical Harvesting Permit guidelines that will need to be considered while investigating mechanical harvesting, as they will be conditions of a potential future permit.

- Harvesting locations are limited to areas specifically delineated on permit map, to accompany WDNR permit submission. Mechanical harvesting will only be allowed in the areas

	specified in the permit and may be revised upon WDNR approval in subsequent years. Onboard GPS may be required. • Harvesting should occur only at depths greater than 3 feet of water and cutting head should always be at least 1.5 feet off bottom. • Submerged plants are the target for the activity and removal of (e.g. bulrushes) and floating-leaf (e.g. water lilies) species needs to be limited because of their ecological value and niche occupation. • Aquatic plants that are cut must be removed from the water, with special care in removing EWM and CLP fragments and turions. • Dislodged aquatic plant *floaters* can be picked up using the mechanical harvester in its shallowest setting. This effort needs to be accounted for in summary reports. • Harvesting operations shall not disturb spawning or nesting fish. No harvesting of native species shall occur before June 1st to preserve muskellunge spawning habitat. Harvesting shall be done in a manner to minimize accidental capture of fish. Any game fish accidentally captured shall be released immediately. Attempts should be made to release all other species. • Reports summarizing harvesting activities shall be given to the Department by November 30, each harvesting season. The report shall include a map showing the areas harvested, the total acres harvested and the total amount of plant material removed from the body of water. The report shall also include a summary of the composition and quantity of plants removed. This can be done by recording the daily percent of the total of individual species harvested (primary species that are causing the need for harvesting), and then calculating the pounds harvested per day. At the end of the month, you can then calculate the percentage and weight of all species harvested.
Action Steps:	
	See description above.

Management Action:	Conduct herbicide management actions towards Eurasian watermilfoil
Timeframe:	Ongoing
Facilitator:	PCOLA Board of Directors
Description:	Eurasian watermilfoil (EWM) management is a quickly evolving field. The PCOLA has participated in the forefront of field research, specifically when engaged with the WDNR, US Army Corps of Engineers Research and Development Center (USACE), and Onterra as a part of the 2012 whole-lake 2,4-D treatment on Wilson Lake.

Volunteers from the PCOLA collected water samples and funded the local share of professional vegetation monitoring surveys on evaluate the efficacy and selectivity of the chemical control strategy. This treatment resulted in multiple years of reduced EWM population. Particularly vulnerable native aquatic plant species were also impacted by this treatment but have largely recovered to date.

In contrast to the whole-lake treatments, some of the herbicide spot treatments failed to meet managers expectations. The unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with WDNR regulators. This is particularly true in areas of increased water exchange via flow or when traditional weak-acid herbicides like 2,4-D have been used.

In recent years there has been a change in preferred strategy amongst many lake managers and regulators when it comes to established EWM populations. Instead of chasing the entire EWM population with management, perhaps focusing on the areas that are causing the largest impacts can be more economical and cause less ecological stress. The WDNR supports using the management method that will impart the least stress on the overall ecosystem.

As a part of the planning process, the PCOLA Planning Committee discussed aquatic plant management alternatives such as mechanical harvesting of nuisance conditions. It is likely that mechanical harvesting could reduce the nuisance conditions in Wilson Lake. However, shallow water and high number of obstacles (i.e. stumps, woody debris) exist within many of the targeted management areas in Wilson Lake that would preclude a mechanical harvester from operating in many areas.

The PCOLA believes herbicide management is logistically feasible and contains fewer implementation challenges than winter drawdown or mechanical harvesting. The association developed the following trigger for EWM management that balances financial and ecological costs with benefit received:

Herbicide spot treatment would be considered when the following criteria are met:

1) *colonized areas of EWM with a density of dominant or greater and are impacting navigation/recreation within the lake*
2) *are of sufficient size and not within areas of higher water exchange where herbicide effectiveness is questioned*
3) *consider basin-wide concentrations, approaches, and chemistries when appropriate*

If the PCOLA's trigger is reached, they would start educating themselves on what is considered the current best management practice (BMP) for EWM herbicide management. This would likely include devising a strategy where a sufficiently large treatment area can be constructed to hold concentration and exposure times for exposed sites.

Future spot herbicide treatments may consider herbicides thought to be effective under short exposure situations. At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike™) are examples of herbicides with reported short exposure time requirements that are employed for invasive watermilfoil control in Wisconsin.

Protected areas would consider additive impacts within an Area of Potential Impact (AOPI), such that if levels reach whole-basin concentrations, they are accounted for in the treatment and monitoring strategy.

Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile.

If PCOLA decides to pursue future herbicide management towards EWM, the following set of bullet points would occur:

- Early consultation with WDNR would occur.
- The preceding annual AIS monitoring report or official email narrative report would outline the precise control and monitoring strategy.
  - Monitoring EWM efficacy by comparing annual late-summer EWM mapping surveys.
  - If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016)* – *Click Here*

    This generally consist of collecting quantitative point-intercept sampling on sites or AOPI before the treatment (pre) and summer following the treatment (post) corresponding to the anticipated scale of the treatment. Herbicide concentration monitoring may also occur surrounding the treatment in these instances.
- An herbicide applicator firm would be selected in late-winter and a conditional permit application would be applied to the WDNR.

	• Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would likely occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June), active growth tissue is confirmed on the target plants, and is after Native American open-water spear harvest has concluded. A focused pretreatment survey would take place approximately a week or so prior to treatment. This site visit would evaluate the growth stage of the EWM (and native plants) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments and dictate approximate ideal treatment timing. *Short-Term EWM Management Plans:* The PCOLA considered an herbicide spot treatment for spring of 2021 with florpyrauxifen-benzyl (ProcellaCOR™) within the southern basin of Wilson Lake. Although the treatment targeted a specific area of dense EWM, basin-wide concentrations and potential outcomes were conveyed. The PCOLA initiated a teleconference with WDNR lakes biologist (Carol Warden), and Onterra (Eddie Heath). The PCOLA opted to postpone herbicide management until spring 2022, allowing the management planning project to be completed and for WDNR grant funds to be sought. During fall of 2021, the PCOLA applied for a WDNR AIS Control Grant for a 2-year project aimed at managing the EWM population on Wilson Lake. The PCOLA aims to bring the EWM population down through strategic herbicide spot treatments that may have basin-wide potential. High use areas would be targeted and follow-up hand-harvesting would be conducted as part of their IPM framework. The project would include proper assessment of the management activities as well as distributable reporting.
Action Steps:	
	See description above.

Management Action:	Conduct hand-harvesting (including DASH) management actions towards Eurasian watermilfoil
Timeframe:	Ongoing
Facilitator:	PCOLA Board of Directors
Description:	The PCOLA would consider contracted hand-harvesting efforts, potentially with diver-assisted suction harvesting (DASH) equipment, as part of their Integrated Pest Management Plan in the three following ways:

New, emerging EWM populations

While established populations exist in Duroy and Wilson lakes, Long and Elk lakes contain little EWM. If new EWM occurrences are identified in this system and may have the ability to establish, the PCOLA would consider hand-harvesting population control measures. Hand-harvesting and DASH are most appropriate for managing small and low density EWM populations. The dark stained water, heavy native plant biomass, and obstructions (i.e. woody debris and stumps) complicate the ability of hand-harvesting to be an effective management strategy, so the PCOLA will objectively review these efforts to make sure they are commensurate with the costs.

Following large-scale management

Many lake groups initiate large-scale management actions, such as large-scale herbicide treatment or winter water drawdown with the intention of implementing smaller-scale control measures (herbicide spot treatments, hand-removal) when EWM begins rebounding. The PCOLA would give preference to non-herbicide control measures between large-scale management efforts.

Occasionally, the EWM rebounds in a fashion that does not lend well to these methods. If the rebounded EWM population exceeds a level that can be controlled using best management practices, the PCOLA will transition to a management goal to "Let Nature Take its Course" and not conduct coordinated active management until it again exceeds the predefined thresholds to trigger larger-scale active management.

Nuisance management

If large and contiguous EWM colonies exist and other active management activities are not being conducted, removing EWM in navigation lanes through hand-harvesting, likely with DASH, may provide temporary relief. The PCOLA would likely defer the costs of conducting the hand-harvesting to the benefitting riparians, but would be involved with aggregating riparian interest, selecting the hand-harvesting firm, and applying for WDNR permits if applicable.

Action Steps:

See description above.

Management Goal 5: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality parameters through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort, but requires program renewal
Facilitator:	PCOLA Board of Directors
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends may lead to the reason of why the trend is occurring. Volunteer water quality monitoring through the Citizen Lake Monitoring Network (CLMN) has occurred in the past on Elk Lake (2000-2005), Long Lake (1990-1993), and Wilson Lake (1998-2008); data has not been collected from Duroy Lake. The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The CLMN contains two water quality monitoring programs, one where the volunteer collects Secchi disk transparency and an advanced CLMN program where water chemistry samples would also be collected (chlorophyll-*a* and total phosphorus). During both of these programs, samples would be collected three times during the summer and once during the spring. The PCOLA will work with the WDNR to receive the proper training and resume participation in the collection of Secchi disk transparency data on all four lakes, likely through separate volunteers. Following a few years of consistent data collection, the PCOLA would be placed on the waiting list for entrance into the advanced CLMN program that includes the collection of water chemistry data. It also must be noted that the CLMN program may be changing in the near future with sample analysis cost coverage not available annually. Recently there has been a move to have new CLMN volunteers collect samples for three years and then stop so that additional lakes can be funded. If a long-term record is desired by the PCOLA then it will be important to maintain the volunteer data collection without a lapse.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to association members during annual meeting.
2.	CLMN volunteer and/or board would facilitate new volunteer(s)

Management Action:	Educational initiative aimed at raising awareness of blue-green algae blooms on Phillips Chain
Timeframe:	Continuation of current effort.
Facilitator:	PCOLA Board of Directors
Description:	Many species of blue-green algae can naturally be found in Wisconsin waters. Like 'true' algae, cyanobacteria or blue-green algae are able to convert sunlight into energy through the process of photosynthesis. Unique to blue-green algae, they are able to extract nitrogen gas from the air and make it usable. Other species of true-algae need to rely on nitrogen available within the water column. Like algae, blue-green algae blooms are associated with increased nutrient levels. Additional information relating to blue-green algae can be found on the WDNR's website: https://dnr.wisconsin.gov/topic/lakes/bluegreenalgae Some species of blue-green algae can produce toxins potentially dangerous to people and animals. Exposure to these toxins occurs can be from ingestion of water, skin contact, and by inhaling aerosolized water droplets. The largest risk of exposure consists of swallowing water containing the toxins, usually during water-sporting activities. Symptoms include nausea, vomiting, diarrhea and in severe cases, liver failure or paralysis. Skin contact with algae can produced blistering of the exposed skin. Allergy-like symptoms including coughing, watery eyes, and nose/throat irritation are most commonly associated when wind and motor boat activity cause the toxins to become aerosolized. Because dogs and other domestic animals actively drink water from lakes, these symptoms can be much more developed and can lead to death in some instances. If you suspect an illness, either from a human or an animal, the case should be reported to the Wisconsin Department of Health Services: https://www.dhs.wisconsin.gov/water/bg-algae/index.htm Please note that this resource solely collects information for tracking blue-green algae outbreaks within the state. Individuals or animals experiencing severe symptoms should consult the appropriate medical attention immediately. The PCOLA will include educational information about blue-green algae and the potential risks related to their toxins within materials distributed to association members. If blue-green algae blooms are observed on Phillips Chain in the future, the PCOLA may decide to have samples collected. Blue-green algae samples can be shipped to the Wisconsin State Laboratory of Hygiene for toxin analysis. The

	cost of the analysis is approximately $400 a sample. Even if toxic blue-green algae are confirmed, there are no control measures that can be taken to remove the algae. Simply limiting exposure during an algae bloom and waiting for the bloom to dissipate is all that can be done. In this instance, the PCOLA would distribute information to association members informing them to limit their use of the lake during the bloom. Although the investigations would not indicate if toxins are present, the PCOLA may try to identify an entity, private citizen, or high school teacher than would have access to a microscope and could identify if cyanobacteria species are present in a water sample.
Action Steps:	
	See description above.

Management Goal 6: Improve Lake and Fishery Resource

<u>Management Action:</u>	Facilitate connecting LNLD members with Healthy Lakes & River Grants
Timeframe:	Summer 2021
Facilitator:	PCOLA Board of Directors
Description:	As discussed in the Shoreland Condition Section (3.3), the Healthy Lakes & Rivers Grant program provides cost share for implementing the following best practices: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program are included within the Shoreland Condition Section (3.3) and can be found at: https://healthylakeswi.com The PCOLA would focus specific education on the importance of shoreland condition and the resources that are available (planning and funding). Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative.
Action Steps:	
	See description above

Management Action:	Continue *Fish Sticks* program
Timeframe:	Summer 2021
Facilitator:	Bill Ruff, with Board of Directors oversight
Description:	As discussed within the previous management action, *fish sticks* are one of the practices available for cost share through the Healthy Lakes and Rivers Grant program. The PCOLA has been creating fish stick habitat for over 5 years, either by felling trees that were already growing near the water's edge or bringing in trees to create more cover for fish and other aquatic life. Since the start of this effort, the volunteer team has paced 69 structures across 20 sperate properties. The PCOLA would continue advertising the *Fish Stick* program, soliciting riparians willing to install these structures. The PCOLA would investigate future funding sources, including the Healthy Lakes and Rivers Grant program and opportunities from Price County.
Action Steps:	
	See description above

Management Action:	Protect natural shorelines
Timeframe:	Summer 2021
Facilitator:	PCOLA Board of Directors
Description:	Approximately 59% of the Phillips Chain of Lake shoreline is *natural/undeveloped.* While a portion of this shoreline is already protected by being owned a Township, County, or the State of Wisconsin, the privately owned areas could be the focus of preservation efforts. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Valuable resources for this type of conservation work include the WDNR, UW-Extension, and Zoning & Land Conservation Department. Several websites of interest include: • Conservation easements or land trusts: (www.northwoodslandtrust.org) • UW-Extension Shoreland Restoration: (https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/ecology/shoreland/default.aspx)

	- WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/) WDNR land acquisition grants are available to pay for the costs of property purchases and conservation easements. Kevin Gauthier (WDNR lakes biologist) or Jill Sunderland (WDNR environmental grants specialist) can be contacted with questions about this specific grant program.
Action Steps:	
	See description above

<u>Management Action:</u>	Investigate initiating a Loon Watch program
Timeframe:	As applicable if volunteerism exists
Facilitator:	PCOLA Board of Directors
Description:	The PCOLA has passively monitored Loon activity and has interest in enrolling in the official Loon Watch Program in conjunction with the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide an understanding of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. This program could also involve the placement of artificial loon nesting platforms. If a volunteer or set of volunteers emerge, the PCOLA would facilitate the enrollment within the Loon Watch Program. The PCOLA would also share results related to sightings and other metrics associated with this program within the newsletter and at annual meetings.
Action Steps:	
	See description above

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Nokomis and Bridge lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deep hole location in the lake that would most accurately depict the conditions of the lake. Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S – 3 feet below surface) and near bottom (B – 3 feet above bottom). 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 - *a*	●		●		●		●		●			
Total Nitrogen	●	●			●	●					●	●
True Color	●				●							
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Hardness	●				●							
Total Suspended Solids	●	●			●	●			●	●		
Calcium	●				●							

In addition, during each sampling event Secchi disk transparency was recorded and a temperature and dissolved oxygen profile was completed using a HQ30d with an LDO probe.

Watershed Analysis

The watershed analysis began with an accurate delineation of the lakes' drainage areas using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD – Fry et. al 2006) were then combined to determine the watershed land cover classifications as part of the *Comprehensive Management Plan for Lake Nokomis* (2010). These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003).

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on the Rice Reservoir to characterize the existing communities within the lakes and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) has been used to complete this study a number of times since 2005. The 2019 point-intercept survey of all lakes was conducted on the Phillips Chain on July 23-24 by Onterra.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*

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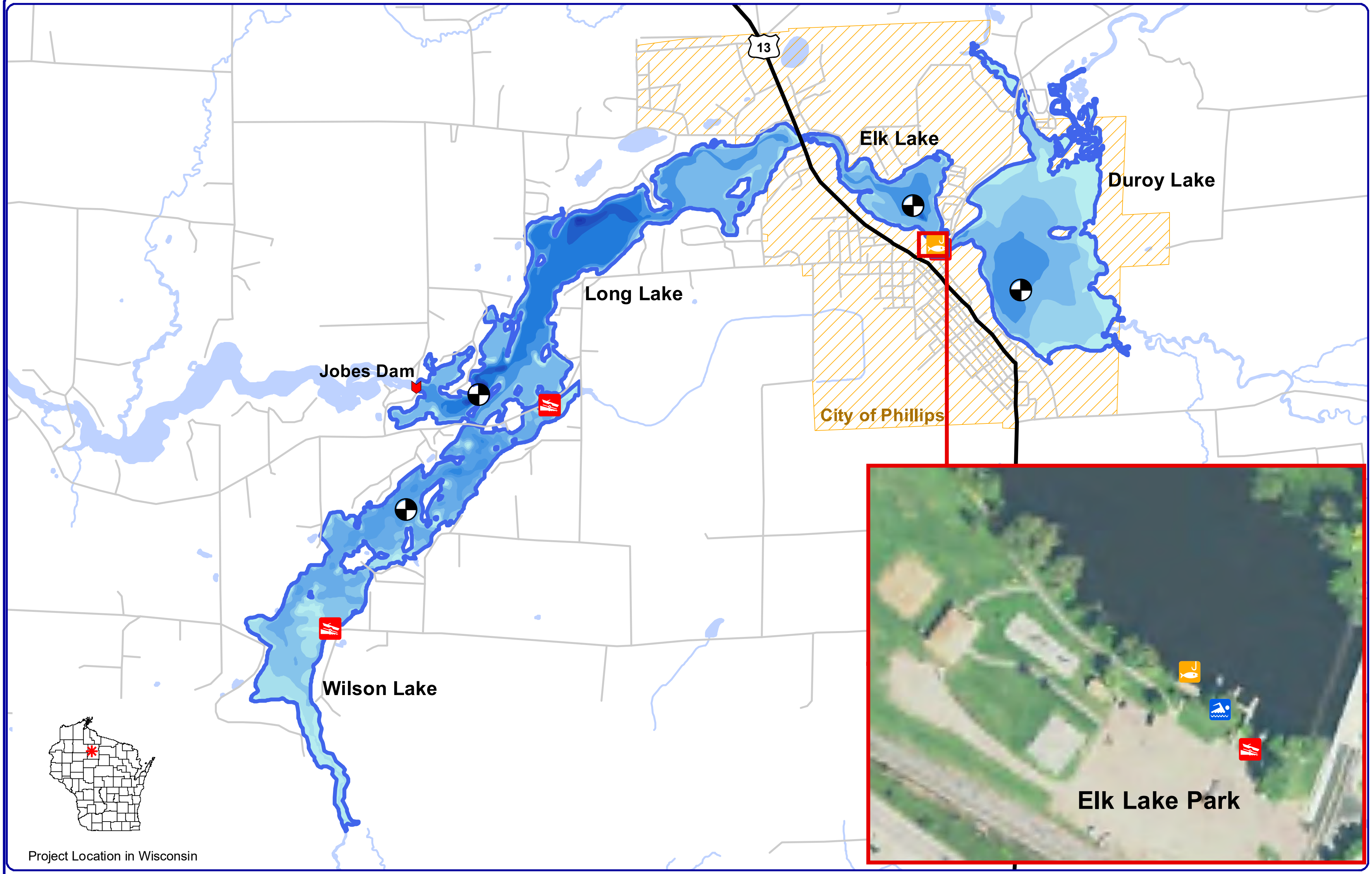

N
W E
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3,400
Feet

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

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, Digitized by Onterra
Orthophoto: NAIP, 2018
Map Date: August 11, 2020 - EJH

Legend

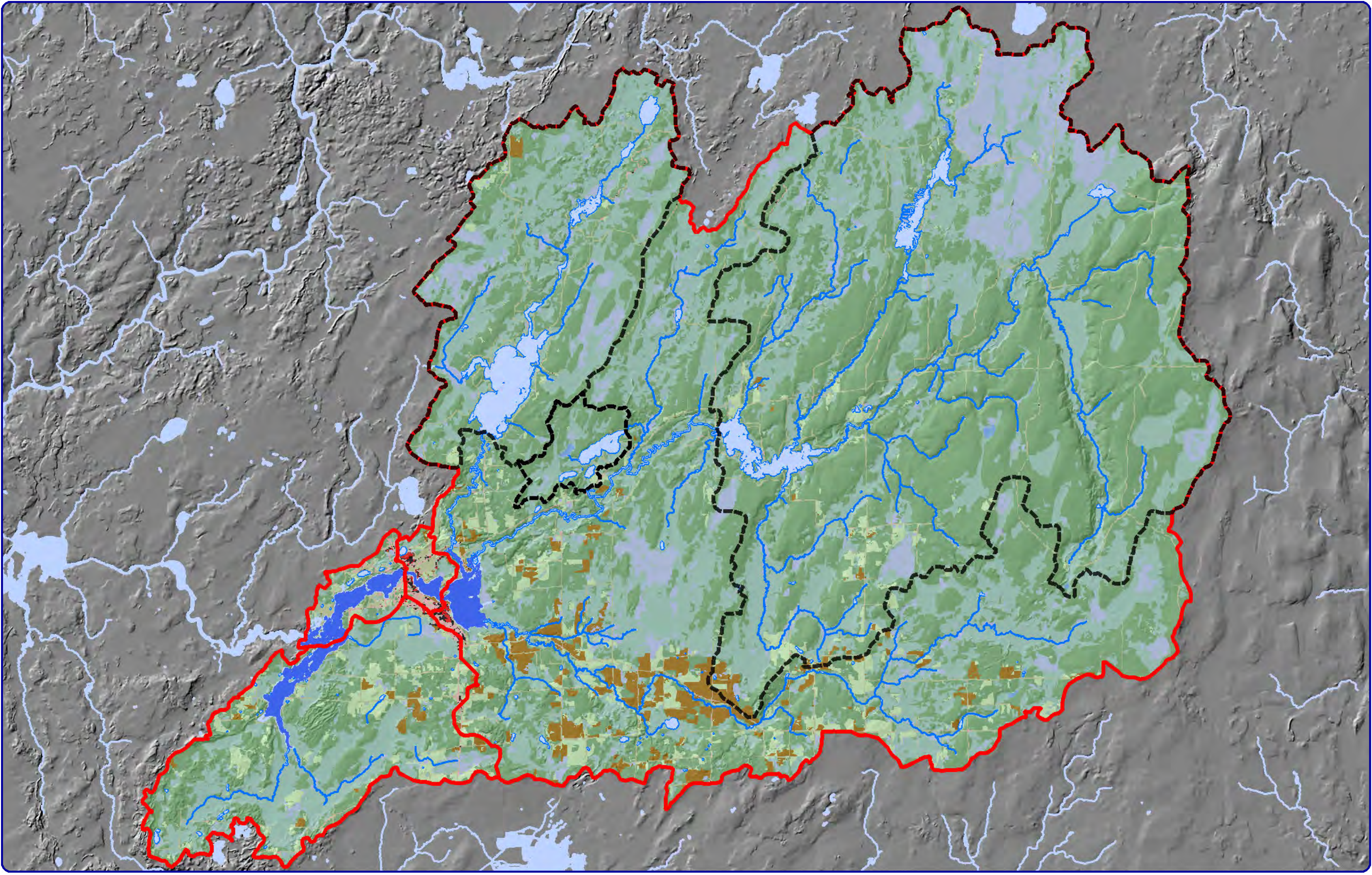
- Phillips Chain~ 1216 total acres *WDNR Definition*
- ◐ Water Quality Sampling Location
- 🟥 Dam
- 🟥 Public Access
- 🟦 Swimming Beach
- 🟧 Fishing Pier

Map 1

Phillips Chain

Price County, Wisconsin

Project Location & Lake Boundaries



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Sources:
Hydro: WDNR
Bathymetry: WDNR/Onterra, 2015
Orthophotography: NAIP 2017
Land Cover: NLCD, 2016
Watershed Boundaries: Onterra, 2020
Map date: January 22, 2020 JMB
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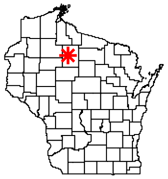


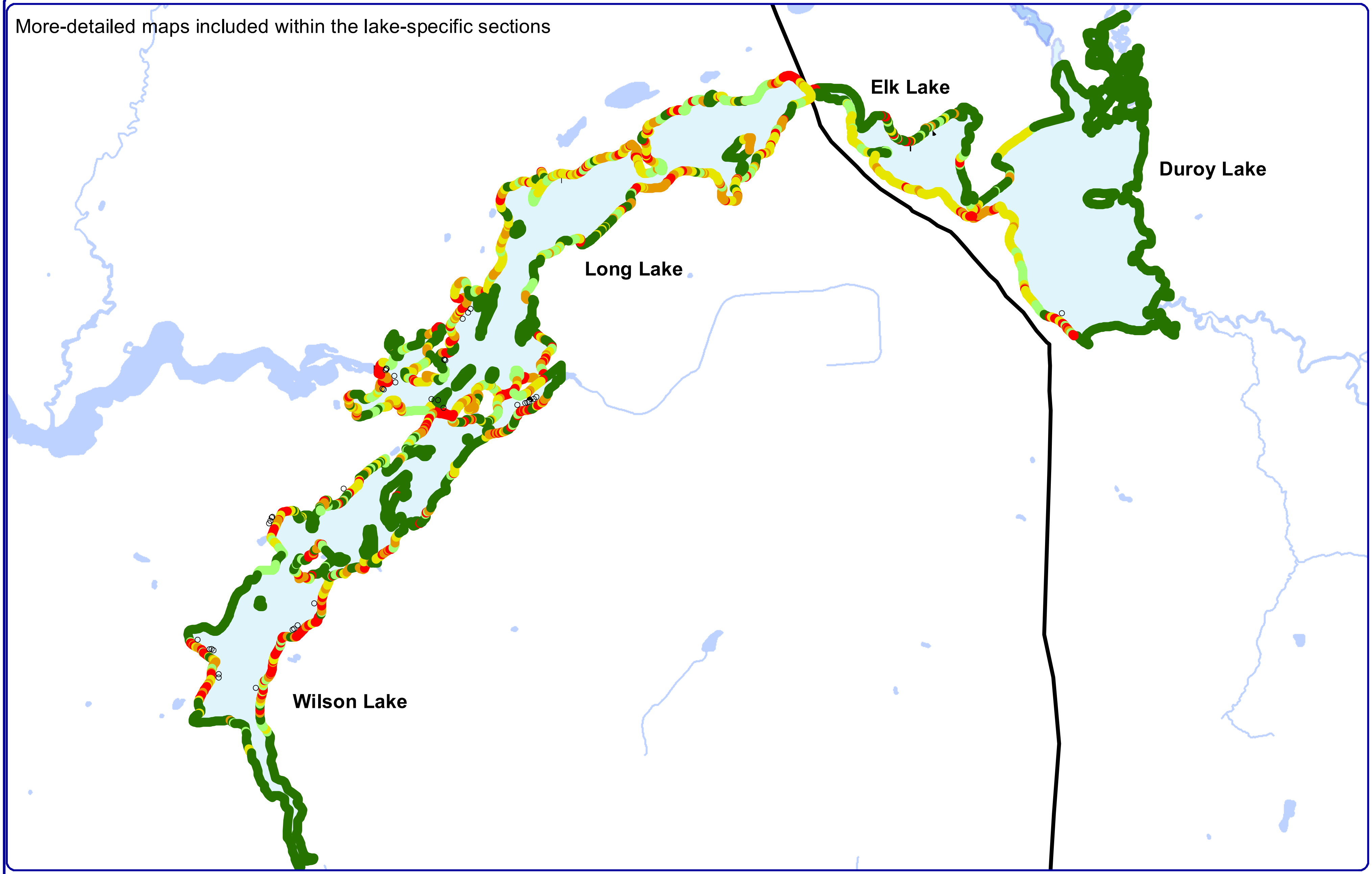
Project Location in Wisconsin

Legend

🟩	Forest	🟩	Rural Open Space
🟩	Forested Wetlands	🟦	Wetland
🟩	Pasture/Grass	🟦	Open Water
🟫	Row Crop Ag.	🟥	Rural Residential

🟥 Watershed Boundary
⬛ Subwatershed Boundary

Map 2
Phillips Chain O' Lakes
Price County, Wisconsin
Watershed Boundaries & Land Cover Types



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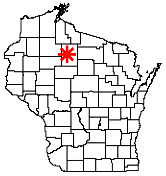
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, Digitized by Onterra
Vegetation: Onterra, 2019
Map Date: August 11, 2020 - EJH


Project Location in Wisconsin

Legend

- 🟩 Natural/Undeveloped
- 🟩 Developed-Natural
- 🟨 Developed-Semi-Natural
- 🟧 Developed-Unnatural
- 🟥 Urbanized

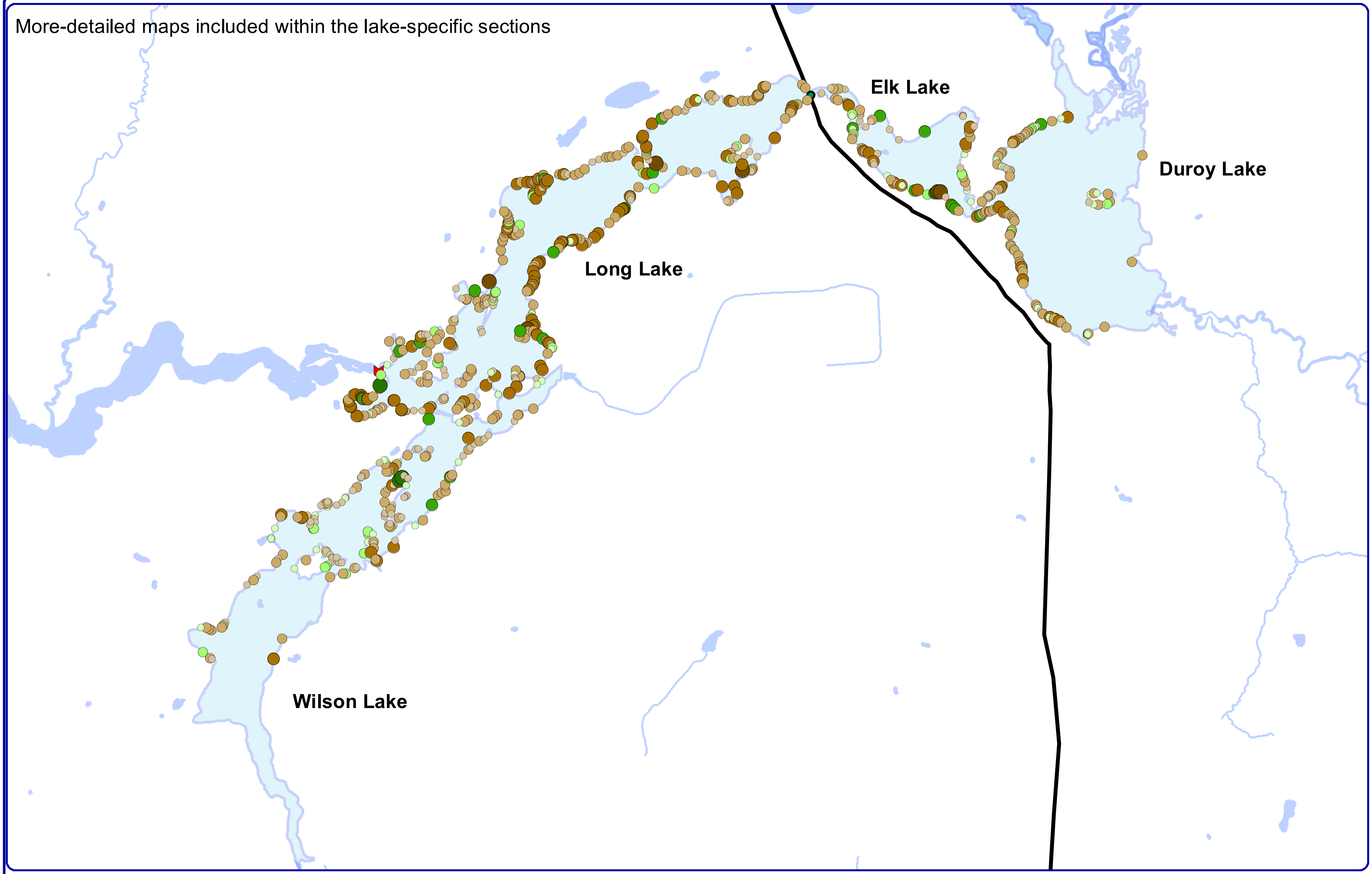
Seawall Modifier

- ▬ Masonary/Metal/Wood
- ○○○ Rip-Rap/Placed Stone

Map 3
Phillips Chain
Price County, Wisconsin

Shoreland Condition Assessment

More-detailed maps included within the lake-specific sections



Legend

2-8 Inch Pieces	8+ Inch Pieces
● No Branches	● No Branches
● Minimal Branches	● Minimal Branches
● Moderate Branches	● Moderate Branches
● Full Canopy	● Full Canopy


Project Location in Wisconsin

Map 4
Phillips Chain
Price County, Wisconsin

Coarse Woody Habitat

Onterra, LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
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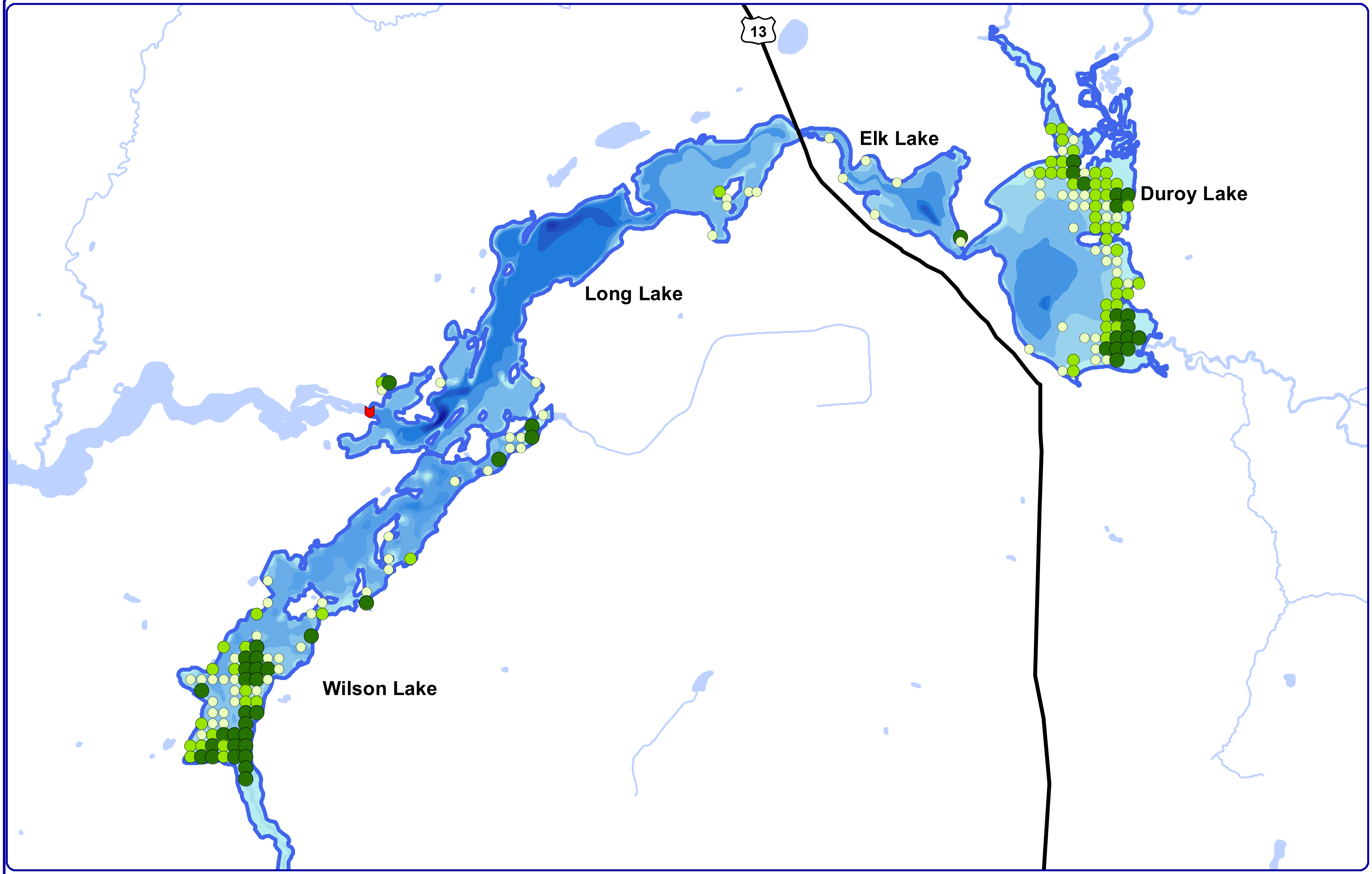
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR, Digitized by Onterra
Vegetation: Onterra, 2019
Map Date: August 11, 2020 - EJH



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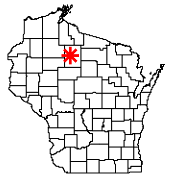

Project Location in Wisconsin

Legend

● Total Rake Fullness = 1
● Total Rake Fullness = 2
● Total Rake Fullness = 3

Map 5
Phillips Chain
Price County, Wisconsin
2019 PI Survey: Aquatic Vegetation Distribution

8.0 INDIVIDUAL LAKE SECTIONS

The remainder of this plan will investigate the data on a lake-by-lake basis. Some of the text may seem redundant if one reads each lake section. However, this is intentional to ensure the information is portrayed to those who only read the chain-wide section and their individual lake-specific section.

Methodology, explanation of analysis and scientific background are contained within the Chain-wide Management Plan document (Section 3.0).

8.1.0 Duroy Lake Introduction

Duroy Lake, Price County, is a drainage lake with a maximum depth of 18 feet and a surface area of 375 acres. This eutrophic lake has an extremely large watershed when compared to the size of the lake. Duroy Lake contains 37 native plant species, of which Northern wild rice was the most common in 2019. Three exotic plant species were observed in 2019 - Eurasian watermilfoil, curly-leaf pondweed, and purple loosestrife.

Field Survey Notes

Duroy Lake is known as a good lake for fishing. With the very low number of residences around Duroy Lake, much of the perimeter is natural, undisturbed shoreline, some of which borders valuable wetland habitat. Duroy Lake contains Northern wild rice which is of great cultural significance to the Ojibwe, as well as provides food and habitat for wildlife and a spawning site for fish.

Photograph 8.1.0-1. Duroy Lake, Price County.

Lake at a Glance* – Duroy Lake

Morphology	
Acreage	375
Maximum Depth (ft)	18
Mean Depth (ft)	5.1
Volume (acre-feet)	1,914
Shoreline Complexity	13.6
Vegetation	
Number of Native Species	36
Threatened/Special Concern Species	None
Exotic Plant Species	EWM, PL, CLP
Simpson's Diversity	0.93
Average Conservatism	7.0
Water Quality	
Wisconsin Lake Classification	Shallow lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Transitional
Watershed to Lake Area Ratio	300:1

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

8.1.1 Duroy Lake Water Quality

Water quality data was collected from Duroy Lake on six occasions in 2019/2020. 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) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Wisconsin DNR staff monitored the lake in 1996 and 2000 for total phosphorus, chlorophyll-*a*, and Secchi disk clarity. All of the lakes in the Phillips Chain have very short hydraulic residence times (all except Wilson Lake less than 14 days) which in the classification scheme of the Wisconsin Department of Natural Resources makes these water bodies officially *impounded flowing waters.* For phosphorus standards, the value for rivers (100 µg/L) is used. The reason for this classification is that with the short residence times, the water quality of these water bodies is mostly reflective of the water quality of the incoming Elk and Little Elk rivers and Squaw Creek. The short residence times also mean that in lake processes have little impact on the lake's water quality. Because there are not comparables for impounded flowing waters, for this report, Duroy Lake will be treated as a lake when comparing its water quality to other lakes within the ecoregion and state wide.

Duroy Lake Trophic Parameters

Near-surface total phosphorus data from Duroy Lake are available for 1996, 2000, and 2019 (Figure 8.1.1-1). The weighted summer average total phosphorus concentration is variable ranging from 41 to 67 µg/L, likely as a result of differences in concentrations in the Elk and Little Elk rivers. The weighted summer average is 57.9 µg/L and falls into the *fair* category for shallow lowland drainage lakes in Wisconsin. Duroy Lake's summer average total phosphorus concentrations are much higher than the median values for both shallow lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion. The elevated phosphorus levels are not surprising as the lake has such a short residence time. The phosphorus concentrations are much less that the phosphorus standard for rivers which is 100 µg/L.

Chlorophyll-*a* data are available from Duroy Lake for the same years as phosphorus, i.e. 1996, 2000, 2019 (Figure 8.1.1-2). Like the weighted average summer phosphorus concentrations, there is a range of chlorophyll-*a* concentrations. Duroy Lake's summer average chlorophyll-*a* concentration is 12.0 µg/L and falls into the *good* category for shallow lowland drainage lakes in Wisconsin. Although Duroy Lake's summer average chlorophyll-*a* concentrations are higher than the median value for shallow lowland drainage lakes in the state and higher than the median value for all lake types in the NLF ecoregion, they are closer than the phosphorus concentrations. This is because with the short residence time in the lake, algae does not have time to significantly increase in the lake over concentrations in the rivers.

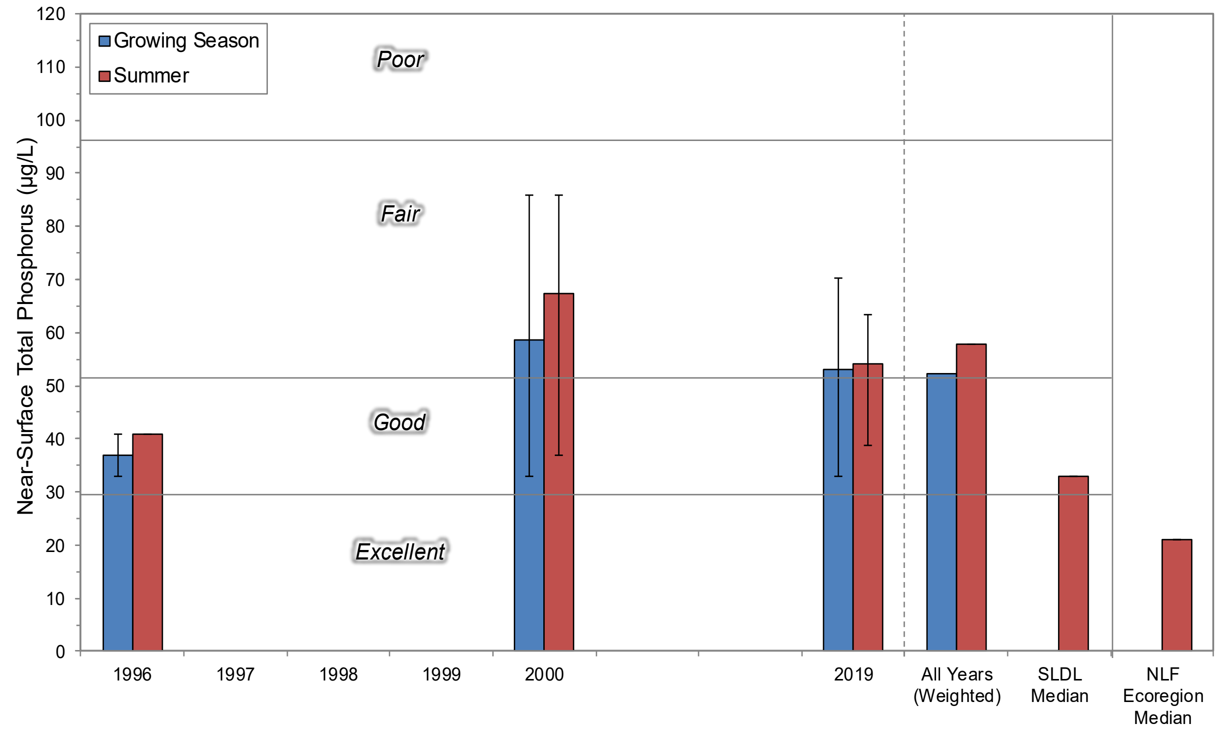


Figure 8.1.1-1. Duroy Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

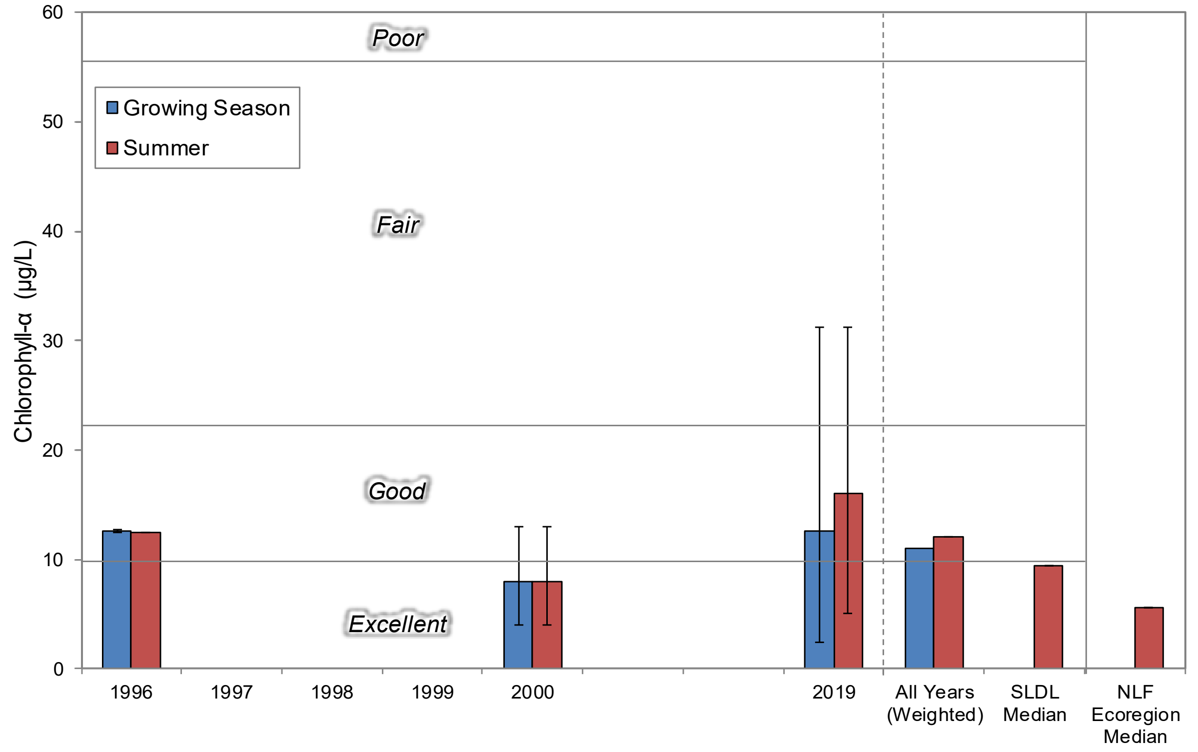


Figure 8.1.1-2. Duroy Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Secchi disk transparency data are available from Duroy Lake for the same years as phosphorus and chlorophyll-*a*, i.e. 1996, 2000, 2019 (Figure 8.1.1-3). Like the weighted average summer phosphorus and chlorophyll-*a* concentrations, there is a range of Secchi disk transparencies, ranging from 2.6 to 4.0 feet. The weighted summer average Secchi disk depth is 3.1 feet and falls onto the border between the *good* and *fair* categories for shallow lowland drainage lakes in Wisconsin. Duroy Lake's weighted summer average Secchi disk depth transparency is a little less the median values for both shallow lowland drainage lakes in the state and for all lake types in the NLF ecoregion.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured in Duroy Lake in 2019 averaged 90 SU (standard units) indicating the lake's water is *highly tea colored* and that the lake's water clarity is likely influenced by dissolved components in the water. This value suggests that the reason the Secchi disk transparency is not as good as expected given the chlorophyll-*a* concentrations.

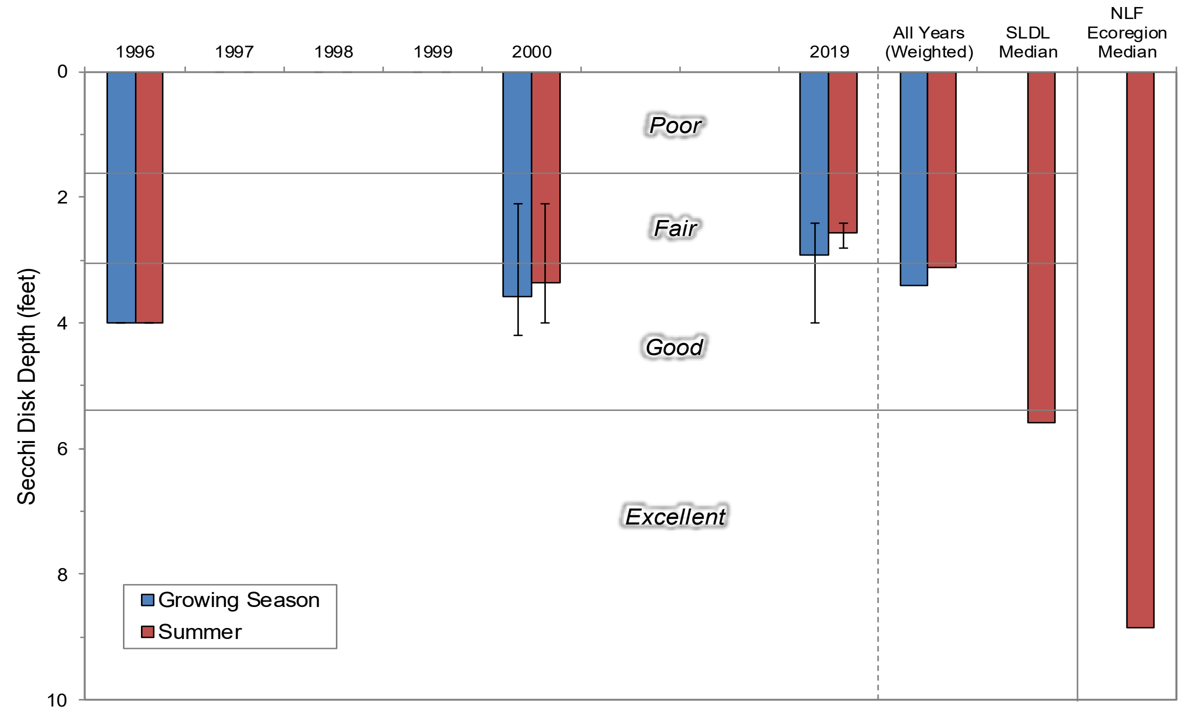


Figure 8.1.1-3. Duroy Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Limiting Plant Nutrient of Duroy Lake

Using midsummer nitrogen and phosphorus concentrations from Duroy Lake in 2019, a nitrogen:phosphorus ratio of 14:1 was calculated. This finding indicates that Duroy Lake is in the transitional zone where the algae may be nitrogen or phosphorus limited. In general, research has shown that cutting phosphorus inputs in these types of lakes will limit plant growth within the lake.

Duroy Lake Trophic State

Figure 8.1.1-4 contains the Trophic State Index (TSI) values for Duroy Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Duroy Lake indicate the lake is at present in an eutrophic state. Duroy Lake's productivity is higher when compared to both other shallow lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

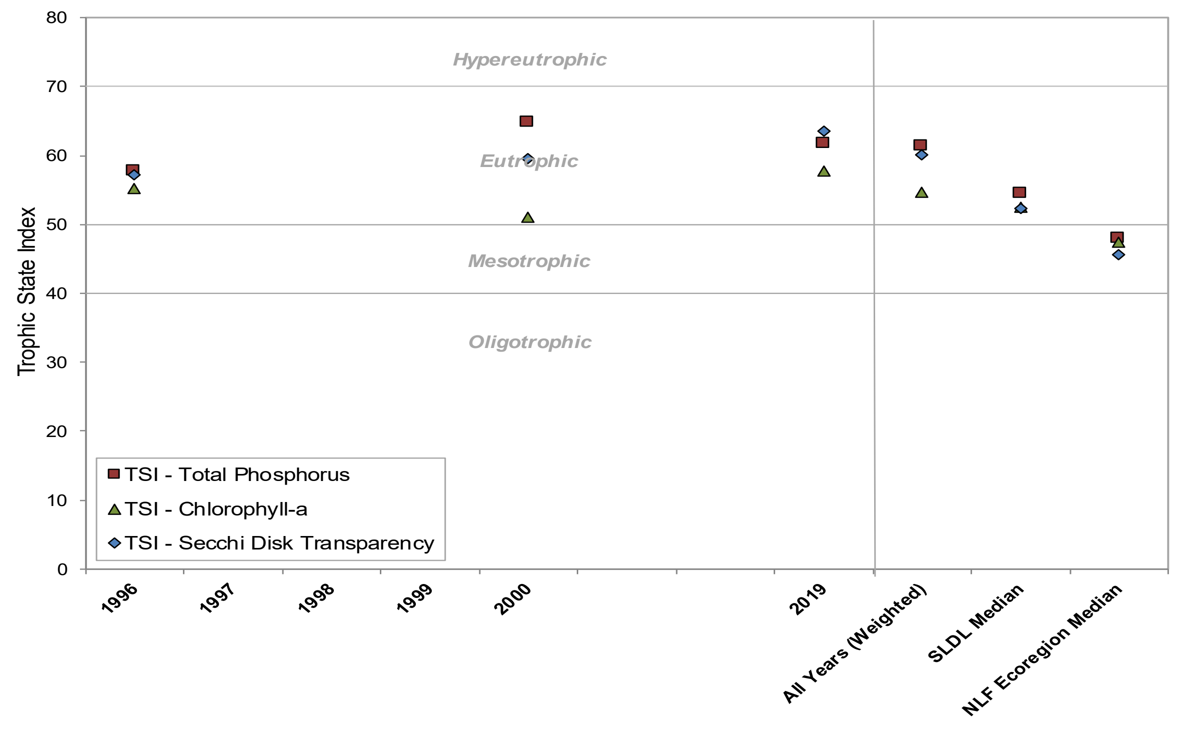


Figure 8.1.1-4. Duroy Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2013.

Dissolved Oxygen and Temperature in Duroy Lake

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

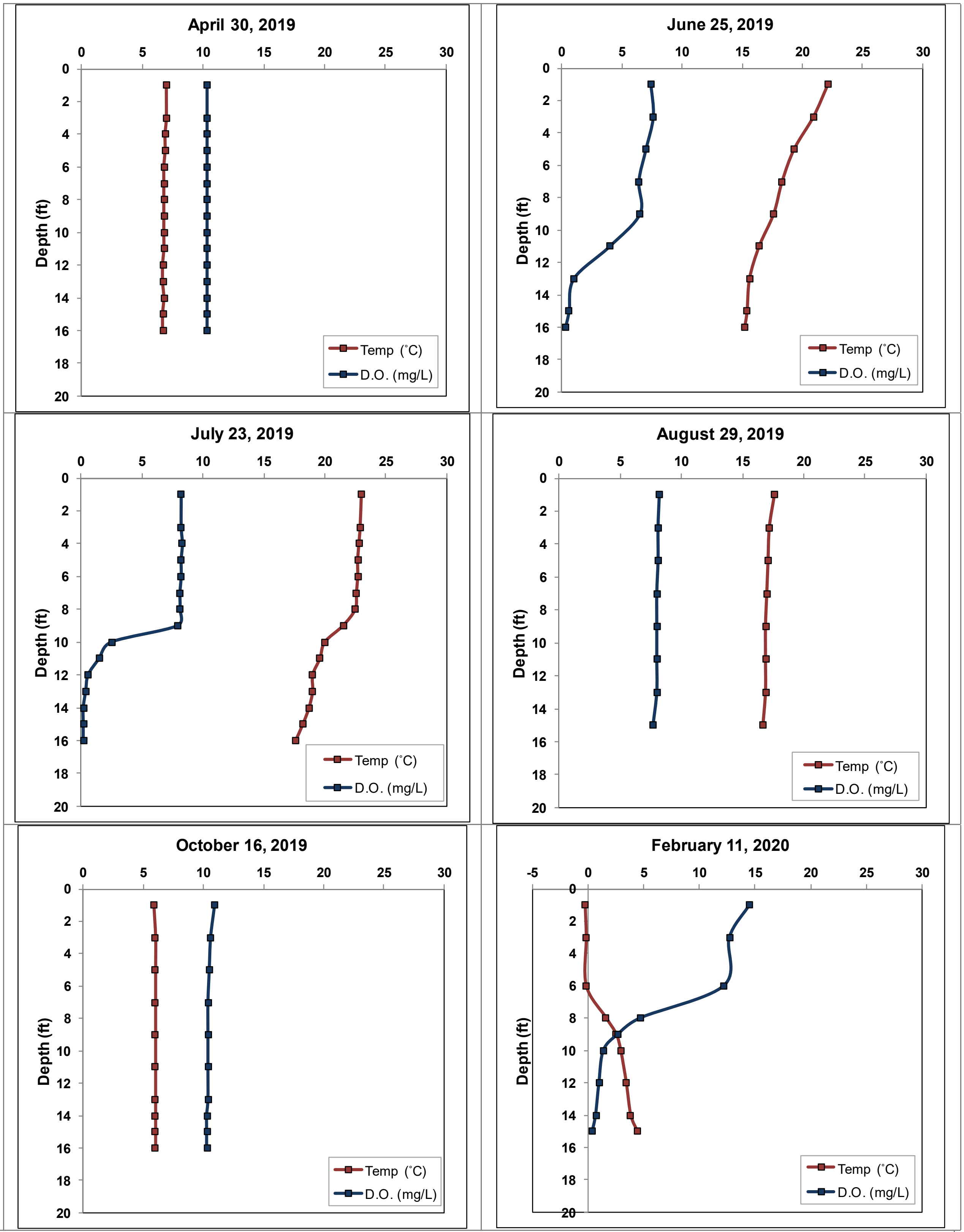


Figure 8.1.1-5. Duroy Lake dissolved oxygen and temperature profiles.

Duroy Lake is a polymictic lake meaning that it mixes periodically during the ice free season. During June and July, the lake was stratified and the bottom of the lake became devoid of oxygen. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixed completely in August, re-oxygenating the water in the lower part of the water column. Nutrients that were segregated to the bottom layer during June and July mixed back into the top water column and were available to algae.

During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2020, oxygen levels remained sufficient throughout the top 7.5 feet of the water column and approached anoxia during the bottom 7.5 feet.

Additional Water Quality Data Collected at Duroy 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 Duroy 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. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below reflect concentrations during July. It is expected these concentrations will change from year to year depending upon precipitation and its impact on flows in the rivers.

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. Duroy Lake's surface water pH was measured at 7.5 during summer 2019 (Figure 8.1.1-6). This value is near 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. The alkalinity in Duroy Lake during July 2019 was measured at 40.5 (mg/L as $CaCO_3$) (Figure, 8.1.1-7) 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 Duroy Lake during July 2019. 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 Duroy Lake's pH of 7.5 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 Duroy Lake was found to be 10.9 mg/L, which is below the optimal range for zebra mussels.

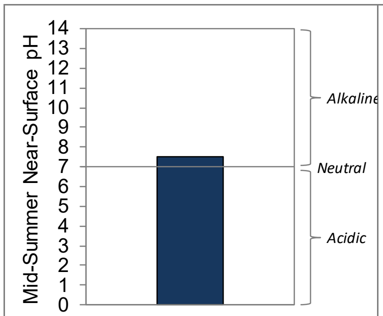


Figure 8.1.1-6. Duroy Lake mid-summer near-surface pH value.

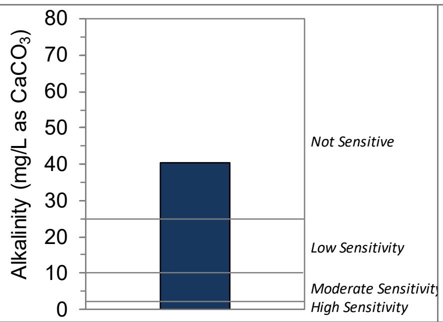


Figure 8.1.1-7. Duroy Lake summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

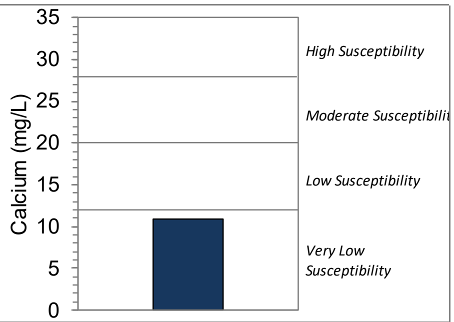


Figure 8.1.1-8. Duroy Lake summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

8.1.2 Duroy Lake Watershed Assessment

Duroy Lake's watershed is 112,952 acres in size (Figure 8.1.2-1). Compared to Duroy Lake's size of 376 acres, this makes for an large watershed to lake area ratio of 300:1. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Duroy Lake's residence time is approximately 3.7 days, or the water within the lake is completely replaced 99 times per year. This very short residence time means that the phosphorus concentration in the lake is similar to the concentration in the inflowing waters, especially the Elk River.

Approximately 63% of the Duroy Lake's watershed is comprised of the Musser, Solberg, and Big Dardis lakes sub-watersheds (Map 2). As discussed in the chain-wide section (3.2), these sub-watersheds will be modeled as point-sources based upon measured phosphorus concentrations in the lake. The remaining 37% of the overall watershed includes the direct watershed, as well as the surface of the lake. Direct phosphorous addition to the lake comes through atmospheric deposition. Forested and wetland land cover types comprise 83% of the direct watershed. These land cover types provide the least amount of phosphorus inputs to a system. Row crop agriculture, urban and residential land cover types deliver the most amount of phosphorus to a system, with less than 7% of the direct watershed consisting of these land cover types and only a small fraction of the overall Duroy Lake watershed.

Using the information in Figure 8.1.2-1, WiLMS estimates 14,924 pounds of phosphorus being delivered to Duroy Lake on an annual basis (Figure 8.1.2-2). Comprising 63% of the watershed area, the three sub-watersheds only deliver a little greater than 56% of the phosphorus to Duroy Lake. Comprising of only 2% of the overall landcover, row crop agriculture from the direct watershed contributes to 16% of the phosphorus budget. Rotational agriculture likely changes the amount of phosphorus this land cover delivers each year. Also, conservational agriculture projects can reduce the amount of phosphorus and have a benefiting impact on the water quality of Duroy and downstream waterbodies.

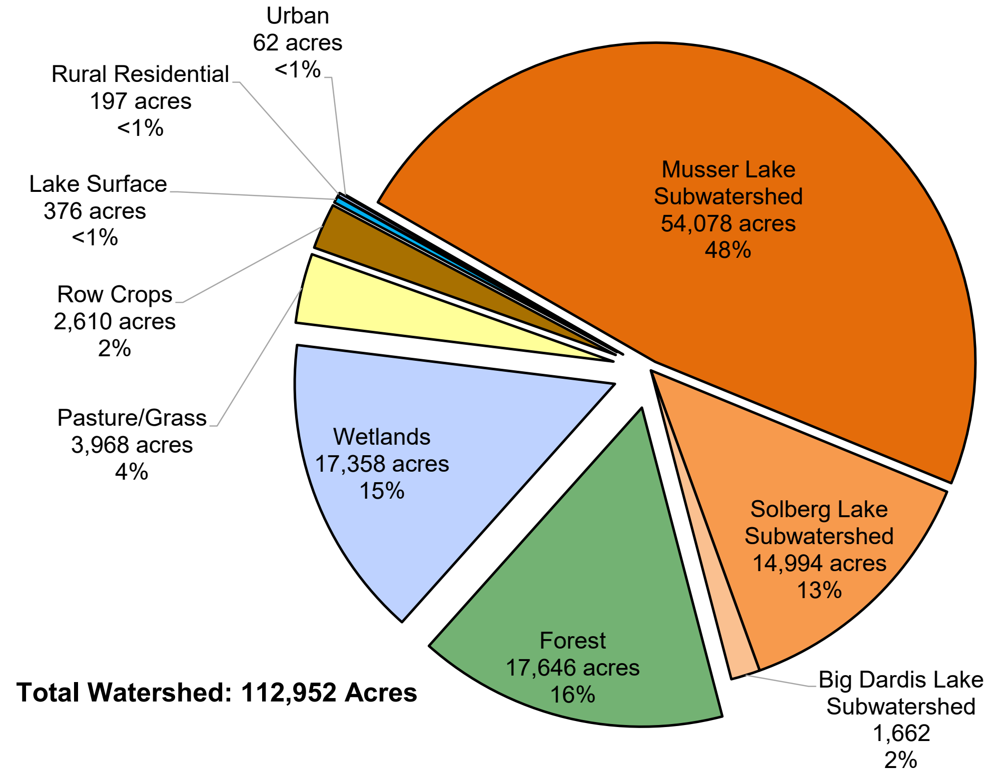


Figure 8.1.2-1. Duroy Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2016).

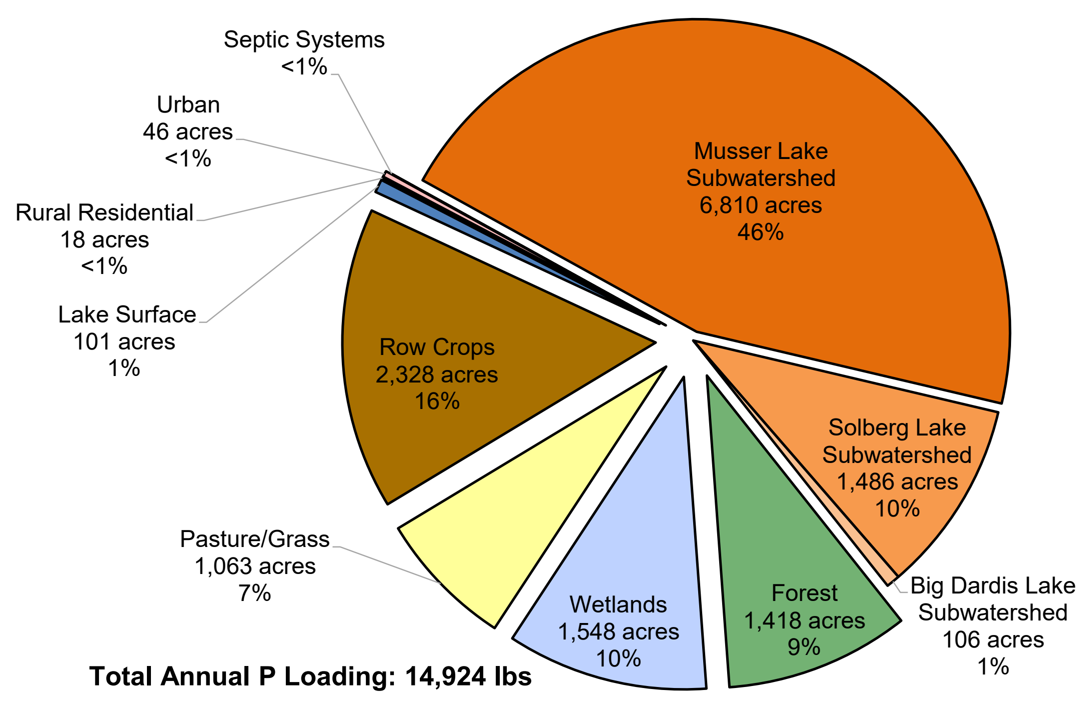


Figure 8.1.2-2. Duroy Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.1.3 Duroy 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 Fall of 2019, Duroy Lake's immediate shoreline was assessed in terms of its development. Duroy Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 7.6 miles (90% 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 state if at all possible. During the survey, 0.3 miles of urbanized and developed–unnatural shoreline (3% of the total shoreline) was observed. If restoration of the Duroy 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. Duroy – Map 1 displays the location of these shoreline lengths around the entire lake.

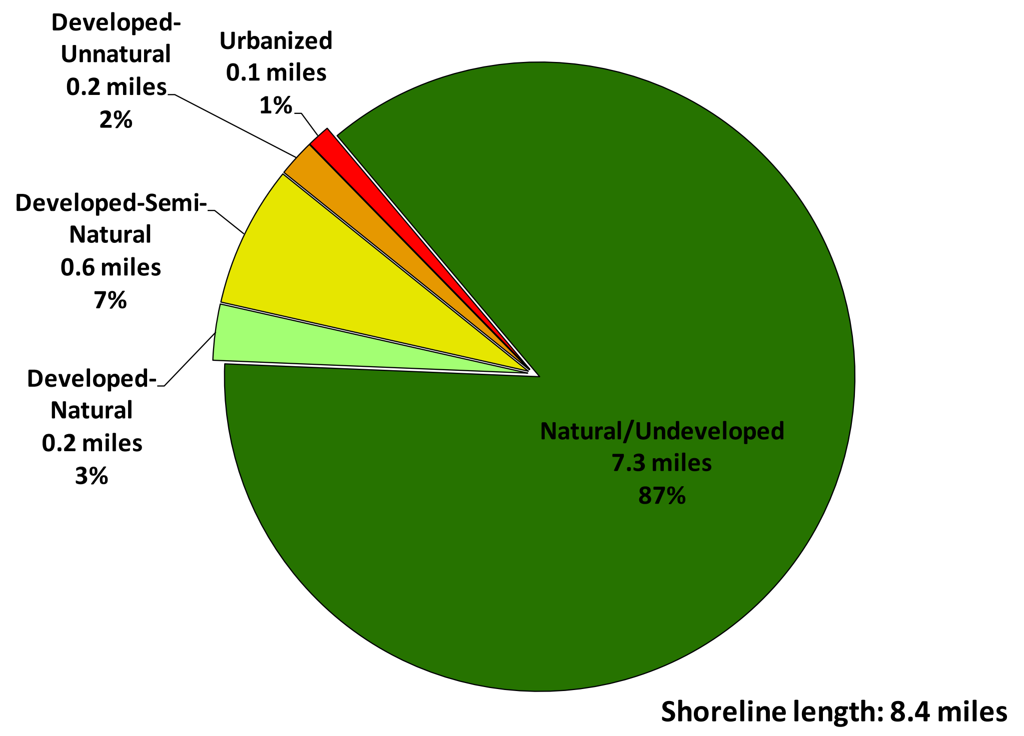


Figure 8.1.3-1. Duroy Lake shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Duroy Lake Map 1.

Coarse Woody Habitat

Duroy Lake was surveyed in 2019 to determine the extent of its coarse woody habitat. 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 117 pieces of coarse woody habitat were observed along 8.4 miles of shoreline, which gives Duroy Lake a coarse woody habitat to shoreline mile ratio of 14:1 (Figure 8.1.3-2). 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 coarse woody habitat are displayed on Duroy Lake Map 2.

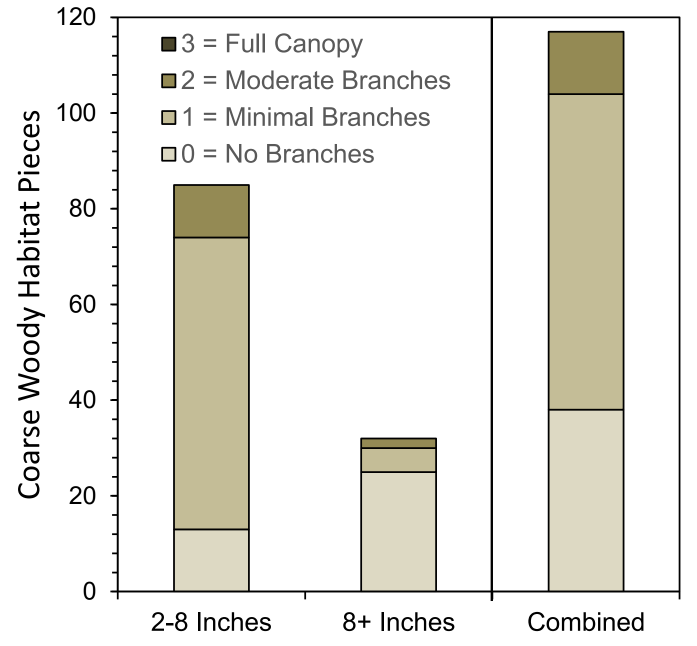


Figure 8.1.3-2. Duroy Lake coarse woody habitat survey results. Based upon a Fall 2019 survey. Locations of Duroy Lake coarse woody habitat can be found on Duroy Lake Map 2.

8.1.4 Duroy Lake Aquatic Vegetation

The aquatic plant point-intercept survey was conducted on Duroy Lake on July 23-24, 2019 by Onterra (Figure 8.1.4-1). The floating-leaf and emergent plant community mapping survey was completed on August 26 to create the aquatic plant community map. During these surveys, a total of 37 species of native aquatic plants were located in and around Duroy Lake (Table 8.1.4-1). Thirty-one of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. The remaining six native species were located visually during the survey, but not sampled on the rake. In addition, three non-native species were located on Duroy Lake: Eurasian watermilfoil (EWM), curly-leaf pondweed (CLP), and narrow-leaved cattail. CLP was discussed on the previous page and EWM and narrow-leaved cattail will be discussed in the subsequent AIS section. A whole-lake point-intercept (PI) survey was also completed on Duroy Lake in 2009 during the last management planning project. The species recorded during this survey are also displayed in Table 8.1.4-1.

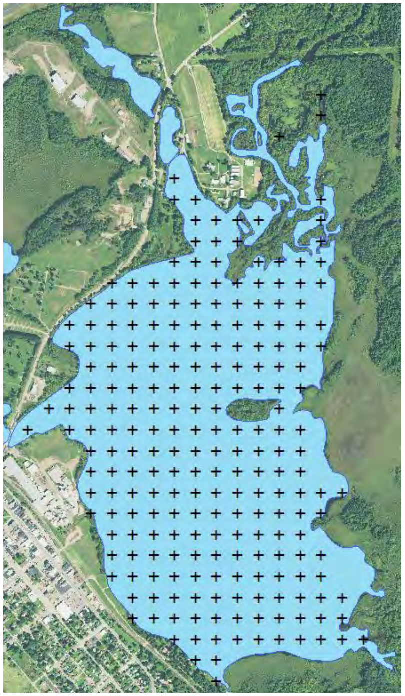


Figure 8.1.4-1. Duroy Lake whole-lake aquatic point-intercept survey sampling locations.

During the 2019 PI survey, aquatic plants were found growing to a depth of 5 feet. As discussed later within this section, many of the plants found during this survey indicate that the overall community is healthy, diverse, and in the case of two species, somewhat rare. Two aquatic plant species found during the 2019 surveys, Vasey's pondweed (*Potamogeton vaseyi*) and autumnal water starwort (*Callitriche hermaphroditica*), are listed by the Natural Heritage Inventory (NHI) Program as species of special concern in Wisconsin. The special concern listing means it is suspected that there is a low abundance of the species within the state, and attention should be focused to help prevent it from becoming threatened or endangered.

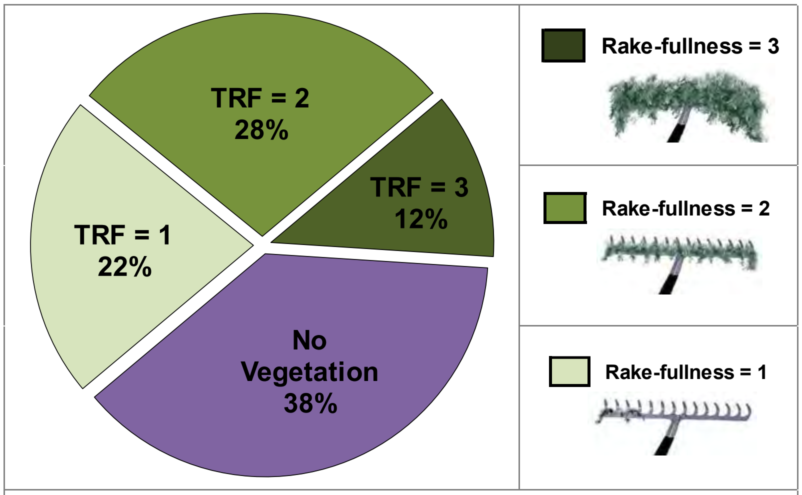


Figure 8.1.4-2. Total rake fullness ratings on Duroy Lake. Created using data from 2019 point-intercept survey.

Of the 231 points on the sampling grid (Figure 8.1.4-1), 201 of them were able to be sampled, and 132 were considered to be littoral (within depths at which plants can grow). Of the 132 point-intercept locations sampled within the littoral zone in 2019, approximately 62% (82 sites) contained aquatic vegetation, with the majority of them being in the eastern half of the lake (Map 5). From the map, it can be seen that the areas containing vegetation are the shallower areas of the lake. The darker stained water in Duroy Lake does not allow for enough sunlight to penetrate very deep to support aquatic plant growth. Aquatic plant rake fullness data (density of plants pulled up on the rake) indicates that about 28% of the littoral sampling sites contained TRF=2, 22% contained TRF=1, and the remaining 12% contained the highest density rating of TRF=3 (Figure 8.1.4-2). Approximately 87% of the point-intercept sampling locations where sediment data was collected at were fine organic substrate (muck), and 13% consisted of sand.

Table 8.1.4-1. Aquatic plant species located in Duroy Lake during the 2009 and 2019 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2009 Onterra	2019 Onterra
Emergent	*Calla palustris*	Water arum	9		X
	Carex comosa	Bristly sedge	5	I	
	Eleocharis palustris	Creeping spikerush	6		X
	Lythrum salicaria	Purple loosestrife	Exotic/Invasive	I	I
	Pontederia cordata	Pickerelweed	9	X	X
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Sparganium eurycarpum	Common bur-reed	5	X	X
	Typha latifolia	Broad-leaved cattail	1	I	
	Zizania palustris	Northern wild rice	8	X	
FL	*Brasenia schreberi*	Watershield	7		I
	Nymphaea odorata	White water lily	6	X	X
	Nuphar variegata	Spatterdock	6	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I	
	Sparganium fluctuans	Floating-leaf bur-reed	10	X	X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	X	X
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Callitriche hermaphroditica	Atumnal water starwort*	9		X
	Callitriche palustris	Common water starwort	8		I
	Callitriche spp.	Water starwort spp.	N/A		
	Ceratophyllum echinatum	Spiny hornwort	10		X
	Chara spp.	Muskgrasses	7	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Elodea nuttallii	Slender waterweed	7		X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive	X	X
	Nitella spp.	Stoneworts	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Potamogeton alpinus	Alpine pondweed	9	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	
	Potamogeton crispus	Curly-leaf pondweed	Exotic/Invasive		X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton obtusifolius	Blunt-leaved pondweed	9	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton berchtoldii	Slender pondweed	7		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton vaseyi	Vasey's pondweed*	10		I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Utricularia vulgaris	Common bladderwort	7		X
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

FL = Floating-leaf; FL/E = Floating-leaf and Emergent; FF = Free-floating
*X = Located on rake during point-intercept survey; I = Incidentally located; * = Special concern species*

Figure 8.1.4-3 shows that wild rice, coontail/spiny hornwort, floating-leaf bur-reed, and muskgrasses and stoneworts were the most frequently encountered native plants in Duroy Lake in 2019. Note that coontail and spiny hornwort, as well as muskgrasses and stoneworts were combined together for the analysis due to their similar morphological characteristics which makes it difficult to differentiate them from one another in the field.

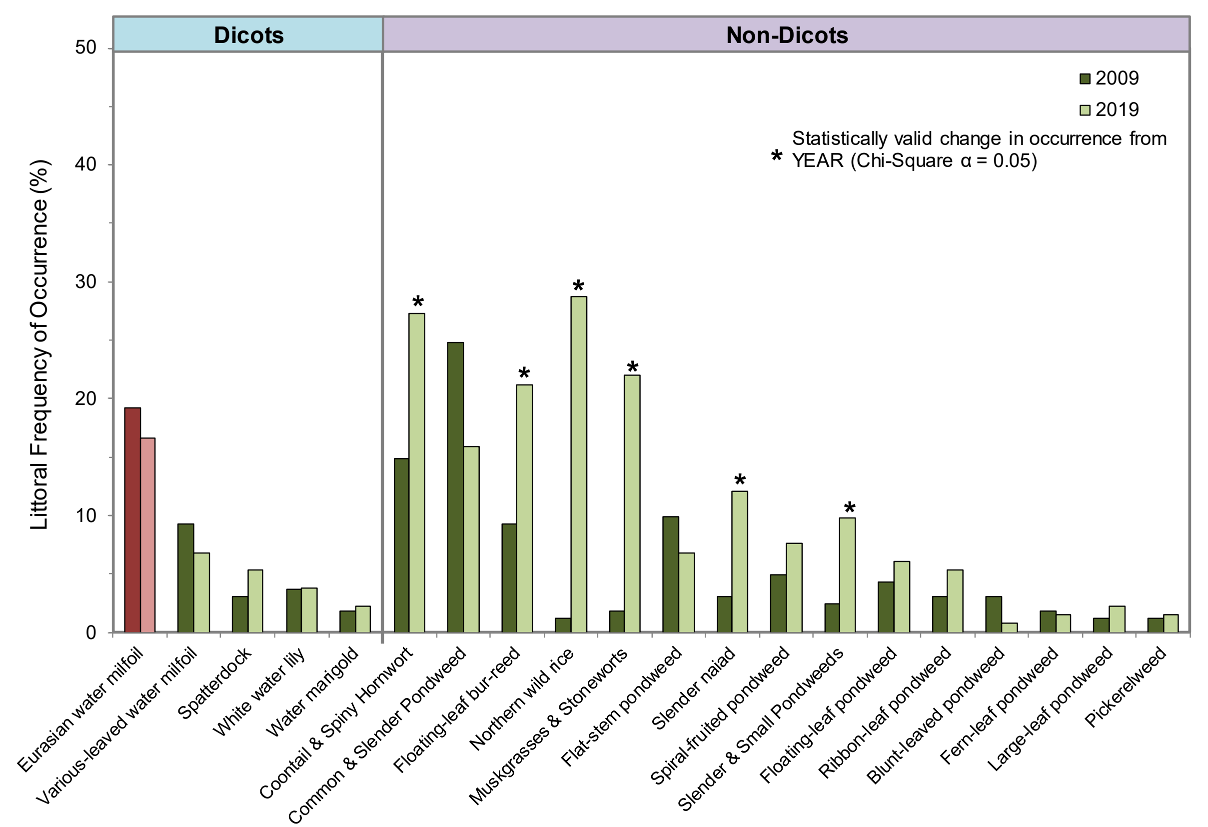


Figure 8.1.4-3. Duroy Lake aquatic plant littoral frequency of occurrence analysis. Chart includes species with a frequency occurrence greater than 1.0% during at least one of the survey years only. Created using data from the 2009 and 2019 point-intercept surveys.

Northern wild rice was the most frequent species located in Duroy Lake during the 2019 point-intercept survey. Due to its cultural significance and the abundance of it within Duroy Lake, it will be discussed in further detail later in this section.

Coontail was the second most frequently encountered aquatic plant in Duroy Lake in 2019 with a littoral occurrence of 24% (Figure 8.1.4-3). As discussed in the chain-wide section, this largely unrooted species is able to derive all of its nutrients directly from the water (Gross, Erhard and Ivanyi 2003). This ability in combination with a tolerance for low-light conditions allows coontail to become more abundant in productive waterbodies with lower water clarity. Coontail has the capacity to form dense beds that mat on the water surface. Coontail also provides many benefits to the aquatic community. Its dense whorls for leaves provide excellent structural habitat for aquatic invertebrates and fish, especially in winter as this plant remains green under the ice. In addition, it competes for nutrients that would otherwise be available for free-floating algae and therefore helps to improve water clarity.

Floating-leaf bur-reed was the third most frequently encountered aquatic plant in Duroy Lake in 2019 with a littoral occurrence of approximately 21%. Floating-leaf bur-reed is an aquatic plant which has long (2.5 to 5 ft) stems and long (2 to 3.25 ft) linear, ribbon-like leaves. Several species of bur-reed exist in Wisconsin, and while some differences exist in the leaves of these plants, the best way to differentiate between them is by the characteristics of their fruits.

Charophytes are a group of macro-algae comprised mainly of muskgrasses and stoneworts, and were the next most commonly encountered species in Duroy Lake in 2019. Charophytes typically do better in systems with good water clarity. Their large beds help to stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorous in the calcium carbonate incrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002).

Because of the high number of native species of plants (species richness) found in Duroy Lake, one may assume that the lake would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence diversity. The diversity index for Duroy Lake's plant community (0.93) lies above the Northern Lakes and Forests Lakes ecoregion median value (0.88), as well as the state median (0.86), indicating the lake holds exceptional diversity (Figure 8.1.4-4).

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 Northern wild rice was found at approximately 29% of the littoral sampling locations, its relative frequency of occurrence is 13%. Explained another way, if 100 plants were randomly sampled from Duroy Lake, 13 of them would be Northern wild rice. This distribution can be observed in Figure 8.1.4-5 where together 7 species account for 60% of the population of plants within Duroy Lake, and the other 26 species account for the remaining 40%. As a reminder, the incidentally located species are not included in this analysis.

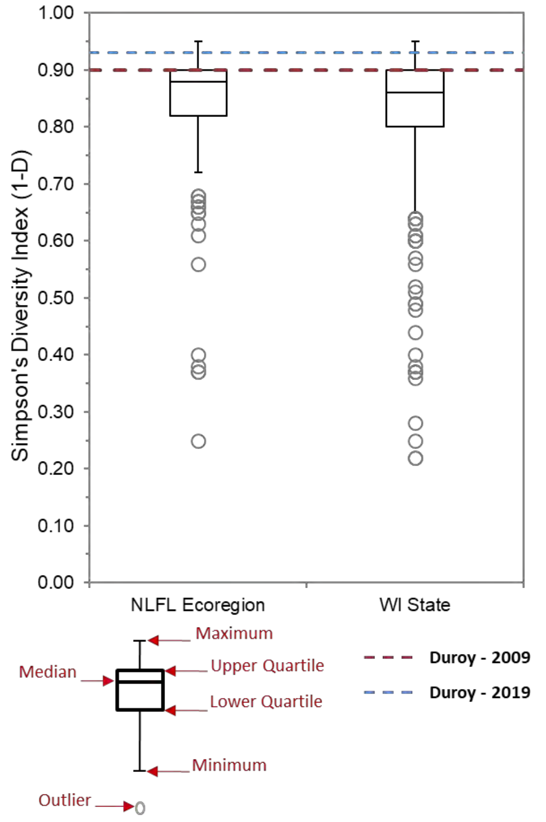


Figure 8.1.4-4. Simpson's diversity for Duroy Lake.

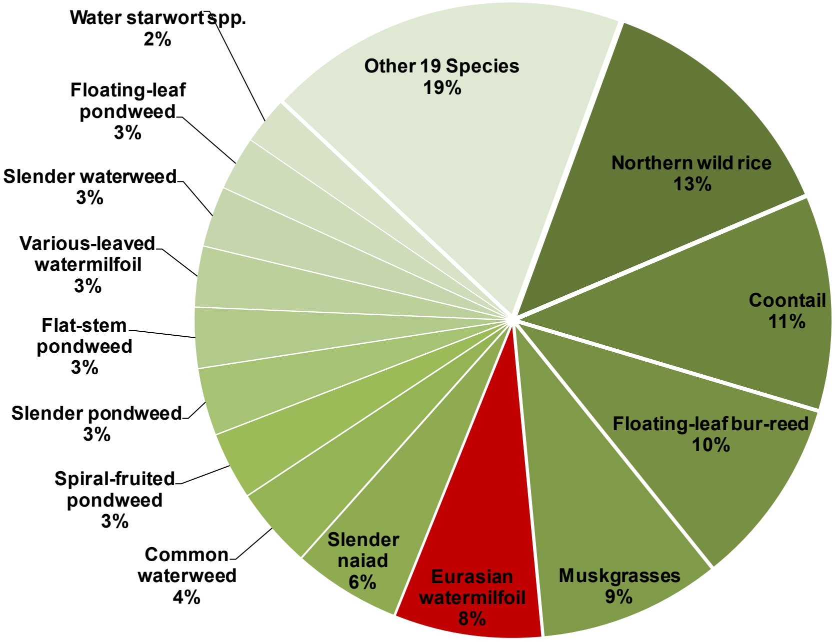


Figure 8.1.4-5. Duroy Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2019 point-intercept survey.

Duroy Lake's average conservatism value in 2019 (7.0) was higher than both the state (6.3) and ecoregion (6.7) medians. This indicates that the aquatic plant community in Duroy Lake is of relatively high quality. Duroy Lake's species richness value also exceeded the ecoregion and state medians. Combining Duroy Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 38.5 in 2019 which is well above the median values for the ecoregion and state as well (Figure 8.1.4-6).

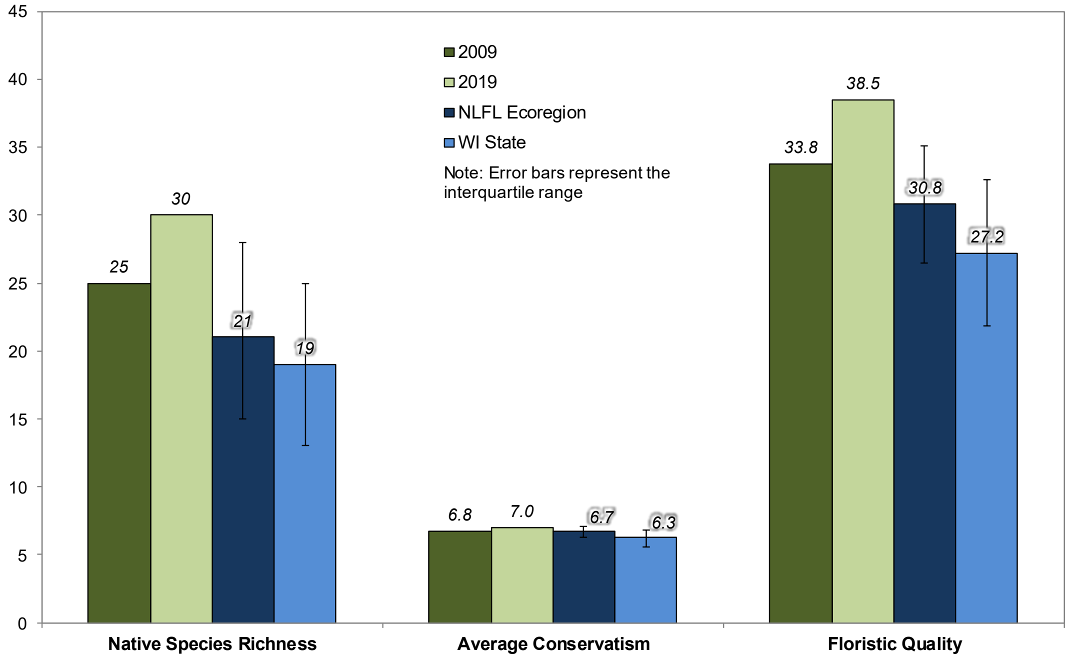


Figure 8.1.4-6. Duroy Lake Floristic Quality Analysis. Created using data from 2009 and 2019 point-intercept surveys.

The quality of Duroy Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas around the lake. The 2019 community map indicates that approximately 129.3 acres of the lake contains these types of plant communities (Duroy Lake Map 3, Table 8.1.4-2). Thirteen native floating-leaf and emergent species were located in and around Duroy Lake in 2019 (Table 8.1.4-1), providing valuable wildlife habitat.

Table 8.1.4-2. Duroy Lake acres of emergent and floating-leaf plant communities from the 2019 community mapping survey.

Plant Community	Acres
Emergent	25.1
Floating-leaf	22.5
Mixed Emergent & Floating-leaf	81.7
Total	**129.3**

Northern Wild Rice

Photograph 8.1.4-1. Northern wild rice.

Wild rice (Photograph 8.1.4-1) is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. *Manoomin*, as it is referred to by Ojibwe Tribal Communities, is of great cultural significance. In addition, wild rice harvesting and consumption is carried out by and benefits both tribal and non-tribal members. Wild rice is also an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish. Perhaps one of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive nutrients, stabilize sediments, and form natural wave-breaks to protect shoreline areas.

Wild rice is an annual plant that relies strictly on seed production to maintain its populations from year-to-year. Water levels and depth have a significant impact on this aquatic species. Once dropped from the parent plant, the seed must be submersed in water to germinate the following year, or remain dormant until another year when conditions are suitable. Deep water prevents light from reaching submersed seedlings, and water that is too shallow prevents sufficient development of the floating leaf stage of the plant and will lead to a poor crop (Aiken et al. 1988). It has been suggested that northern wild rice requires constant or slowly falling water levels throughout the growing season to prevent uprooting in soft sediments (Vennum 1988).

Using the floating-leaf and emergent community mapping data from the 2009, 2013, and 2019 surveys, locations that contained wild rice were extrapolated from the overall results and used to create wild rice location maps (Figure 8.1.4-7). It is important to note that since the data used to create these maps were not made specifically to map only the wild rice, some of the indicated areas may not reflect precise boundary lines and should be seen only as an approximate representation of areas which were observed to contain wild rice within them. Figure 8.1.4-7 illustrates that wild rice tends to grow in similar (shallower) areas of Duroy Lake, and that 2019 shows the largest area containing wild rice that was mapped, of the three years.

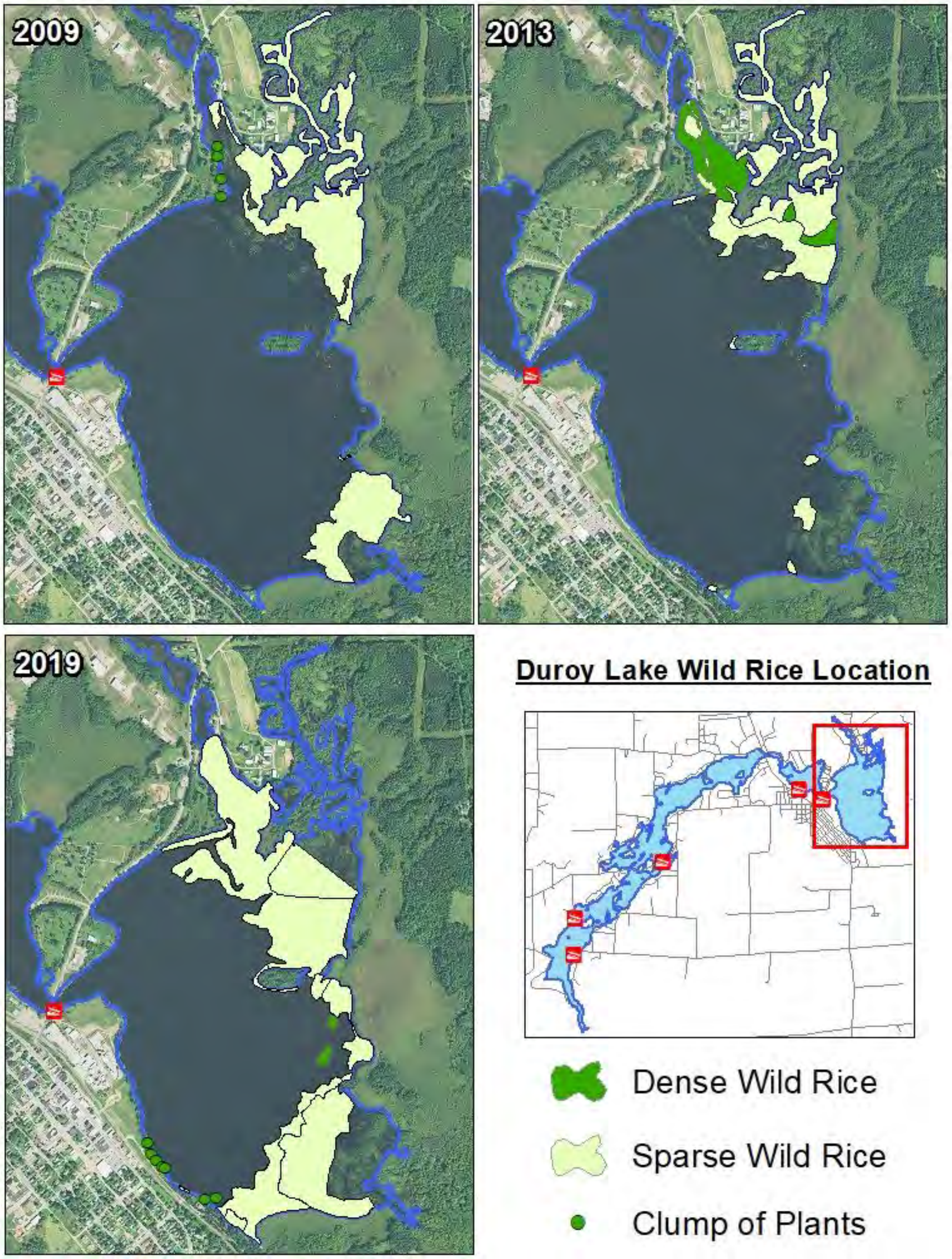


Figure 8.1.4-7. Locations of Northern wild rice on Duroy Lake. Created using community mapping survey data from 2009, 2013 and 2019.

Traditional ecological knowledge from Native American communities indicates that wild rice tends to grow in a 4-year cycle that includes one good year, one bad year, and two average years. While the data presented here and not complete enough to evaluate this statement, it is nonetheless interesting and valuable data that can be used in future comparisons and correlations to analyze changes that may be happening in the lake over time.

Curly-Leaf Pondweed

An Early-Season Aquatic Invasive Species (ESAIS) survey was conducted by Onterra ecologists on Duroy Lake on June 11, 2019. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of the non-native curly-leaf pondweed which should be at or near its peak growth at this time. During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques are applied to AIS locations considered to be *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*. During this survey, several point-based occurrences of curly-leaf pondweed (CLP) were marked, with the majority of them being *single or few plants*. The CLP occurrences in the northern and eastern portions of Duroy Lake (Figure 8.1.4-8) were located during the ESAIS survey, and the points in the southern portion of the lake were located during a subsequent point-intercept survey in August and added to the ESAIS map for reference, as well as to indicate additional areas to inspect more closely during future surveys. Typically by August, most CLP has died back for the season.

Figure 8.1.4-8. Locations of curly-leaf pondweed occurrences on Duroy Lake. Created using data from a 2019 Early-Season AIS survey.

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum;* EWM) was first verified in Duroy Lake in 2000. EWM often has an affinity for softer sediments, which as displayed previously, makes up 87% of Duroy Lake's bottom substrate, making it an ideal place for EWM to thrive.

PCOLA has sponsored a number of AIS control projects aimed at managing the EWM population on the Phillips Chain, starting in 2011. Starting in 2009, late-season EWM mapping surveys have periodically occurred on the Phillips Chain using a consistent density rating system (Figure 8.1.4-9). Please note that this figure only represents only the acreage of mapped EWM polygons, not EWM mapped within point-based methodologies (*Single or Few Plants, Clumps of Plants,* or *Small Plant Colonies*). Said another way, EWM marked with point-based mapping methods do not contribute to colonized acreage as shown on Figure 8.1.4-9. Duroy Lake Map 4 shows the results of the latest EWM mapping survey that occurred in 2019.

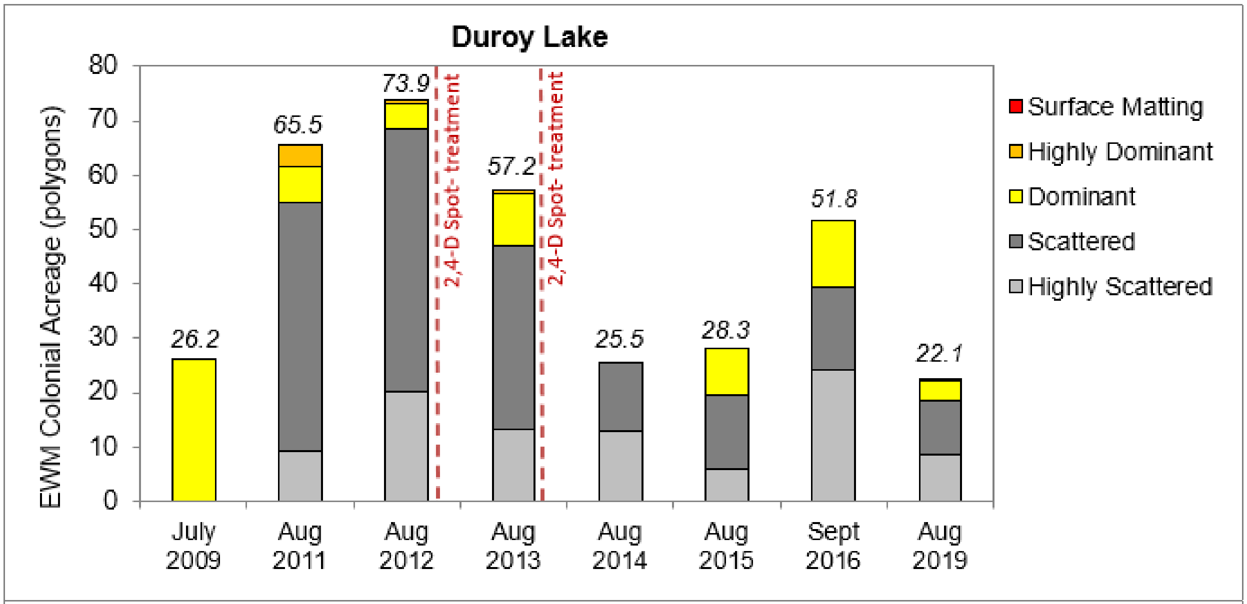


Figure 8.1.4-9. Acreages of EWM mapped in Duroy Lake. Created using data from EWM Peak-Biomass (Late-Season AIS) surveys.

During this timeframe, two herbicide spot treatments have occurred on Duroy Lake (Table 8.1.4-3). Both treatments occurred with liquid 2,4-D amine towards the top of their maximum application rate (3.0-4.0 ppm ae). These treatments both took place long the eastern margins of Duroy Lake and in close proximity to wild rice populations. Wild rice is known to be suspectable to some herbicide formulations including 2,4-D, especially at early life stages. For these reasons, the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) provides careful review of herbicide treatment in areas of wild rice. In 2013, GLIFWC expressed disapproval of the Duroy herbicide treatment plan. Future EWM management in this area, particularly if it involves herbicide use, should include early discussion with GLIFWC and WDNR biologists.

Table 8.1.4-3. Duroy Lake EWM treatment history.

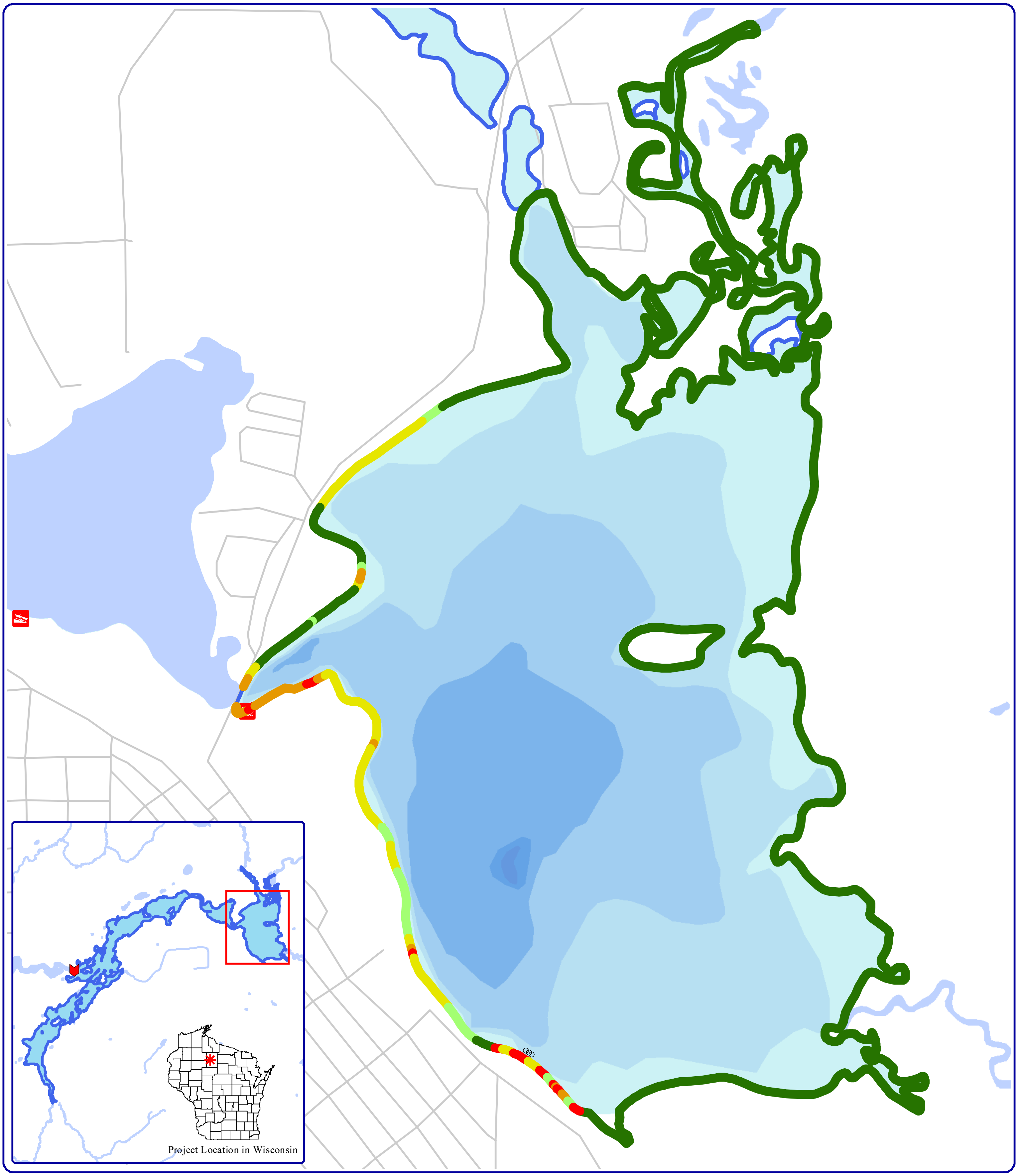
Date	Acres	Product	Amount Applied		Pounds of Active Ingredient
4/25/2012	6.4	DMA 4 (amine)	47	gallons	178.6
6/20/2013	9.9	DMA 4 (amine)	85	gallons	323.0

Purple Loosestrife

In 2007 and 2008, a WDNR biologist had released *Galleracella* spp. beetles in two locations around Duroy Lake which had purple loosestrife colonies growing in an attempt at biological control of the plants.

Onterra located purple loosestrife in several locations along shore in the southern half of Duroy Lake during their 2019 surveys (Figure 8.1.4-10). Slightly more purple loosestrife was located in 2019 than during 2009 surveys.

Figure 8.1.4-10. Purple loosestrife locations around Duroy Lake in August 2019.



Legend

Natural/Undeveloped

Developed-Natural

Developed-Semi-Natural

Developed-Unnatural

Urbanized

Seawall Modifier

Masonary/Wood Seawall

Rip-Rap/Placed Stone

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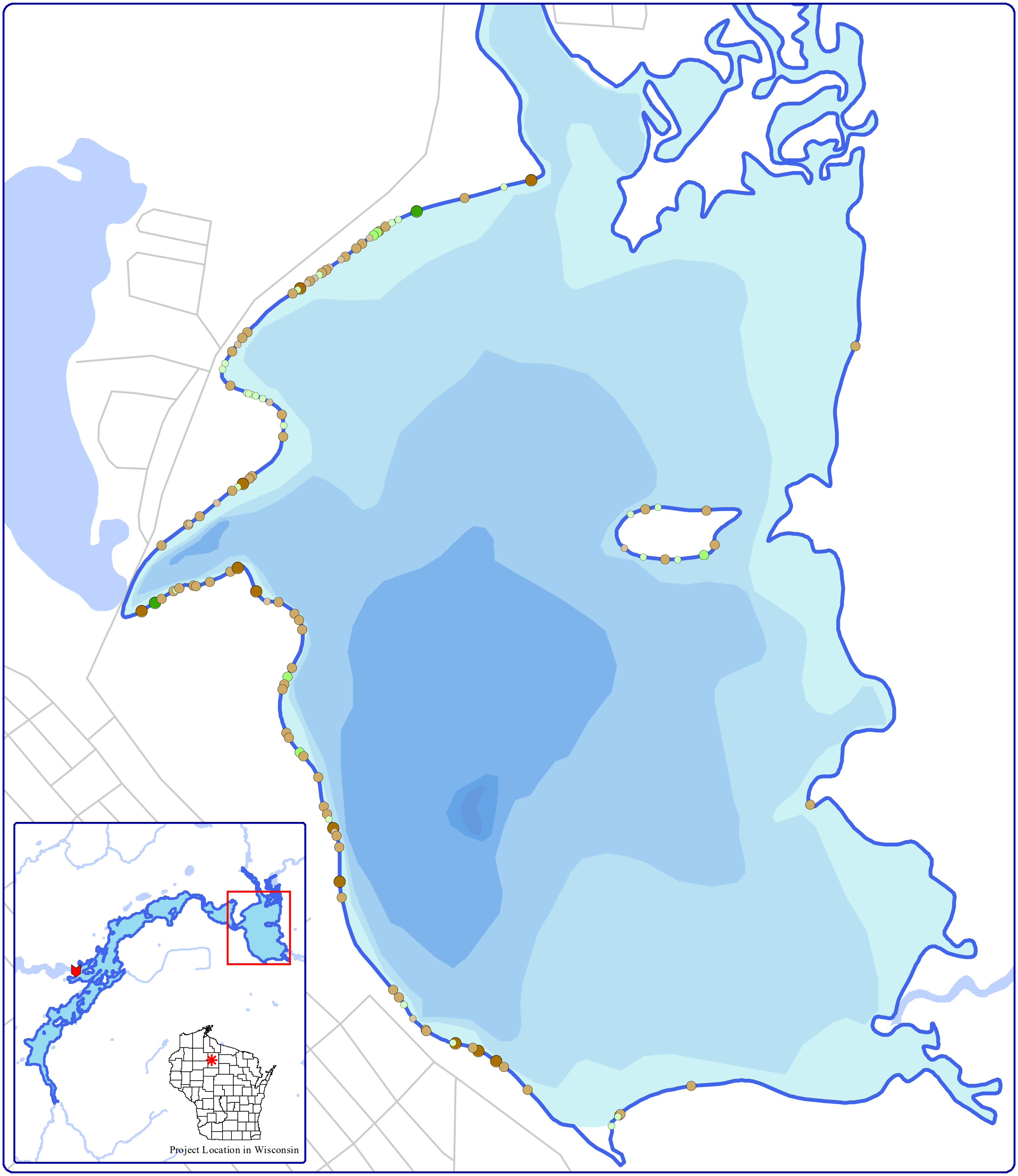
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 3, 2019 JMB

Duroy - Map 1
Duroy Lake
Price County, Wisconsin
Shoreland Condition Assessment



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Legend

2-8 Inch Pieces	8+ Inch Pieces
● No Branches	● No Branches
● Minimal Branches	● Minimal Branches
● Moderate Branches	● Moderate Branches
● Full Canopy	● Full Canopy

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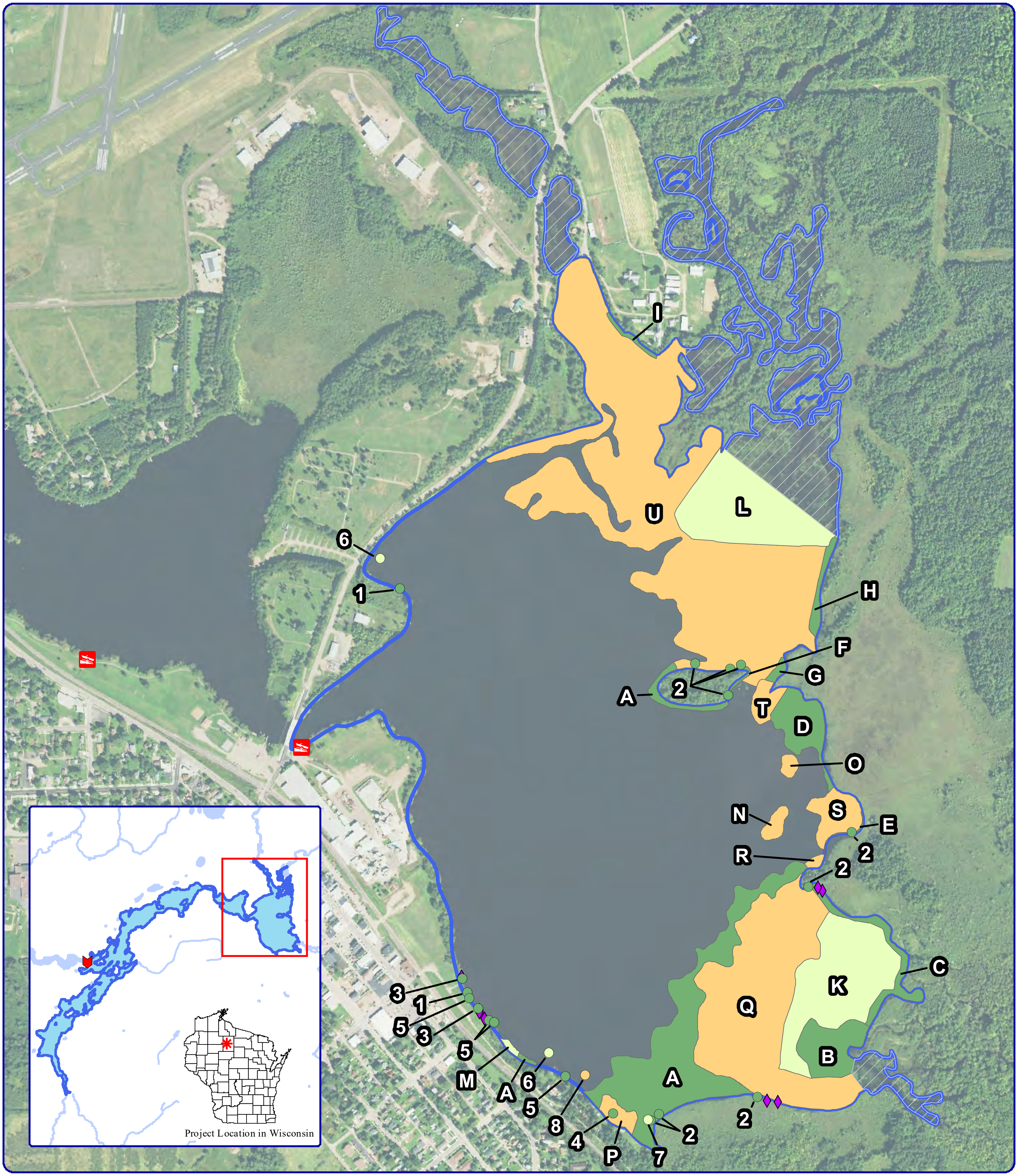
Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: October 14, 2019 JMB

Duroy - Map 2

Duroy Lake
Price County, Wisconsin

Coarse Woody Habitat



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Legend

Small Plant Communities

- ● Emergent
- ● Floating-leaf
- ● Mixed Floating-leaf & Emergent
- ◆ Purple Loosestrife

Large Plant Communities

- ▨ Emergent
- ▨ Floating-leaf
- ▨ Mixed Floating-leaf & Emergent
- ▨ Unnaviagable Area; Not Able to Survey

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Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: December 18, 2019 AMS

Duroy - Map 3

Duroy Lake

Price County, Wisconsin

Aquatic Plant Communities

Duroy Lake 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Duroy - Map 3

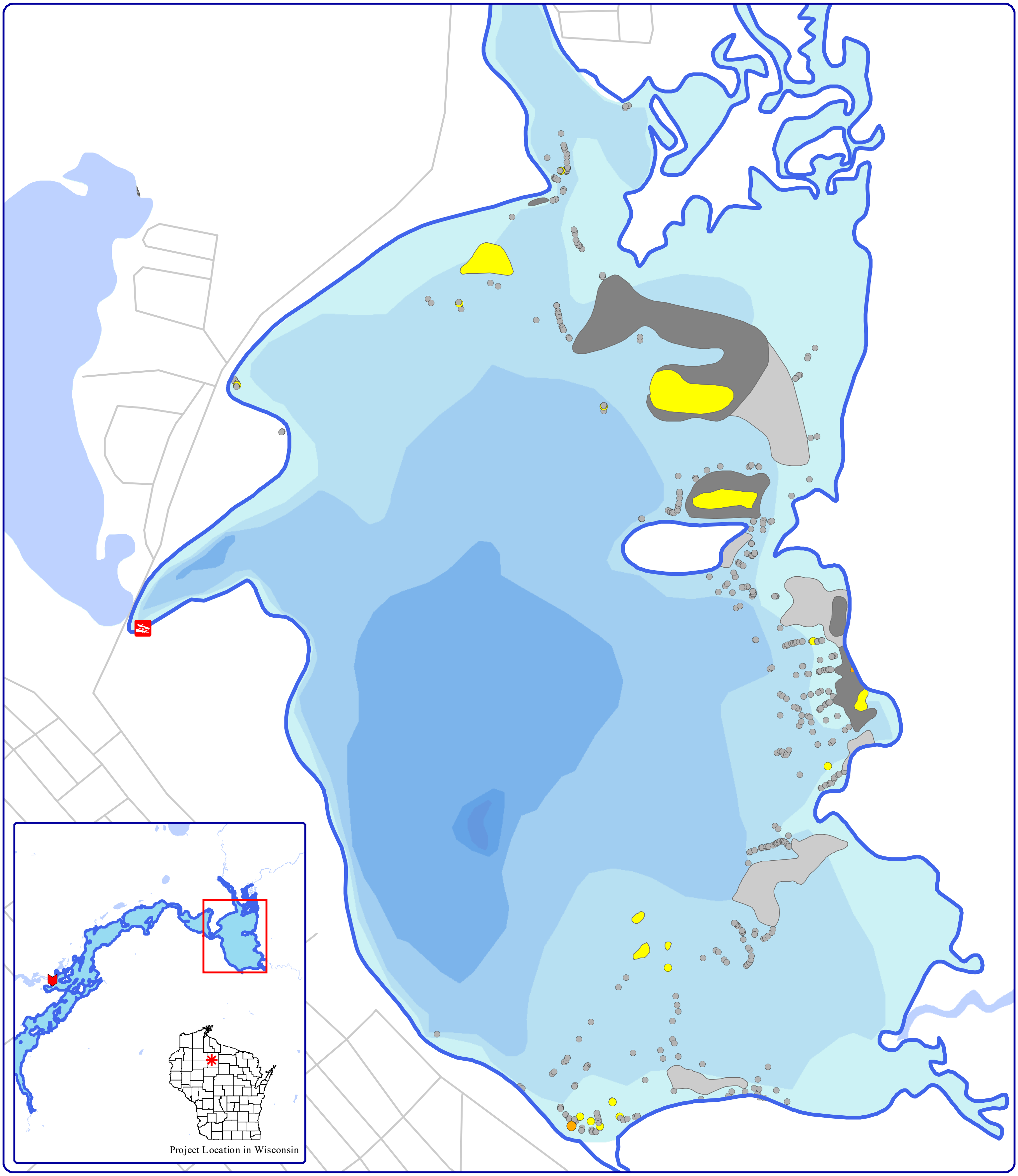
Large Plant Community (Polygons)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Acres
A	**Wild rice sp.**								15.17
B	**Common bur-reed**	Unbranched bur-reed							3.52
C	**Adj. Wetland**								1.76
D	**Wild rice sp.**	**Pickerelweed**	**Floating-leaf bur-reed**						3.14
E	**Purple loosestrife**								0.08
F	**Common bur-reed**								0.12
G	**Pickerelweed**								0.27
H	**Pickerelweed**	Creeping Spikerush	Common bur-reed						0.76
I	**Common bur-reed**	**Pickerelweed**							0.28
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
J	**White water lily**								0.08
K	**Floating-leaf bur-reed**	**Spatterdock**	White water lily						11.62
L	**Bur-reed sp. (Unknown 1)**	**WIld rice sp.**	**Floating-leaf bur-reed**	White water lily					10.65
M	**White water lily**	Floating-leaf bur-reed							0.15
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
N	**Creeping spikerush**	**Wild rice sp.**	**Floating-leaf bur-reed**	White water lily					0.67
O	**Wild rice sp.**	**Floating-leaf bur-reed**							0.41
P	**Wild rice sp.**	**Floating-leaf bur-reed**	White water lily						0.90
Q	**Unbranched bur-reed**	**Wild rice sp**	Watershield						23.02
R	**Wild rice sp.**	**Spatterdock**	Floating-leaf bur-reed	White water lily	Common bur-reed				0.20
S	**Wild rice sp.**	**Floating-leaf bur-reed**	Unbranched bur-reed	Spatterdock					2.32
T	**Creeping spikerush**	**Pickerelweed**	**Floating-leaf bur-reed**	**Wild rice sp.**	Softstem bulrush				1.12
U	**Wild rice sp.**	**Floating-leasf bur-reed**	White water lily	Unbranched bur-reed	Commom arrowhead	Pickerelweed			53.08

Small Plant Community (Points)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8
1	**Common bur-reed**							
2	**Pickerelweed**							
3	**Softstem bulrush**	Wild rice sp.						
4	**Softstem bulrush**							
5	**Wild rice sp.**							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
6	**White water lily**							
7	**Spatterdock**							
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
8	**White water lily**	Wild rice sp.						

Bolded species are considered most dominant within each community; Scientifc names can be found in the species list in Table 8.1.4-1



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Legend

▨ Highly Scattered	● Single or Few Plants
▨ Scattered	● Clumps of Plants
▨ Dominant	● Small Plant Colony
▨ Highly Dominant	
▨ Surface Matting *(None)*	

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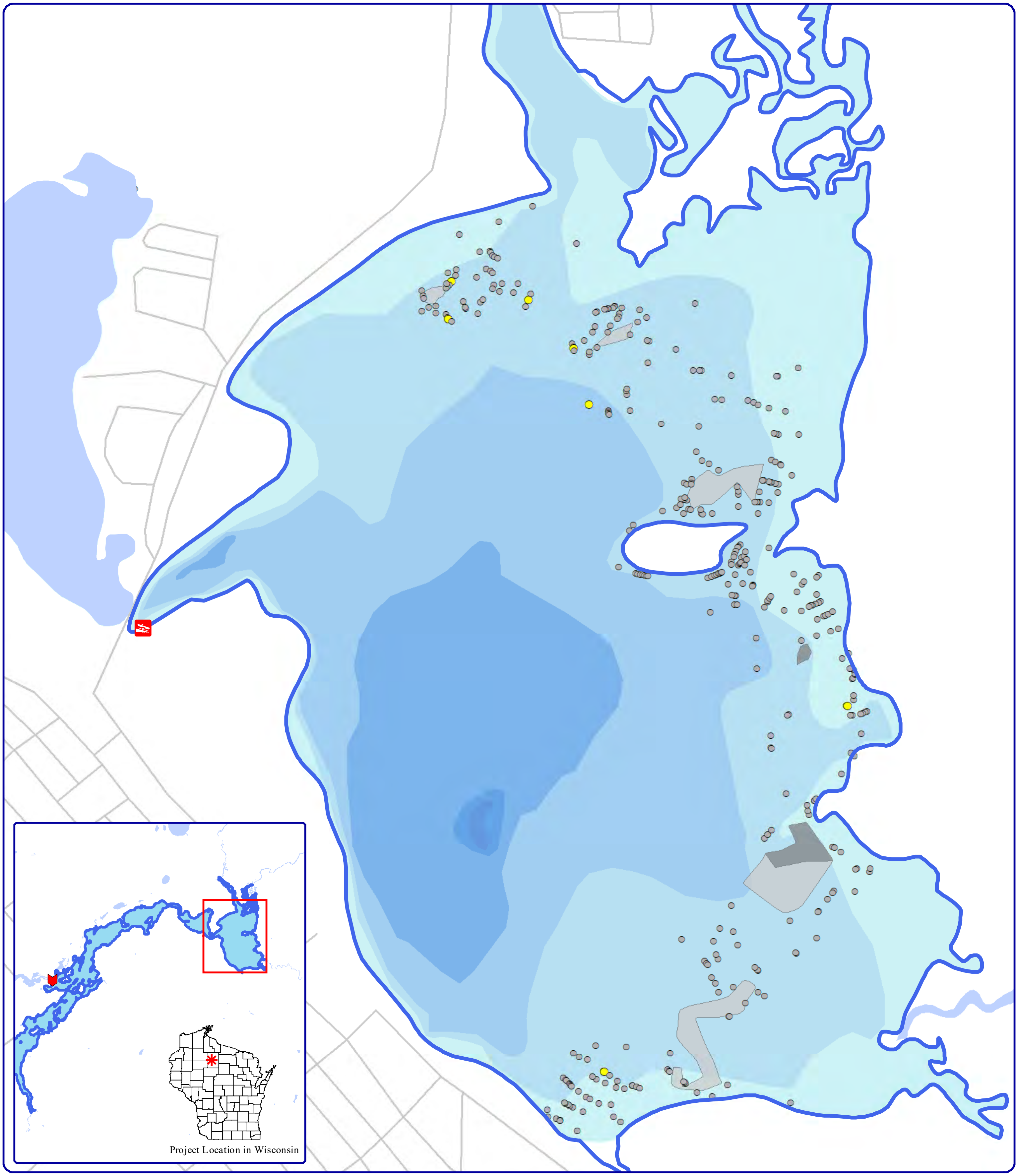
Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: October 14, 2019 JMB
Filename: PhillipsChain_EWM_PB_Aug19_Duroy.mxd

Duroy - Map 4

Duroy Lake
Price County, Wisconsin

August 2019 EWM Survey Results



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Feet

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Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: October 14, 2019 JMB
Filename: PhillipsChain_EWM_PB_Aug19_Duroy.mxd

Legend

- ▨ Highly Scattered
- ▨ Scattered
- 🟨 Dominant
- 🟧 Highly Dominant
- 🟥 Surface Matting *(None)*
- ● Single or Few Plants
- ● Clumps of Plants
- ● Small Plant Colony

Duroy - Map 5

Duroy Lake

Price County, Wisconsin

August 2020 EWM Survey Results

8.2.0 Elk Lake Introduction

Elk Lake, Price County, is a drainage lake with a maximum depth of 25 feet and a surface area of 91 acres. This eutrophic lake has an extremely large watershed when compared to the size of the lake. In 2019, 13 native plant species were located in Elk Lake, of which white water lily was the most common. One exotic plant, Eurasian watermilfoil, was observed in 2019.

Field Survey Notes

The shoreline of Elk Lake contains a public campground, a resort, and Elk Lake Park which contains a public boat launch and a fishing pier, providing recreational opportunities for outdoor enthusiasts. Elk Lake has historically had a very low frequency of aquatic vegetation. Of the 85 sampled sites within the littoral zone of Elk Lake during the 2019 point-intercept survey, only 7

Photograph 8.2.0-1. Elk Lake, Price County. Photo credit Price County.

Lake at a Glance* – Elk Lake

Morphology	
Acreage	91
Maximum Depth (ft)	25
Mean Depth (ft)	7.5
Volume (acre-feet)	678
Shoreline Complexity	13.6
Vegetation	
Number of Native Species	14
Threatened/Special Concern Species	None
Exotic Plant Species	EWM
Simpson's Diversity	0.73
Average Conservatism	5.9
Water Quality	
Wisconsin Lake Classification	Deep lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Transitional
Watershed to Lake Area Ratio	1249:1

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

8.2.1 Elk Lake Water Quality

Water quality data was collected from Elk Lake on six occasions in 2019/2020. 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) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Wisconsin DNR staff monitored the lake in 1996 and 2000 for total phosphorus, chlorophyll-*a*, and Secchi disk clarity. All of the lakes in the Phillips Chain have very short hydraulic residence times (all except Wilson Lake less than 14 days) which in the classification scheme of the Wisconsin Department of Natural Resources makes these water bodies officially *impounded flowing waters.* For phosphorus standards, the value for rivers (100 µg/L) is used. The reason for this classification is that with the short residence times, the water quality of these water bodies is mostly reflective of the water quality of the incoming Elk and Little Elk rivers and Squaw Creek. In the case of Elk Lake which is immediately downstream of Duroy Lake, Elk Lake's water quality is essentially the same as Duroy Lake's. The short residence time also means that inlake processes have little impact on the lake's water quality. Because there are not comparables for impounded flowing waters, for this report, Elk Lake will be treated as a lake when comparing its water quality to other lakes within the ecoregion and state wide.

Elk Lake Trophic Parameters

Near-surface total phosphorus data from Elk Lake are available for 1996, 2000, 2001, and 2019 (Figure 8.2.1-1). The weighted summer average total phosphorus concentration is variable ranging from 40 to 97 µg/L, likely as a result of differences in concentrations in the Elk and Little Elk rivers. The weighted summer average is 67.3 µg/L and falls into the *poor* category for deep lowland drainage lakes in Wisconsin. Elk Lake's summer average total phosphorus concentrations are much higher than the median values for both deep lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion. The elevated phosphorus levels are not surprising as the lake has such a short residence time. The phosphorus concentrations are much less that the phosphorus standard for rivers which is 100 µg/L.

Chlorophyll-*a* data are available from Elk Lake for the same years as phosphorus, i.e. 1996, 2000, 2001, and 2019 (Figure 8.2.1-2). Like the weighted average summer phosphorus concentrations, there is a range of chlorophyll-*a* concentrations. Elk Lake's summer average chlorophyll-*a* concentration is 16.1 µg/L and falls into the *fair* category for deep lowland drainage lakes in Wisconsin. Although Elk Lake's summer average chlorophyll-*a* concentrations are higher than the median value for deep lowland drainage lakes in the state and higher than the median value for all lake types in the NLF ecoregion they are closer than the phosphorus concentrations. This is because with the short residence time in the lake, algae does not have time to significantly increase in the lake.

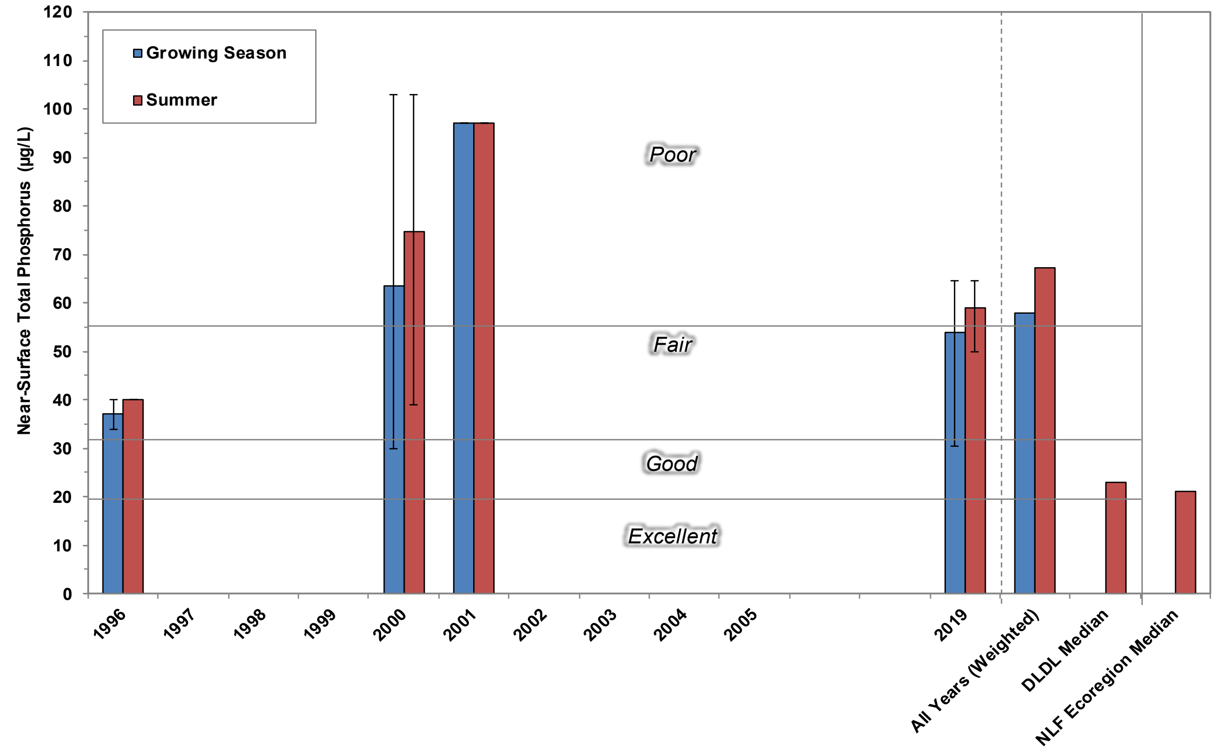


Figure 8.2.1-1. Elk Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

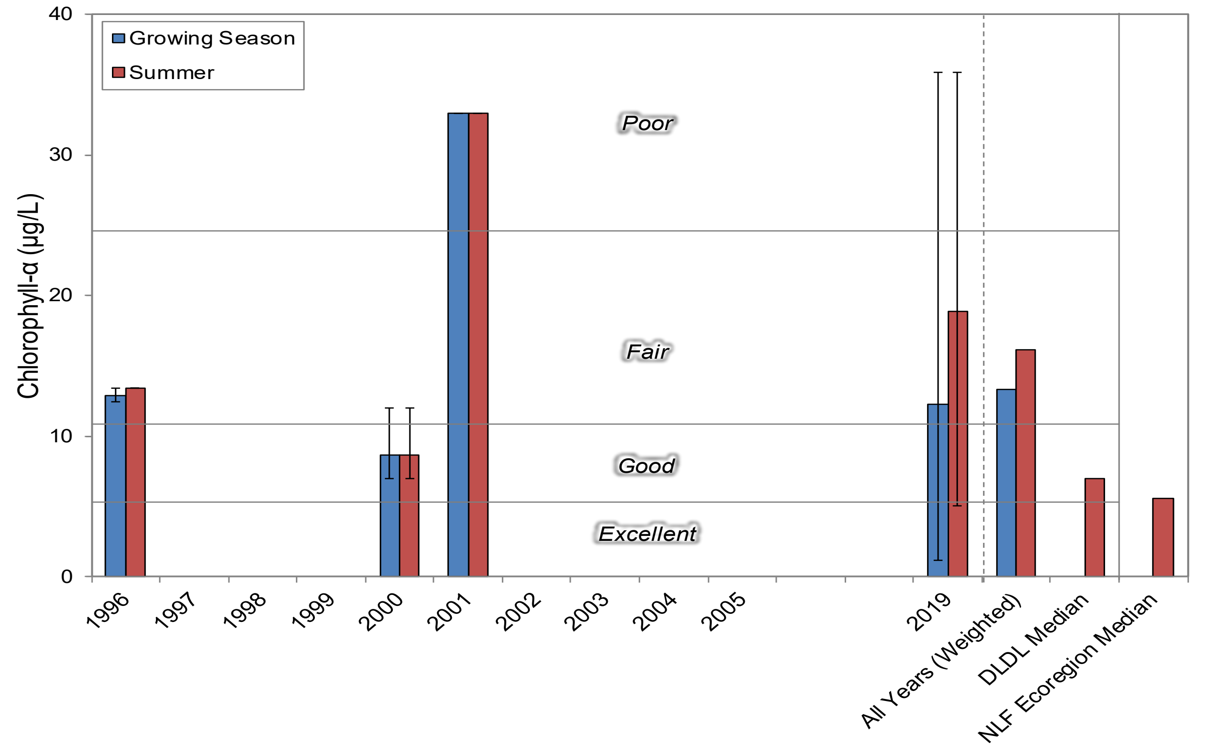


Figure 8.2.1-2. Elk Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Secchi disk transparency data are available from Elk Lake for more years than phosphorus and chlorophyll-*a*. Secchi data is available for 1996, 2000-2005, and 2019 (Figure 8.2.1-3). Like the weighted average summer phosphorus and chlorophyll-*a* concentrations, there is a range of Secchi disk transparencies, ranging from 2.4 to 4.0 feet. The weighted summer average Secchi disk depth is 3.2 feet and falls in the *fair* category for deep lowland drainage lakes in Wisconsin. Elk Lake's weighted summer average Secchi disk depth transparency is much shallower than the median values for both deep lowland drainage lakes in the state and for all lake types in the NLF ecoregion.

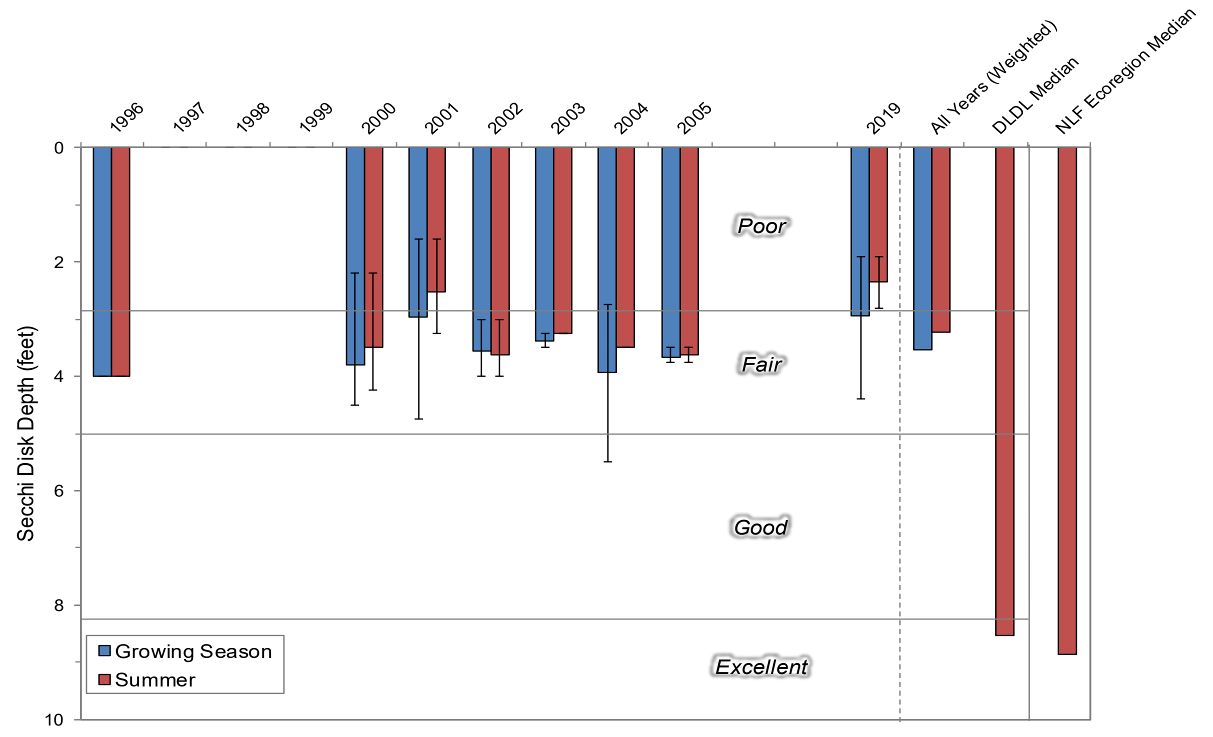


Figure 8.2.1-3. Elk Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Elk Lake in 2019 averaged 90 SU (standard units) indicating the lake's water is *highly tea colored* and that the lake's water clarity is likely influenced by dissolved components in the water. This value suggests that the reason the Secchi disk transparency is not as good as expected given the chlorophyll-*a* concentrations.

Limiting Plant Nutrient of Duroy Lake

Using midsummer nitrogen and phosphorus concentrations from Elk Lake in 2019, a nitrogen:phosphorus ratio of 12:1 was calculated. This finding indicates that Elk Lake is in the transitional zone where the algae may be nitrogen or phosphorus limited. In general, research has shown that cutting phosphorus inputs in these types of lakes will limit plant growth within the lake.

Elk Lake Trophic State

Figure 8.2.1-4 contains the Trophic State Index (TSI) values for Elk Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Elk Lake indicate the lake is at present in a eutrophic state. Elk Lake's productivity is higher when compared to both other deep lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

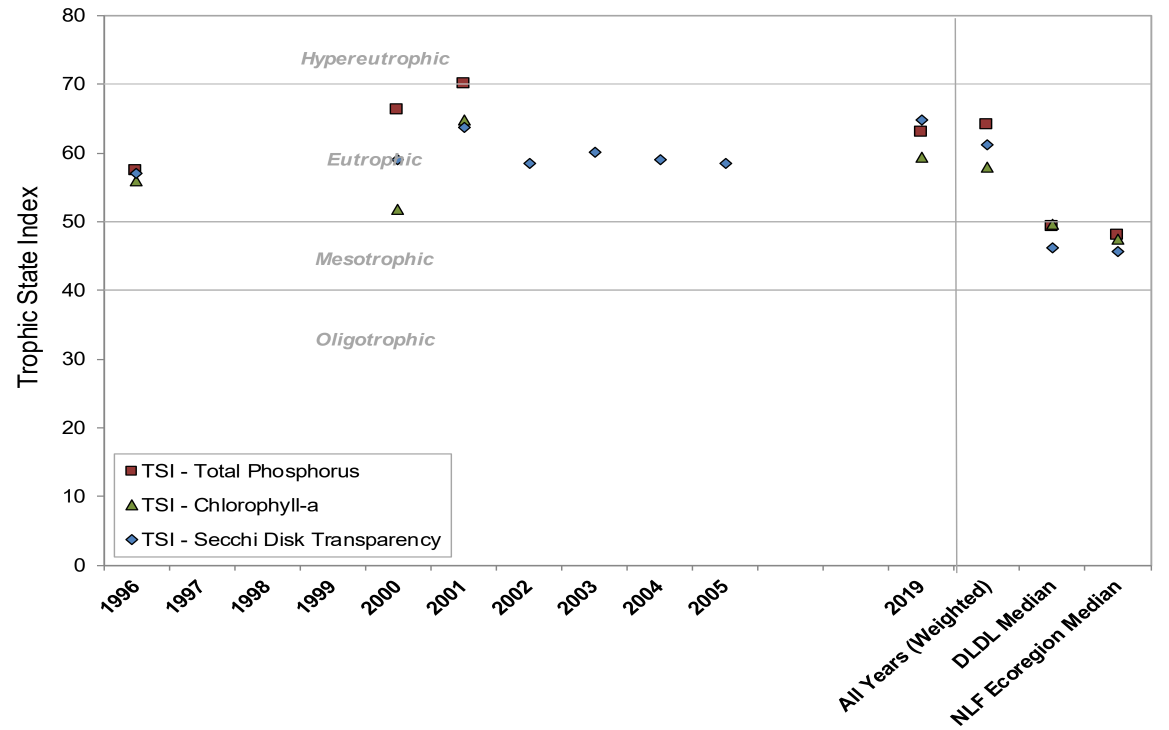


Figure 8.2.1-4. Elk Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2013.

Dissolved Oxygen and Temperature in Elk Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Elk Lake by Onterra staff. Graphs of those data are displayed in Figure 8.2.1-5 for all sampling events.

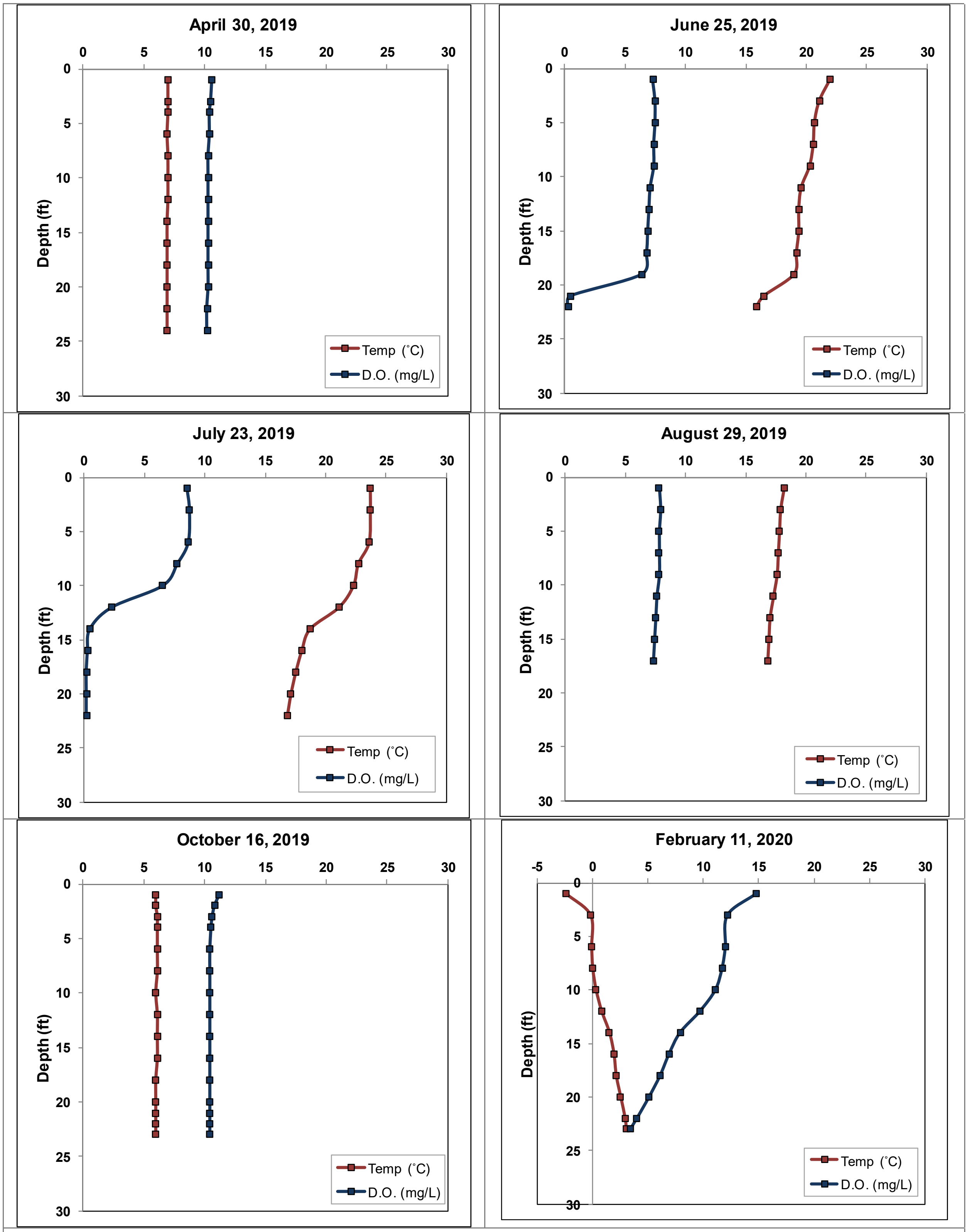


Figure 8.2.1-5. Elk Lake dissolved oxygen and temperature profiles.

Elk Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the June and July, the lake was stratified and the bottom of the lake became void of oxygen. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixed completely in August, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2020, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

Additional Water Quality Data Collected at Elk 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 Elk 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. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below reflect concentrations during July. It is expected these concentrations will change from year to year depending upon precipitation and its impact on flows in the rivers.

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. Elk Lake's surface water pH was measured at roughly 7.6 during summer 2019 (Figure 8.2.1-6). This value is near 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. The alkalinity in Elk Lake during July 2019 was measured at 42.7 (mg/L as $CaCO_3$) (Figure, 8.2.1-7) 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 Elk Lake during July 2019. 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 Elk Lake's pH of 7.6 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 Elk Lake was found to be 12 mg/L, which ion the border between very low and low susceptibility for the optimal range for zebra mussels.

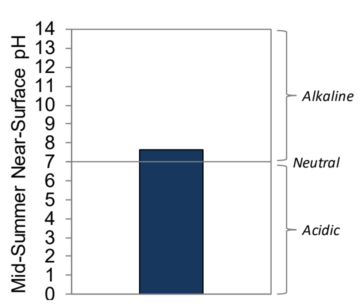


Figure 8.2.1-6. Duroy Lake mid-summer near-surface pH value.

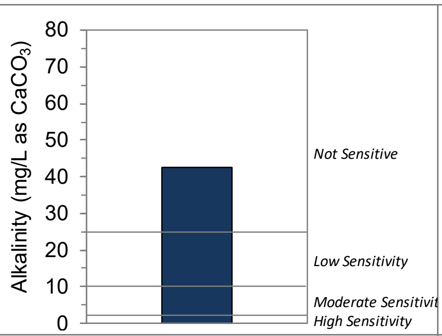


Figure 8.2.1-7. Elk Lake summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

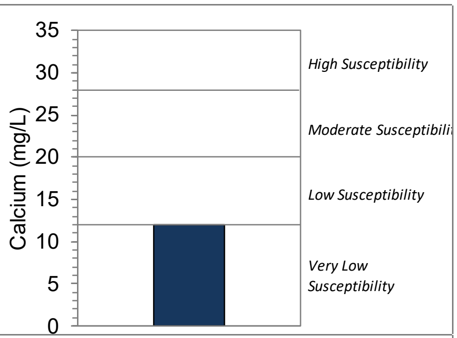


Figure 8.2.1-8. Elk Lake summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

Elk Lake Heavy Metal Contamination

As will be discussed in the Elk Lake Aquatic Vegetation Section (8.2.4), Elk Lake has a very sparse aquatic plant communities with low density. While this can be partly attributed to the substrate (coarse and fine gravel) and morphology (steeply sloped, narrow littoral zone), there has been concern over contamination from a metal plating company that formerly discharged wastewater into Elk Lake. There was speculation that these contaminants were impacting aquatic plant growth in Elk and Long Lakes.

Results from sediment samples taken from Elk Lake in the 1970's showed that concentration of chromium and copper exceeded levels known as lethal to small, bottom-dwelling benthic organisms (MacDonald et. al. 2000). Further testing in 2009 determined that chromium and copper concentrations had decreased somewhat, though this may be due to dilution by additional sediment deposition. Results for select metals from a 2005 sediment sample are summarized in Table 8.2.1-1. Threshold effect concentrations are based upon affects to benthic (bottom dwelling) organisms which are valuable indicator species of water pollution (WDNR 2003).

Table 8.2.1-1. Heavy metal concentrations and Sediment Quality Guidelines from Elk Lake, 2005. Samples were collected by the WDNR near the Wastewater Treatment Plant outfall. Guidelines represent standards set for benthic organism tolerance levels.

Metal	Dry Wt (mg/kg)	Concern Level 1 (lowest) - 4 (highest)
Chromium	207	4
Copper	85.6	2
Lead	80	2
Silver	<0.5	1
Zinc	281	2

8.2.2 Elk Lake Watershed Assessment

Elk Lake's watershed is 113,696 acres in size. Compared to Elk Lake's size of 91 acres, this makes for a large watershed to lake area ratio of 1,249:1. The watershed is comprised primarily of the Duroy Lake sub-watershed (>99%) while the remaining 744 acres compromise <1% of Elk Lakes direct watershed. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Elk Lake's residence time is less than one day, or the water within the lake is completely replaced 456 times per year. This short residence time means that the phosphorus concentration in the lake should be similar to the upstream Duroy Lake.

Approximately 99% of Elk Lake's watershed is comprised of the Duroy sub-watershed (Map 2). As discussed in the chain-wide section (3.2), the Duroy sub-watershed was modeled as point-source based upon measured phosphorus concentrations in the lake. The remaining 1% of the overall watershed includes the direct watershed, as well as the surface of the lake. Direct phosphorous addition to the lake comes through atmospheric deposition. Forested and wetland land cover types comprise 26% of the direct watershed. These land cover types provide the least amount of phosphorus inputs to a system. Row crop agriculture, urban, and residential land cover types deliver the most amount of phosphorus to a system, with 29% of the direct watershed consisting of these land cover types and only a small fraction of the overall Elk Lake watershed.

WiLMS estimates 21,192 pounds of phosphorus being delivered to Elk Lake on an annual basis. Comprising 99% of the watershed area, the Duroy sub-watershed delivers 99% of the phosphorus load (20,984 pounds) to Elk Lake. The direct watershed phosphorus load and impact is considered to be very minimal as it delivers 1% (207 pounds) of the overall phosphorus load to Elk Lake.

8.2.3 Elk 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 Fall of 2019, Elk Lake's immediate shoreline was assessed in terms of its development. Elk Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.9 miles (67% of the total shoreline) of natural/undeveloped and developed-natural 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 state if at all possible. During the survey, 0.1 miles of urbanized and developed–unnatural shoreline (9% of the total shoreline) was observed. If restoration of the Elk 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. Elk Lake Map 1 displays the location of these shoreline lengths around the entire lake.

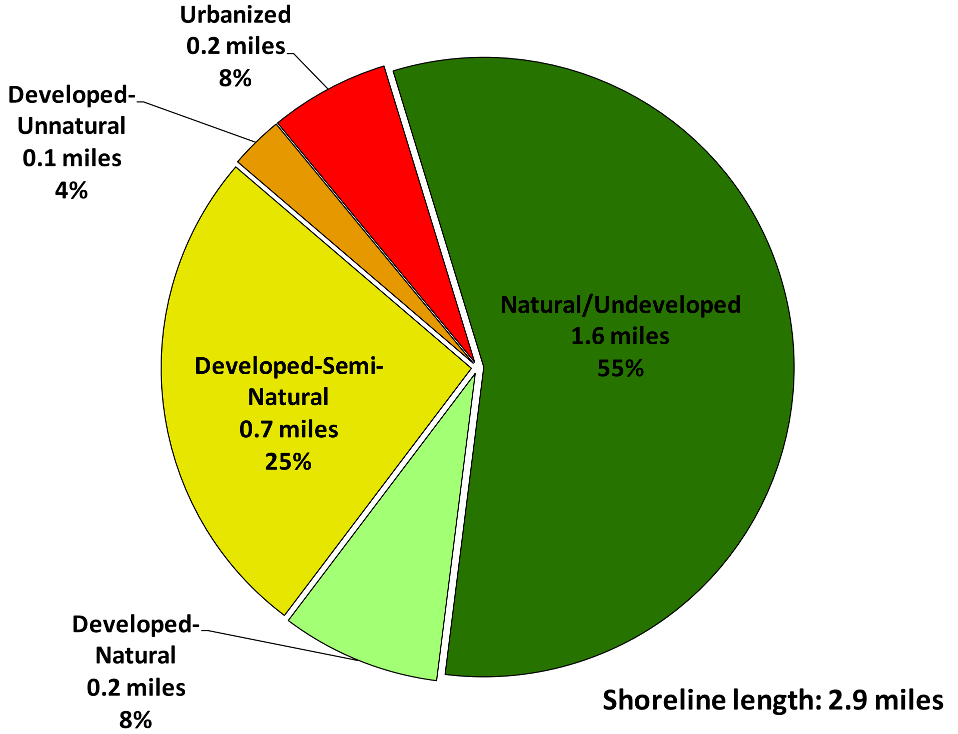


Figure 8.2.3-1. Elk Lake shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Elk Lake Map 1.

Coarse Woody Habitat

Elk Lake was surveyed in 2019 to determine the extent of its coarse woody habitat (Figure 8.2.3-2). 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.

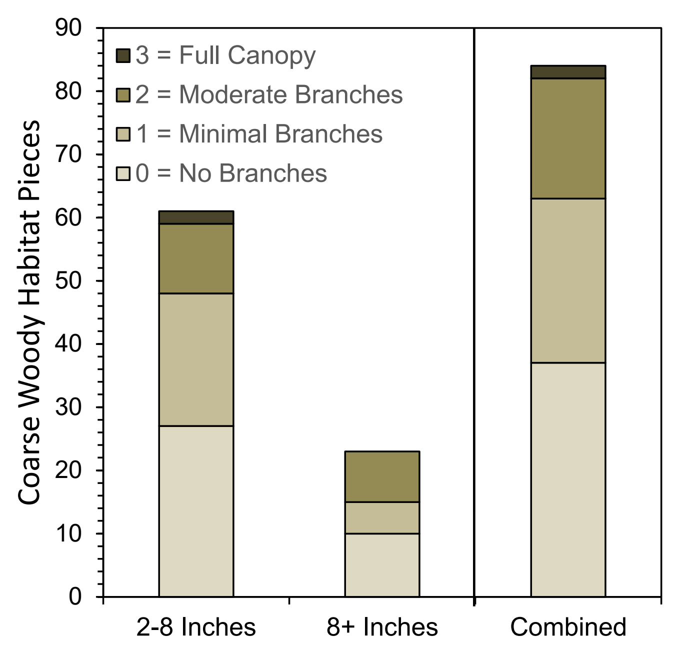


Figure 8.2.3-2. Elk Lake coarse woody habitat survey results. Based upon a Fall 2019 survey. Locations of Elk Lake coarse woody habitat can be found on Elk Lake Map 2.

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 coarse woody habitat are displayed on Elk Lake Map 2.

8.2.4 Elk Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) survey was conducted by Onterra ecologists on Elk Lake on June 11, 2019. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of the non-native curly-leaf pondweed which should be at or near its peak growth at this time. During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat. No occurrences of AIS were located in or around Elk Lake during this survey.

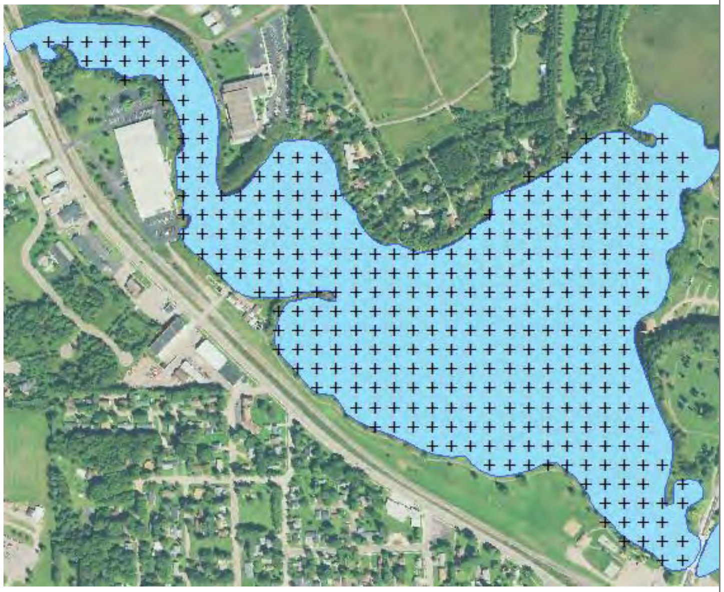


Figure 8.2.4-1. Elk Lake whole-lake aquatic point-intercept survey sampling locations. n=343

The aquatic plant point-intercept survey was conducted on Elk Lake on July 23, 2019 by Onterra (Figure 8.2.4-1). The floating-leaf and emergent plant community mapping survey was completed on August 26 to create the aquatic plant community map. During these surveys, a total of 13 species of native aquatic plants were located in and around Elk Lake (Table 8.2.4-1). Ten of these species were sampled directly during the point-intercept survey and are used in the analysis that follows. The remaining three native species were located visually during the survey, but not sampled on the rake. In addition, one non-native species was located visually on Elk Lake - Eurasian watermilfoil (EWM). The EWM in Elk Lake will be discussed in its own subsection at the end of the Aquatic Vegetation section. A whole-lake point-intercept (PI) survey was also completed on Elk Lake in 2009 during the last management planning project. The species recorded during this survey are also displayed in Table 8.2.4-1 for comparison between the two years.

During the 2019 PI survey, aquatic plants were found growing to a depth of 4 feet. Of the 343 points on the sampling grid (Figure 8.2.4-1), 54 were littoral (within depths at which plants can grow), and only a total of 7 sites contained vegetation. Each of these sites that contained aquatic plants were very close to shore (5). One possibility for the very low occurrence of aquatic vegetation in Elk Lake is the historic heavy metal contaminated sediment which was discussed previously in the Water Quality Section. Another contributing factor could be that 56% of the substrate in Elk Lake is hard sand which only select plant species can grow in, and 19% of the substrate is rock which plants cannot grow in alone. Further complicating plant growth is the steep contours around the margin of Elk Lake, restricting the littoral zone to a small area.

Table 8.2.4-1. Aquatic plant species located in Elk Lake during the 2009 and 2019 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2009 Onterra	2019 Onterra
E	*Pontederia cordata*	Pickerelweed	9	I	I
	Sparganium eurycarpum	Common bur-reed	5	I	
	Typha latifolia	Broad-leaved cattail	1	I	
	Typha spp.	Cattail sp.	1		I
FL	*Nuphar variegata*	Spatterdock	6	X	
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium* spp.	Bur-reed species	N/A		I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	X	X
	Myriophyllum sibiricum	Northern water milfoil	7		X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	I	I
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton spirillus	Spiral-fruited pondweed	8		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8		X
FF	*Lemna minor*	Lesser duckweed	5	X	
	Lemna turionifera	Turion duckweed	2		X

E = Emergent; FL = Floating-leaf; FL/E = Floating-leaf/emergent; FF = Free-floating
X = Located on rake during point-intercept survey

Aquatic plant rake fullness data (density of plants pulled up on the rake) was collected as well during the point-intercept survey. Only one of the vegetated sites contained a total rake fullness (TRF) of 3, the highest density rating (Figure 8.2.4-2). This was in a small protected bay on the far east side of the lake. The remaining six vegetated sites contained the lowest density rating of TRF=1, indicating that where plants do occur in Elk Lake, they are of low density.

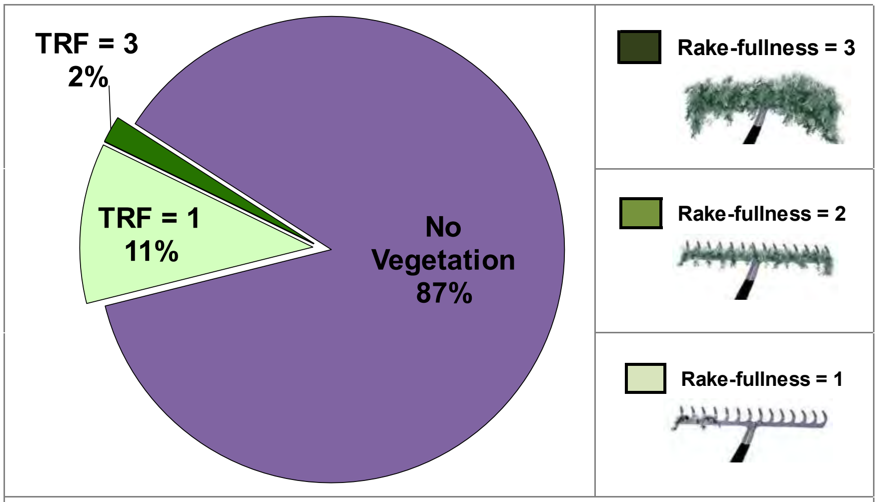


Figure 8.2.4-2. Total rake fullness ratings on Elk Lake. Created using data from 2019 point-intercept survey.

Figure 8.2.4-3 shows the littoral frequency of occurrence of all species located in Elk Lake during the 2009 and 2019 surveys. The figure shows an increase in the frequency of several aquatic plant species from 2009 to 2019, with six of these increases being statistically significant. White water lily was the most frequently encountered species both years. White water lily is easy to spot with its round, notched lily pads and bright white and fragrant flowers. Its leaves and rhizomes are eaten by some wildlife; but while floating, provide habitat for aquatic organisms as well as a place for some insects and amphibians to lay their eggs.

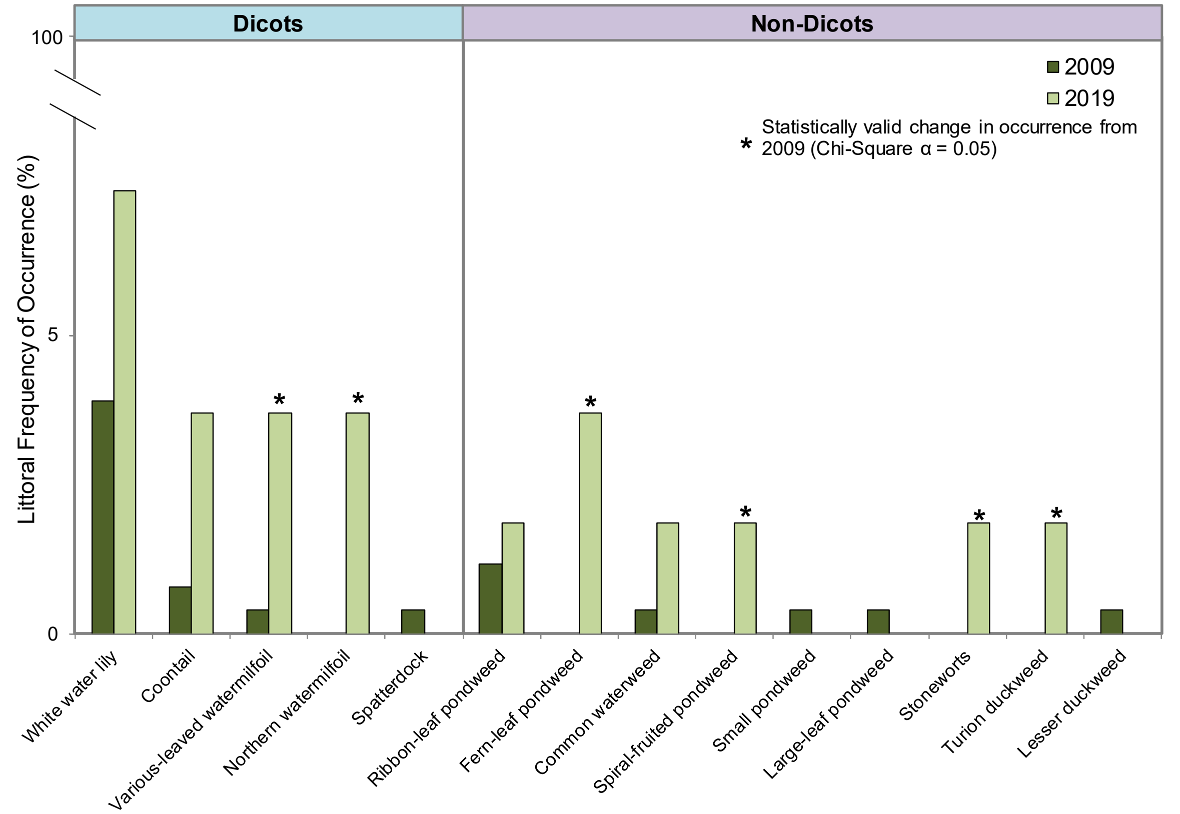


Figure 8.2.4-3. Elk Lake aquatic plant littoral frequency of occurrence analysis. Created using data from the 2009 and 2019 point-intercept surveys.

The next most common species found in Elk Lake all had littoral frequencies of occurrence of 3.7% during the 2019 survey. They are: coontail, various-leaved watermilfoil, northern watermilfoil, and fern-leaf pondweed.

Various-leaved watermilfoil and northern watermilfoil are both native species of watermilfoil that are often found growing in soft sediments in lakes with higher water clarity. Their feathery foliage traps filamentous algae and detritus, providing valuable invertebrate habitat. Because they prefer higher water clarity, their populations are declining state-wide as lakes are becoming more eutrophic.

Fern-leaf pondweed is generally found growing in thick beds over soft substrates where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. As its name indicates, this plant resembles a terrestrial fern frond in appearance and is often a dominant species in plant communities of northern Wisconsin lakes. This plant often goes without being noticed, as it grows low within the water column and rarely causes conditions that interfere with recreation and navigation. Fern-leaf pondweed survives mostly as an evergreen plant throughout the winter when many other native plants are dormant.

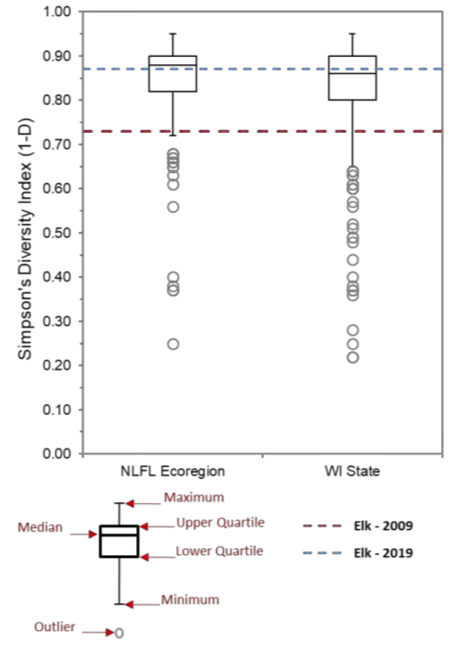


Figure 8.2.4-4. Simpson's diversity index for Elk Lake.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, how evenly the species are distributed throughout the system also influence diversity. The diversity index for Elk Lake's plant community (0.87 in 2019) falls in between the state (0.86) and ecoregion (0.88) medians, making it near average (Figure 8.2.4-4). This was not the case however for the 2009 survey which yielded a Simpson's diversity value of 0.73.

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 white water lily was found at 7.4% of the littoral sampling locations in 2019, its relative frequency of occurrence is 23% since so few other species were located in the lake. Explained another way, if 100 plants were randomly sampled from Elk Lake, 23 of them would be white water lily. This distribution can be observed in Figure 8.2.4-5 where together 5 species account for 71% of the population of plants within Elk Lake, and the other 5 species account for the remaining 29%. As a reminder, the incidentally located species are not included in this analysis.

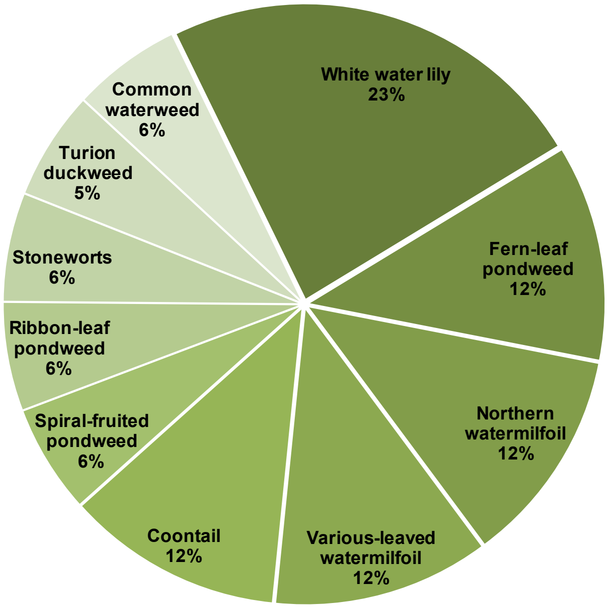


Figure 8.2.4-5. Elk Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2019 point-intercept survey.

Elk Lake's average conservatism value was below both the state and ecoregion medians for both surveys (Figure 8.2.4-6). This indicates that the aquatic plant community in Elk Lake is of below average quality. Elk Lake's species richness value was also well below the ecoregion and state medians. Combining Elk Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 18.7 in 2019 which is below the median values for the ecoregion and state as well.

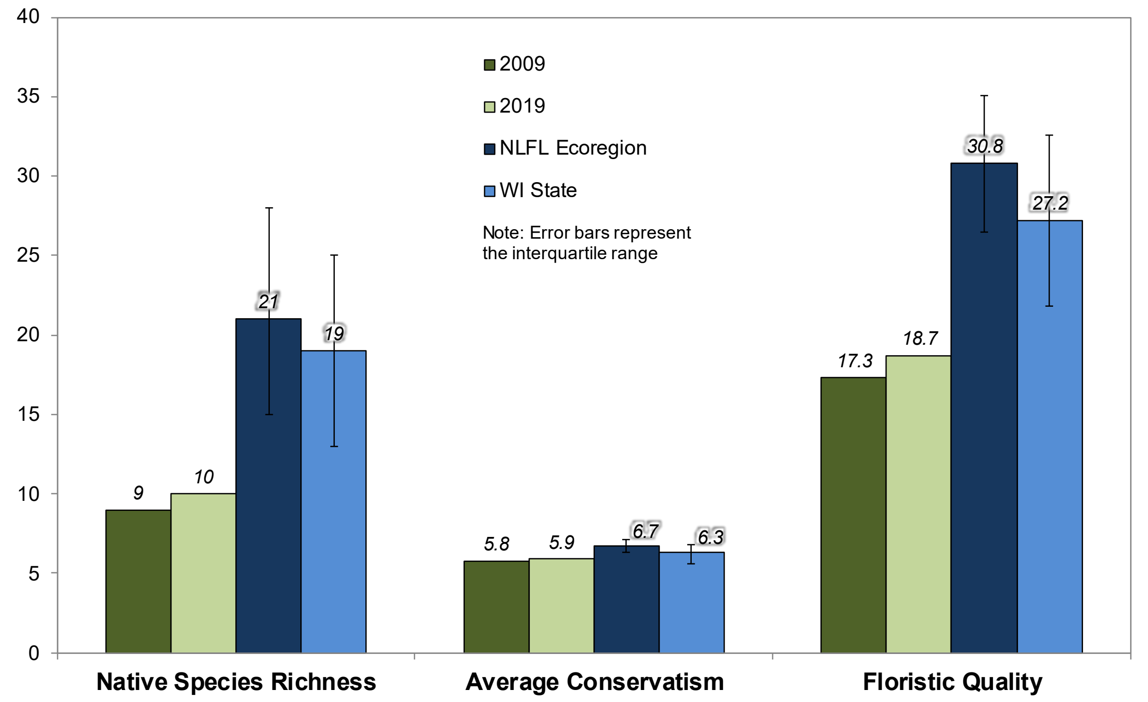


Figure 8.2.4-6. Elk Lake Floristic Quality Analysis. Created using data from 2009 and 2019 point-intercept surveys.

The quality of Elk Lake can also be assessed by the incidence of emergent and floating-leaf plant communities that occur around the lake. The 2019 community map indicates that approximately 1.6 acres of the lake contains these types of plant communities (Elk Lake Map 3, Table 8.2.4-2). This is less than 2% of the lake which is comparatively quite low.

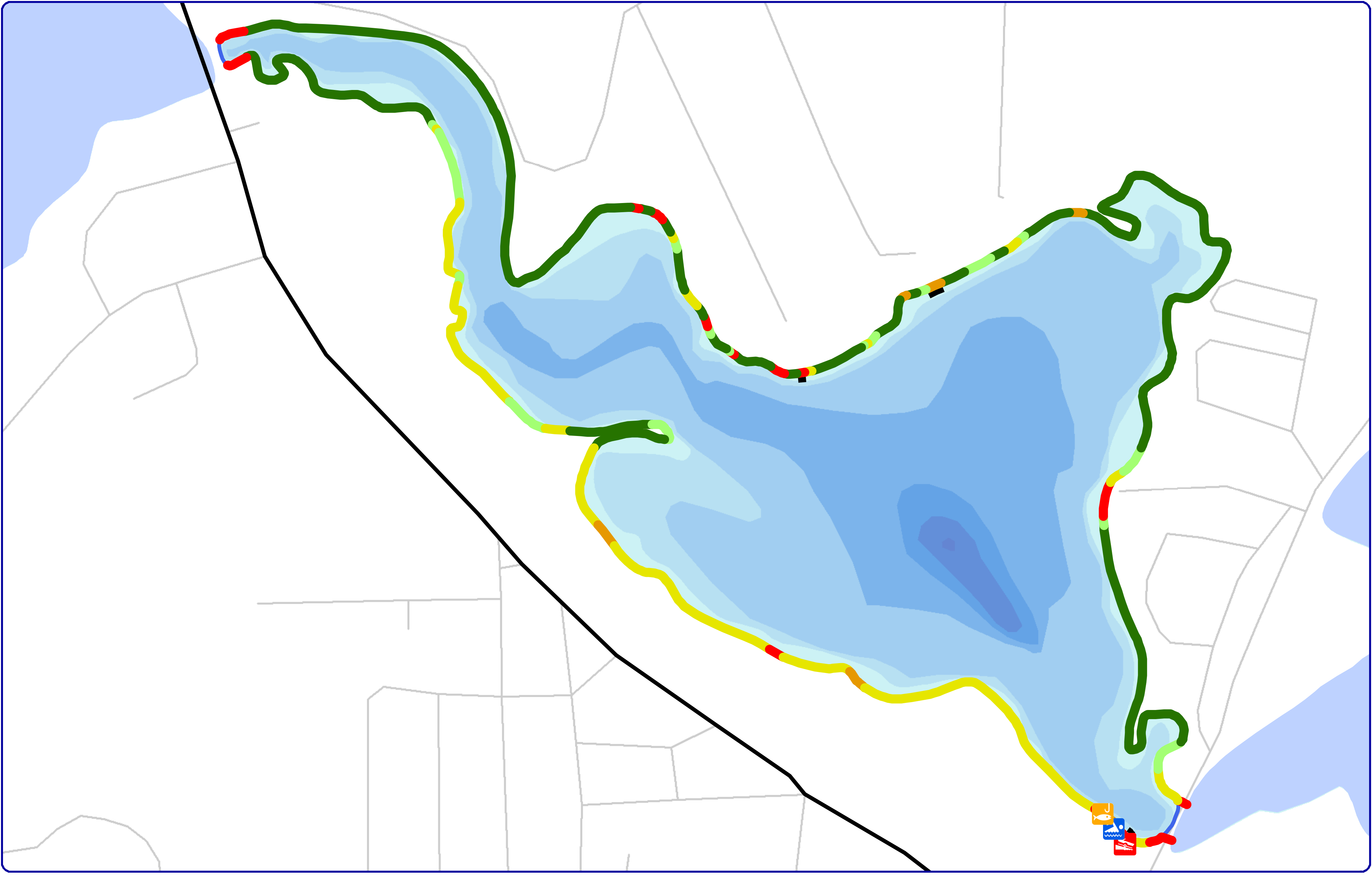
Table 8.2.4-2. Elk Lake acres of emergent and floating-leaf plant communities from the 2019 community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-leaf	0.6
Mixed Emergent & Floating-leaf	1.1
Total	**1.6**

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum;* EWM) was first verified in Elk Lake in 2002. EWM has an affinity for softer sediments, which as displayed previously, makes up only 25% of Elk Lake's bottom substrate.

PCOLA has sponsored a number of AIS control projects aimed at managing the EWM population on the Phillips Chain, starting in 2011. Starting in 2009, late-season EWM mapping surveys have periodically occurred on the Phillips Chain using a consistent density rating system. On Elk Lake, no colonized EWM has been located during this time period, with only *Single or Few Plants* being observed. Elk Lake Map 4 shows the results of the latest EWM mapping survey that occurred in 2019.



Elk - Map 1

Elk Lake

Price County, Wisconsin

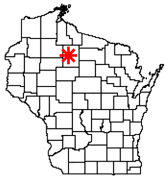
Shoreland Condition Assessment

Legend

- 🟩 Natural/Undeveloped
- 🟩 Developed-Natural
- 🟨 Developed-Semi-Natural
- 🟧 Developed-Unnatural
- 🟥 Urbanized

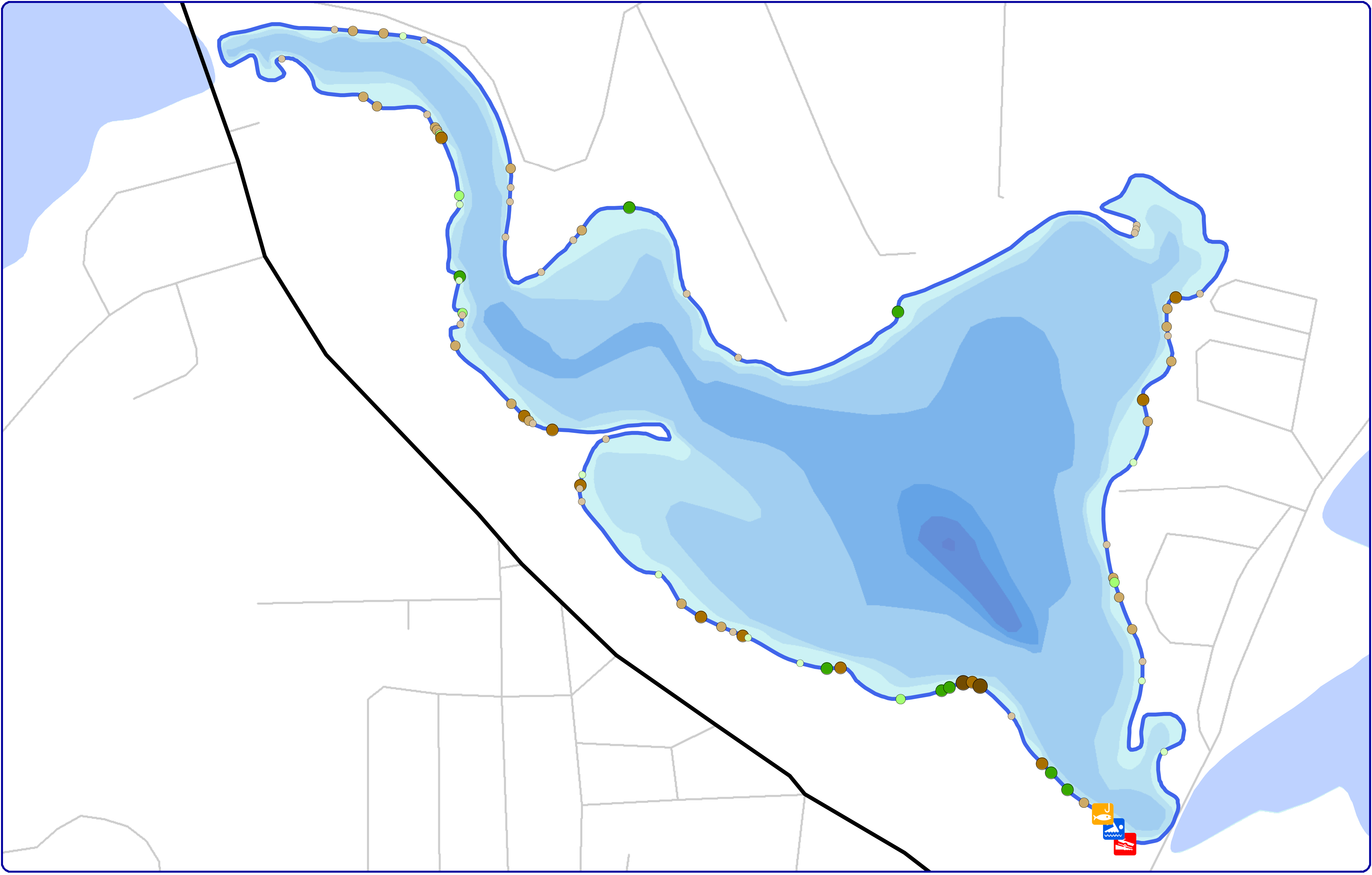
Seawall Modifier

- ▬ Masonry/Metal/Wood
- ○○○○○○ Rip-Rap/Placed Stone


Project Location in Wisconsin

Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 3, 2019 JMB
Filename: PhillipsChain_SA_2019_Elk.mxd

Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com



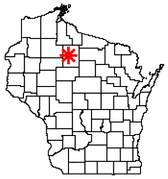
N
W E
S

600

Feet

Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 3, 2019 JMB
Filename: PhillipsChain_SA_2019_Elk.mxd

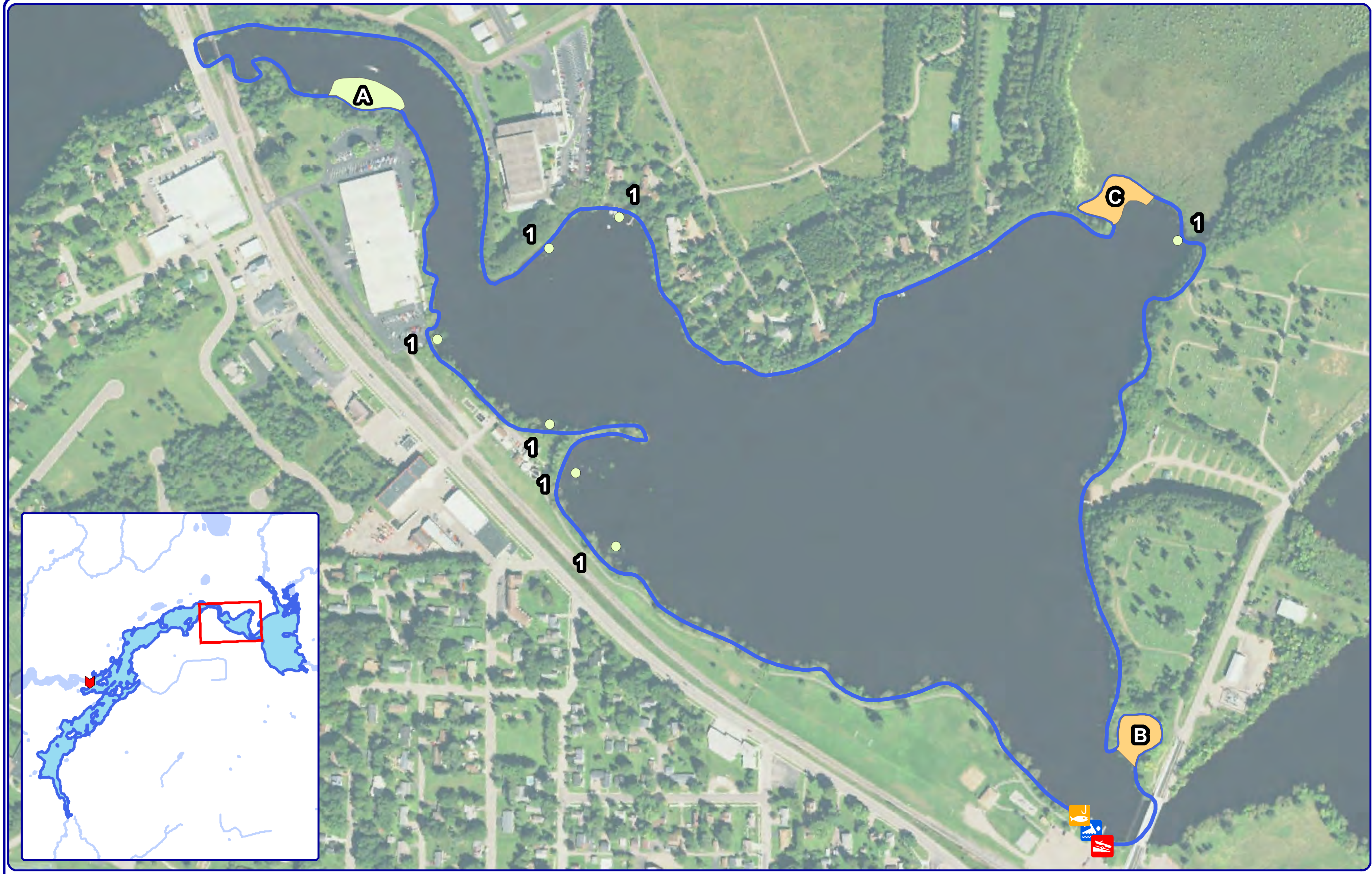


Project Location in Wisconsin

Legend

2-8 Inch Pieces	8+ Inch Pieces
● No Branches	● No Branches
● Minimal Branches	● Minimal Branches
● Moderate Branches	● Moderate Branches
● Full Canopy	● Full Canopy

Elk - Map 2
Elk Lake
Price County, Wisconsin
Coarse Woody Habitat Assessment



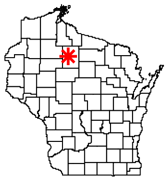
N
W E
S

490

Feet

Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Plants: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 19, 2019 AMS
Filename: PhillipsChain_Comm_2019_Elk.mxd



Project Location in Wisconsin

Legend

Small Plant Communities
- ● Emergent
- ○ Floating-leaf
- ● Mixed Floating-leaf & Emergent

Large Plant Communities
- 🟩 Emergent
- ▨ Floating-leaf
- 🟧 Mixed Floating-leaf & Emergent

Elk - Map 3

Elk Lake

Price County, Wisconsin

Aquatic Plant Communities

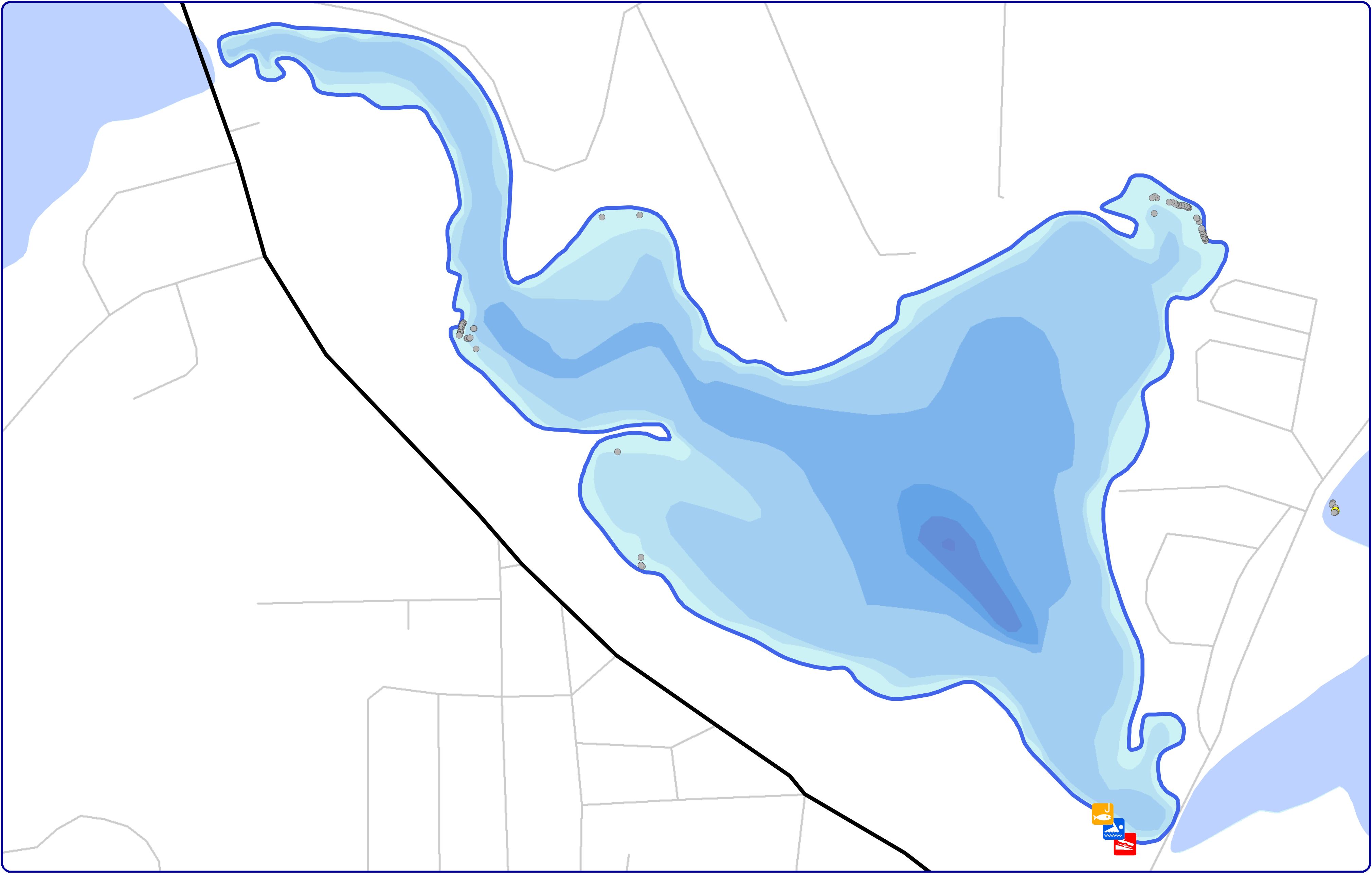
Elk Lake 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Elk - Map 3

Large Plant Community (Polygons)									
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
A	**White water lily**								0.56
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
B	**White water lily**	Pickerelweed	Bur-reed sp. (sterile)						0.51
C	**White water lily**	Cattail sp.	Bur-reed sp. (sterile)	Pickerelweed					0.57

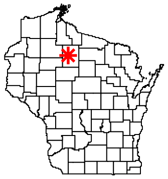
Small Plant Community (Points)								
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	**White water lily**							

Bolded species are considered most dominant within each community; Scientifc names can be found in the species list in Table 8.2.4-1



Onterra, LLC
Lake Management Planning
815 Prosper Rd
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 3, 2019 JMB
Filename: PhillipsChain_SA_2019_Elk.mxd



Project Location in Wisconsin

Legend

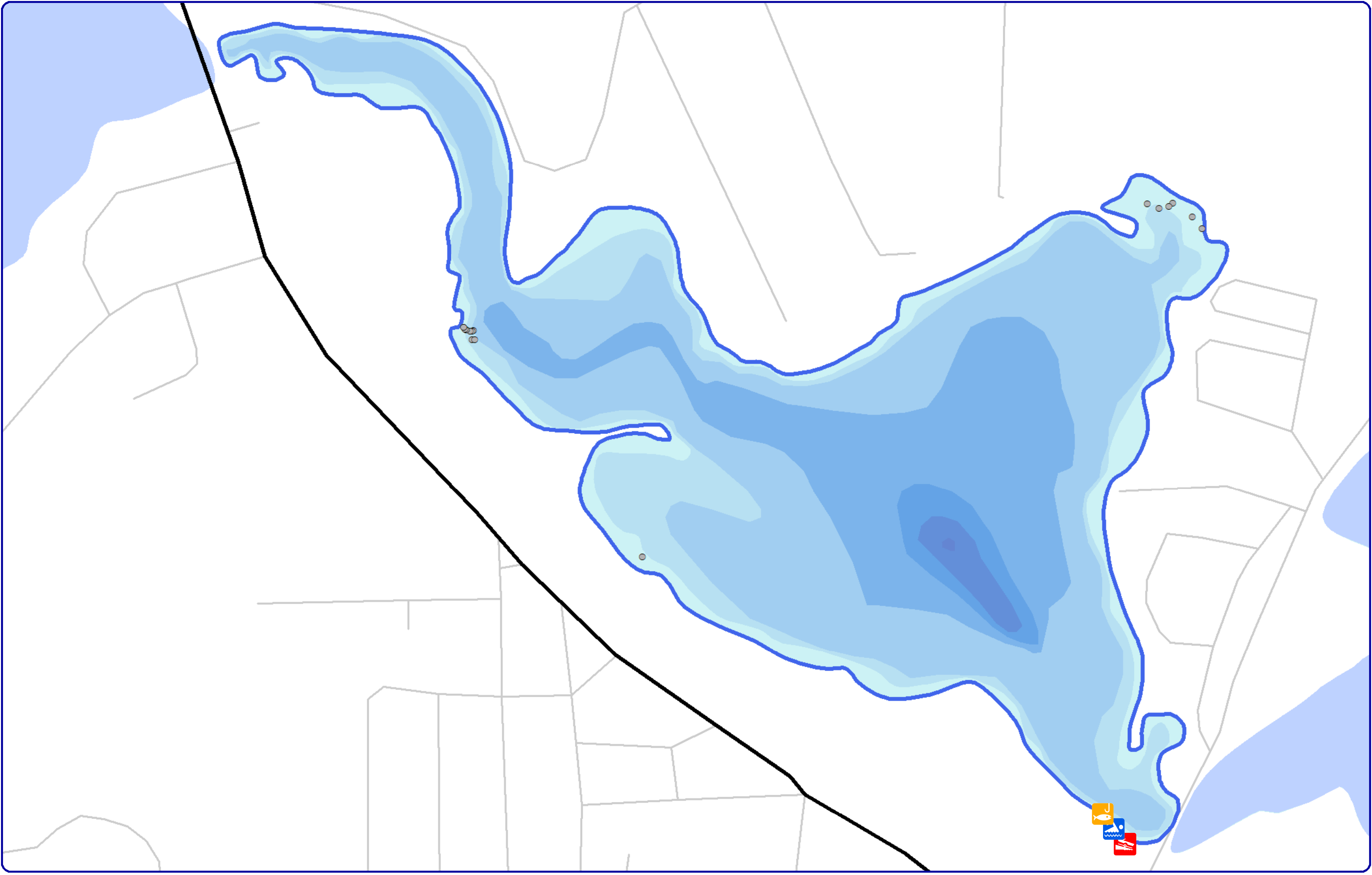
▢ Highly Scattered	· Single or Few Plants
▩ Scattered	🟡 Clump of Plants
🟨 Dominant	🟠 Small Plant Colony
🟧 Highly Dominant	
🟥 Surface Matting	

Elk - Map 4

Elk Lake

Price County, Wisconsin

August 2019 EWM Survey Results



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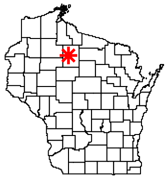


Project Location in Wisconsin

Legend

- ⬜ Highly Scattered
- ⬛ Scattered
- 🟨 Dominant
- 🟧 Highly Dominant
- 🟥 Surface Matting
- ● Single or Few Plants
- ● Clump of Plants
- ● Small Plant Colony

Elk - Map 5

Elk Lake

Price County, Wisconsin

August 2020 EWM Survey Results

8.3.0 Long Lake Introduction

Long Lake, Price County, is a drainage lake with a maximum depth of 54 feet and a surface area of 407 acres. This eutrophic lake has an extremely large watershed when compared to the size of the lake. In 2019, 20 native plant species were located in Long Lake – slender naiad and common waterweed were the most common. No exotic plant species were located in Long Lake during the 2019 surveys, although Eurasian watermilfoil has been located during previous surveys.

Field Survey Notes

The shores of Long Lake contain several resorts and a golf club. While aquatic plants are not very abundant in Long Lake, it is known to contain Vasey's pondweed, a species of concern in the state which requires high-quality conditions to survive.

Photograph 8.3.0-1. Long Lake, Price County. Photo Credit, Nate Kopp (YouTube).

Lake at a Glance* – Long Lake

Morphology	
Acreage	407
Maximum Depth (ft)	54
Mean Depth (ft)	10.4
Volume (acre-feet)	4,223
Shoreline Complexity	14.8
Vegetation	
Number of Native Species	32
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	EWM
Simpson's Diversity	0.89
Average Conservatism	6.5
Water Quality	
Wisconsin Lake Classification	Deep lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	313:1

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

8.3.1 Long Lake Water Quality

Water quality data was collected from Long Lake on six occasions in 2019/2020. 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) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Wisconsin DNR staff monitored the lake in 1996 and 2000 for total phosphorus, chlorophyll-*a*, and Secchi disk clarity. All of the lakes in the Phillips Chain have very short hydraulic residence times (all except Wilson Lake less than 14 days) which in the classification scheme of the Wisconsin Department of Natural Resources makes these water bodies officially *impounded flowing waters.* For phosphorus standards, the value for rivers (100 µg/L) is used. The reason for this classification is that with the short residence times, the water quality of these water bodies is mostly reflective of the water quality of the incoming Elk and Little Elk rivers and Squaw Creek. In the case of Long Lake which is immediately downstream of Elk and Wilson lakes, Long Lake's water quality is a combination of the two lakes. There is a greater flow from Elk Lake compared with Wilson Lake so Elk Lake's water quality has a larger influence on the water quality of Long Lake. The short residence times also mean that in-lake processes have little impact on the lake's water quality. Because there are not comparables for impounded flowing waters, for this report the Long Lake will be treated as a lake when comparing its water quality to other lakes within the ecoregion and state wide.

Long Lake Trophic Parameters

Near-surface total phosphorus data from Long Lake are available for 1996, 2000, and 2019 (Figure 8.3.1-1). The weighted summer average total phosphorus concentration is variable ranging from 42 to 72 µg/L, likely as a result of differences in concentrations in the Elk and Little Elk rivers. The weighted summer average is 57.3 µg/L and falls on the border between the *fair and poor* categories for deep lowland drainage lakes in Wisconsin. Long Lake's summer average total phosphorus concentrations are much higher than the median values for both deep lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion. The elevated phosphorus levels are not surprising as the lake has such a short residence time. The phosphorus concentrations are much less that the phosphorus standard for rivers which is 100 µg/L.

Chlorophyll-*a* data are available from Long Lake for the same years as phosphorus, i.e. 1996, 2000, 2019 (Figure 8.3.1-2). Like the weighted average summer phosphorus concentrations, there is a range of chlorophyll-*a* concentrations. Long Lake's summer average chlorophyll-*a* concentration is 14.1 µg/L and falls into the *good* category for deep lowland drainage lakes in Wisconsin. Although Long Lake's summer average chlorophyll-*a* concentrations are higher than the median value for deep lowland drainage lakes in the state and higher than the median value for all lake types in the NLF ecoregion they are closer than the phosphorus concentrations. This is because with the short residence time in the lake, algae does not have time to significantly increase in the lake.

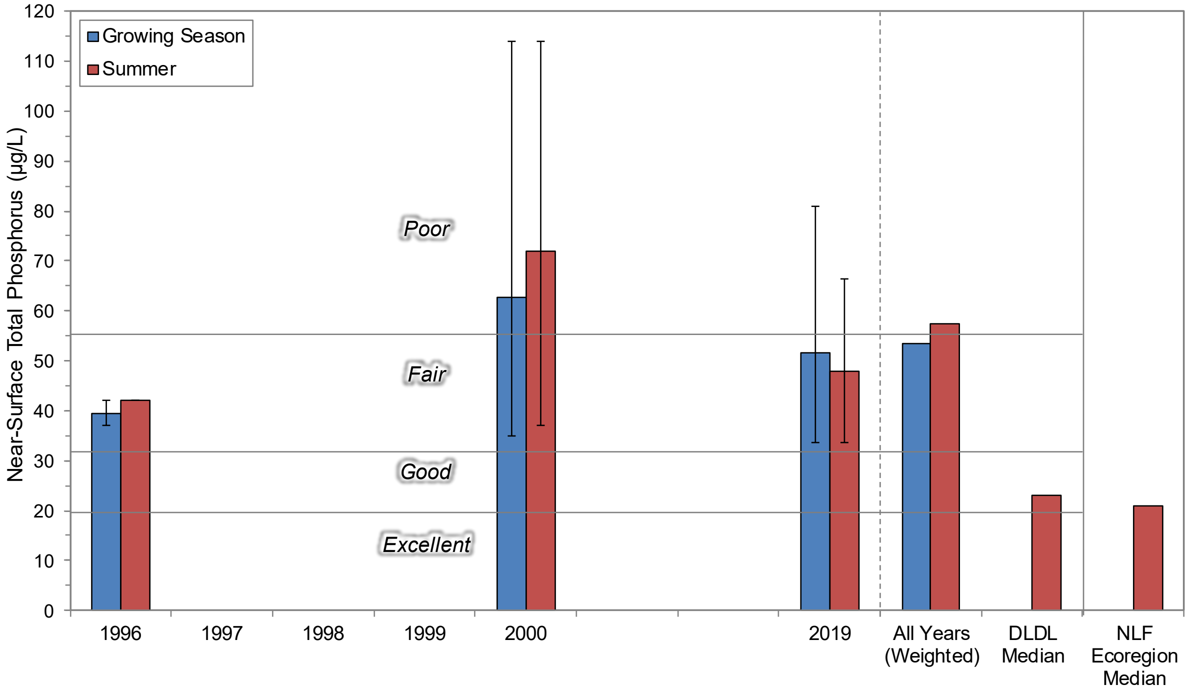


Figure 8.3.1-1. Long Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

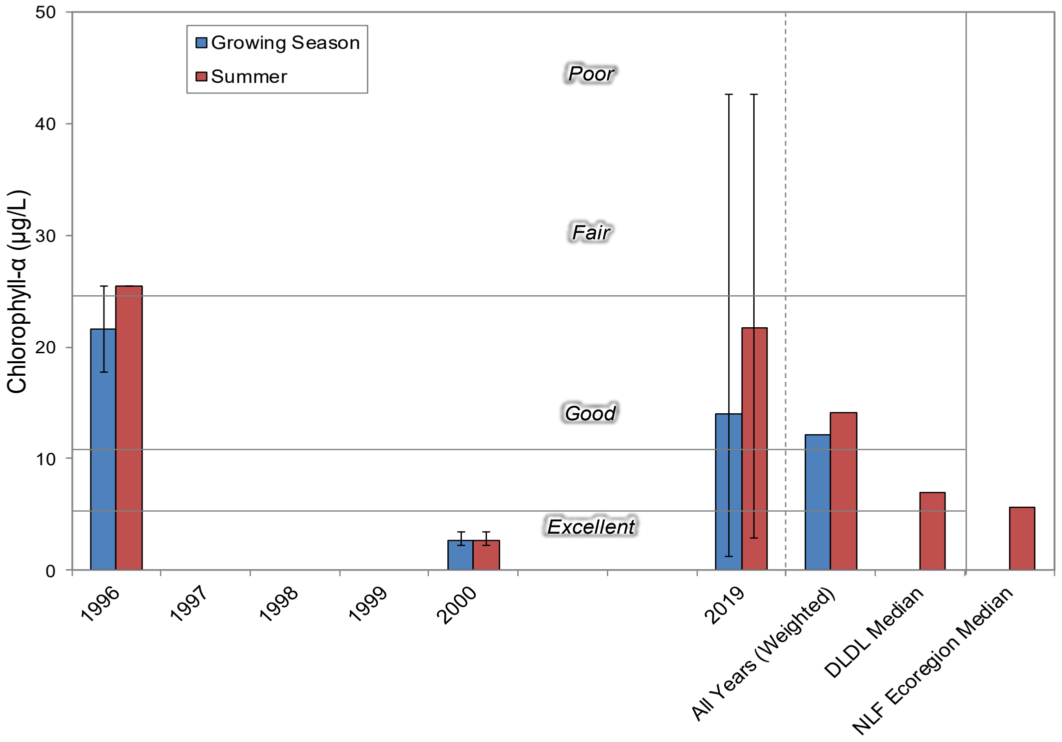


Figure 8.3.1-2. Long Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Secchi disk transparency data are available from Long Lake for more years than for phosphorus and chlorophyll-*a*. Secchi data is available for 1990-1993, 1996, 1999-2000, and 2019 (Figure 8.3.1-3). Like the weighted average summer phosphorus and chlorophyll-*a* concentrations, there is a range of Secchi disk transparencies, ranging from 3.6 to 18.6 feet. During the early 1990s, water clarity was considerably better than it has been since 1996. The weighted average for the early 1990s was 14.4 feet but since 1996 the average is 4.2 feet. Although the weighted summer average Secchi disk depth for all years is 12.1 feet and places the lake in the *excellent* category, since 1996 the weighted average Secchi depth would place the lake in the *fair* category for deep lowland drainage lakes in Wisconsin. Long Lake's weighted summer average Secchi disk depth transparency for the last 15 years is much shallower than the median values for both shallow lowland drainage lakes in the state and for all lake types in the NLF ecoregion.

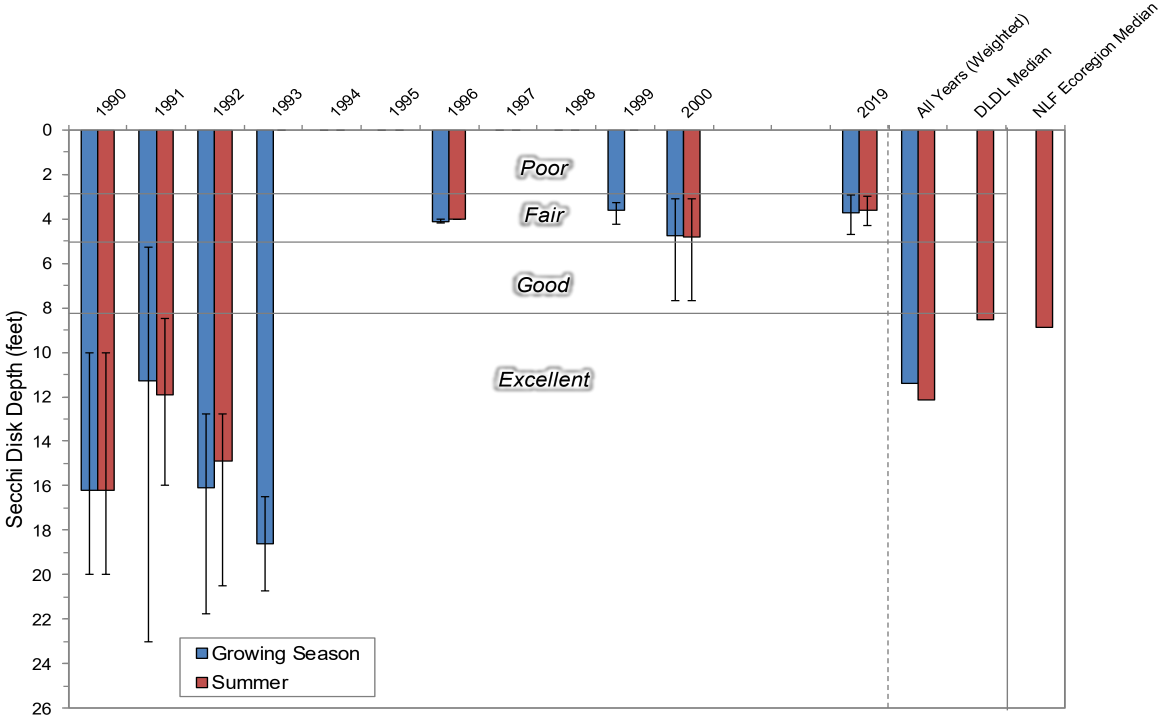


Figure 8.3.1-3. Long Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Long Lake in 2019 averaged 85 SU (standard units) indicating the lake's water is *highly tea colored* and that the lake's water clarity is likely influenced by dissolved components in the water. This value suggests that the reason the Secchi disk transparency is not as good as expected given the chlorophyll-*a* concentrations.

Limiting Plant Nutrient of Long Lake

Using midsummer nitrogen and phosphorus concentrations from Long Lake, a nitrogen:phosphorus ratio of 21:1 was calculated. This finding indicates that Long Lake is phosphorus limited like most Wisconsin Lakes. In general, research has shown that cutting phosphorus inputs in these types of lakes will limit plant growth within the lake.

Long Lake Trophic State

Figure 8.3.1-4 contains the Trophic State Index (TSI) values for Long Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Long Lake indicate the lake is at present in a eutrophic state. Long Lake's productivity is higher when compared to both other shallow lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

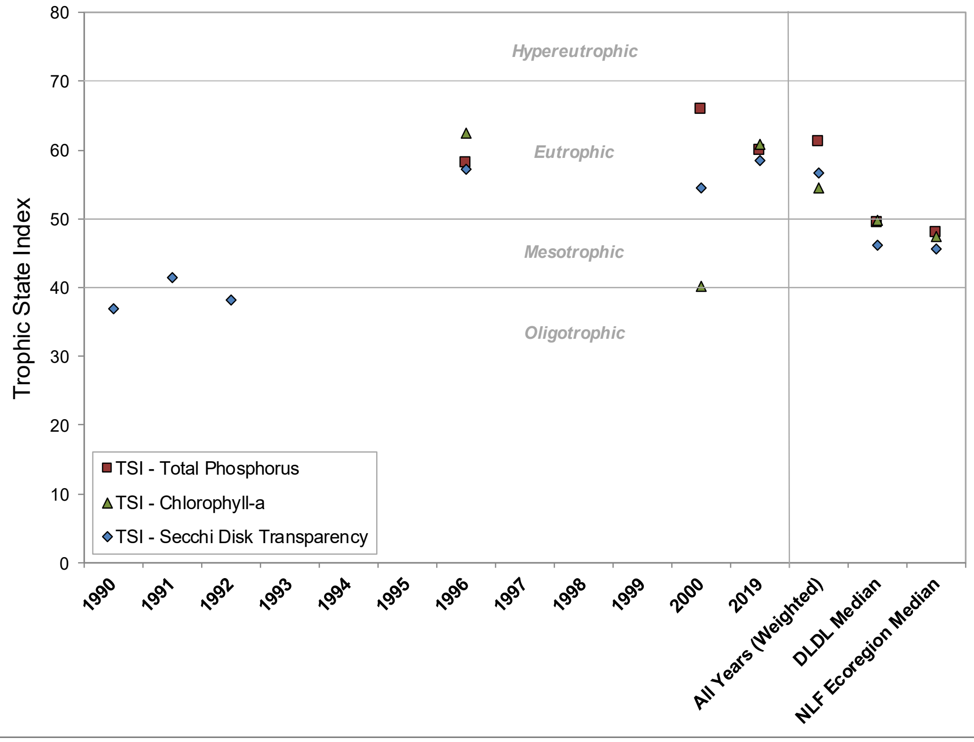


Figure 8.3.1-4. Long Lake, state-wide deep, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2013.

Dissolved Oxygen and Temperature in Long Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Long Lake by Onterra staff. Graphs of those data are displayed in Figure 8.3.1-5 for all sampling events.

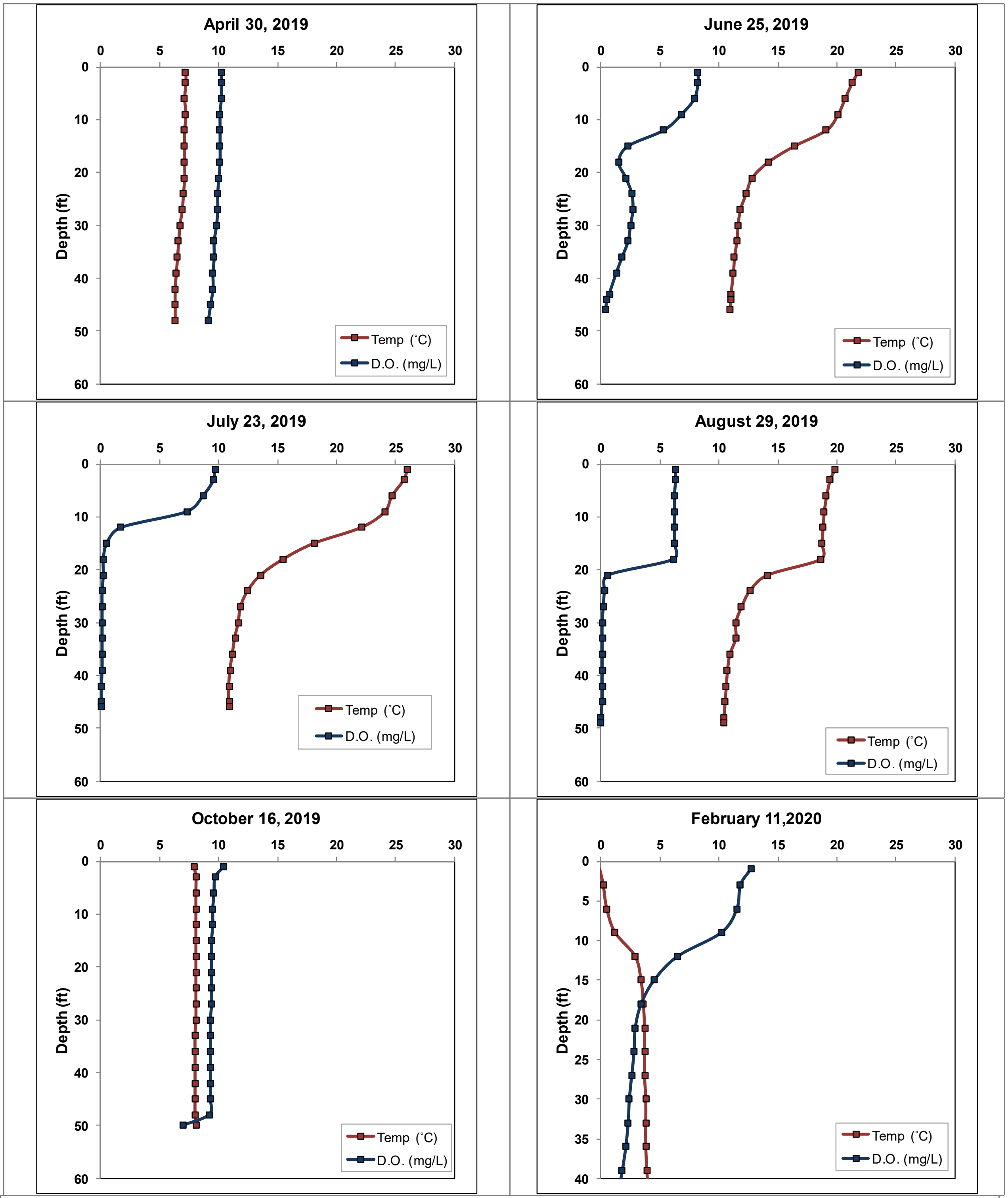


Figure 8.3.1-5. Long Lake dissolved oxygen and temperature profiles.

Long Lake is a dimictic lake, meaning it mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During summer the lake is stratified and the bottom of the lake becomes void of oxygen. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixed completely again by October, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2020, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

Additional Water Quality Data Collected at Long 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 Long 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. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below reflect concentrations during July. It is expected these concentrations will change from year to year depending upon precipitation and its impact on flows in the rivers.

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. Long Lake's surface water pH was measured at roughly 7.8 during summer 2019 (Figure 8.3.1-6). This value is near 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. The alkalinity in Long Lake during July 2019 was measured at 37.4 (mg/L as $CaCO_3$) (Figure, 8.1.1-7) 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 Long Lake during July 2019. 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 Long Lake's pH of 7.8 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 Long Lake was found to be 10.8 mg/L, which is below the optimal range for zebra mussels.

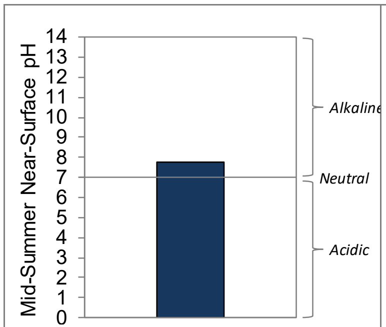


Figure 8.3.1-6. Long Lake mid-summer near-surface pH value.

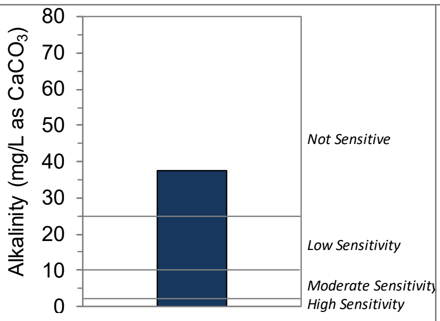


Figure 8.3.1-7. Long Lake summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

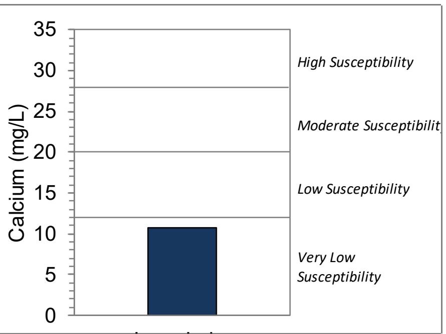


Figure 8.3.1-8. Long Lake summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

8.3.2 Long Lake Watershed Assessment

Long Lake's watershed is 127,288 acres in size. Compared to Long Lake's size of 407 acres, this makes for a large watershed to lake area ratio of 313:1. The watershed is comprised of the Elk Lake sub-watershed (90%), the Wilson Lake sub-watershed (10%), and the Long Lake direct watershed is comprised of <1%. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Long Lake's residence time is approximately four days, or the water within the lake is completely replaced 107 times per year. With the very short residence time in Long Lake, the phosphorus concentration will largely be very similar to the concentration in Elk Lake.

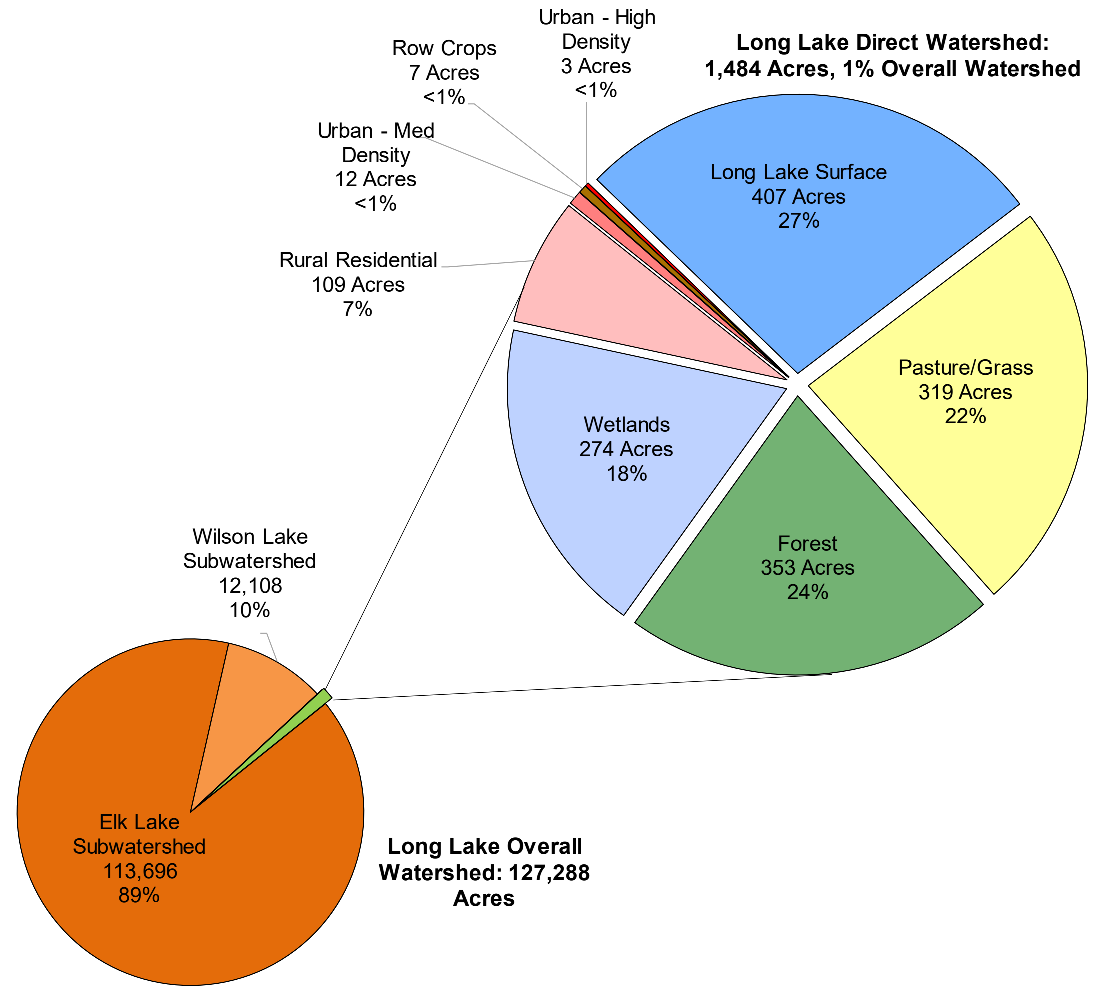


Figure 8.3.2-1. Long Lake overall and direct watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2016).

Approximately 99% of Long Lake's watershed is comprised of the Elk Lake and Wilson Lake sub-watersheds (Map 2). As discussed in the chain-wide section (3.2), these sub-watersheds were modeled as point-sources based upon measured phosphorus concentrations in the lakes. The remaining 1% of the overall watershed includes the direct watershed, as well as the surface of the lake. Direct phosphorous addition to the lake comes through atmospheric deposition. Forested and wetland land cover types comprise 42% of the direct watershed (Figure 8.3.2-1).

These land cover types provide the least amount of phosphorus inputs to a system. Row crop agriculture, urban and residential land cover types deliver the most amount of phosphorus to a system, with 9% of the direct watershed consisting of these land cover types and only a small fraction of the overall Long Lake watershed.

WiLMS estimates 38,477 pounds of phosphorus being delivered to Long Lake on an annual basis (Figure 8.3.2-2). Comprising 99% of the watershed area, the two sub-watersheds deliver 99% of the phosphorus to Long Lake. Comprising of only 1% of the overall landcover and 280 pounds of phosphorus, row crop agriculture from the direct watershed contributes to <1% of the phosphorus budget. Rotational agriculture likely changes the amount of phosphorus this land cover delivers each year. Also, conservational agriculture projects can reduce the amount of phosphorus and have a benefiting impact on the water quality of Long Lake and downstream waterbodies.

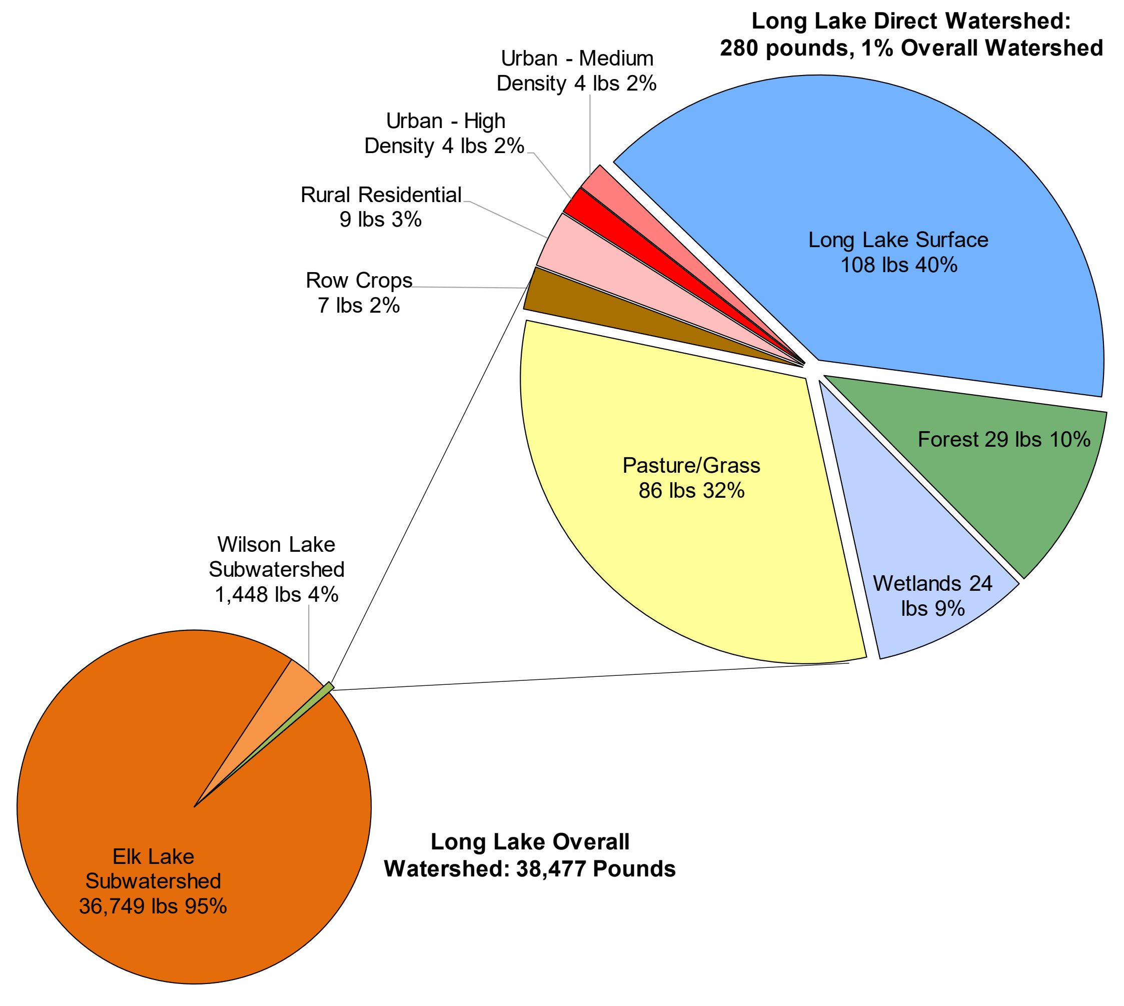


Figure 8.3.2-2. Long Lake overall and direct watershed phosphorus loading proportions. Wisconsin Lakes Modeling Suite (WiLMS).

8.3.3 Long 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 Fall of 2019, Long Lake's immediate shoreline was assessed in terms of its development. Long Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 5.6 miles (51% of the total shoreline) of natural/undeveloped and developed-natural 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, 3.0 miles of urbanized and developed–unnatural shoreline (28% of the total shoreline) was observed. If restoration of the Long 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. Long Lake Map 1 displays the location of these shoreline lengths around the entire lake.

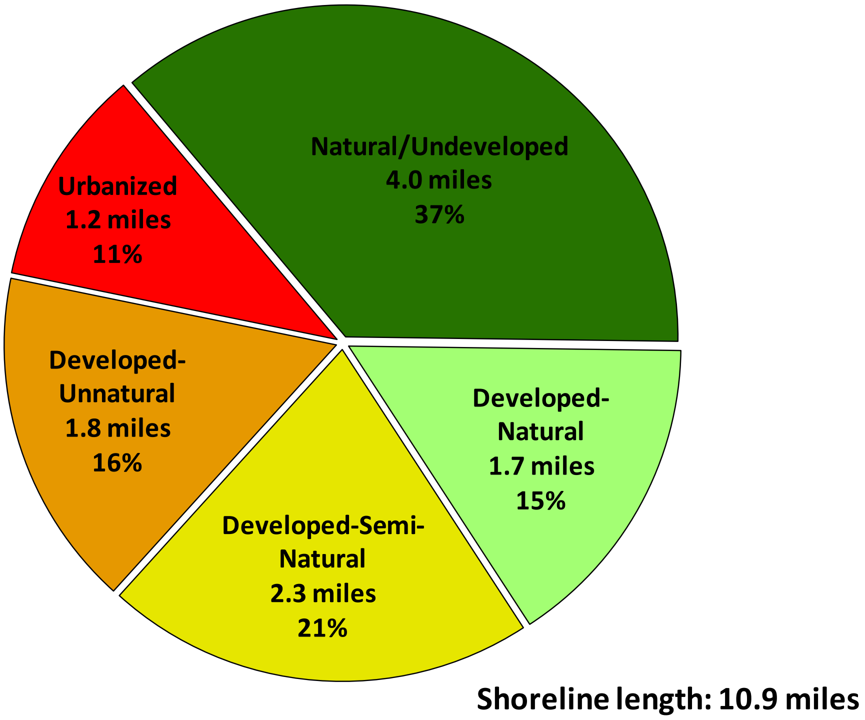


Figure 8.3.3-1. Long Lake shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Long Lake Map 1.

Coarse Woody Habitat

Long Lake was surveyed in 2019 to determine the extent of its coarse woody habitat (Figure 8.3.3-2). 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 409 pieces of coarse woody habitat were observed along 10.9 miles of shoreline, which gives Long Lake a coarse woody habitat to shoreline mile ratio of 37:1. 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 coarse woody habitat are displayed on Long Lake Map 2.

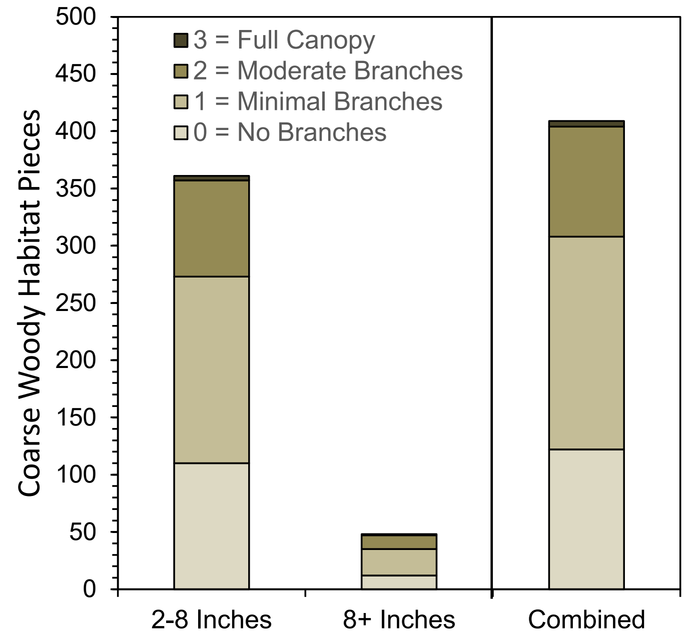


Figure 8.3.3-2. Long Lake coarse woody habitat survey results. Based upon a Fall 2019 survey. Locations of Long Lake coarse woody habitat can be found on Long Lake Map 2.

8.3.4 Long Lake Aquatic Vegetation

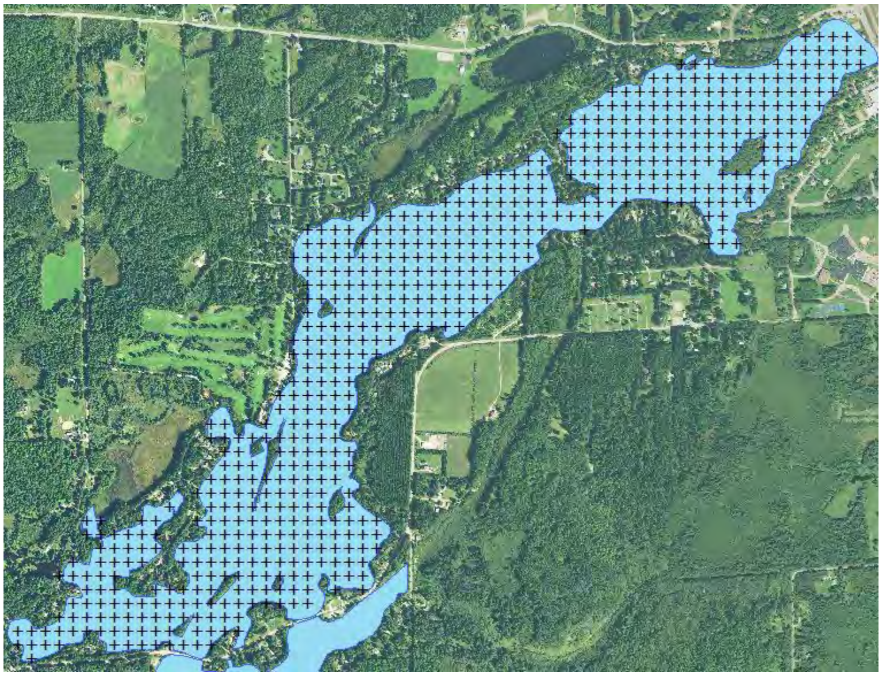


Figure 8.3.4-1. Long Lake whole-lake aquatic point-intercept survey sampling locations. n=630

The aquatic plant point-intercept survey was conducted on Long Lake on July 23, 2019 by Onterra (Figure 8.3.4-1). The floating-leaf and emergent plant community mapping survey was completed on August 26 to create the aquatic plant community map. During these 2019 surveys, a total of 20 species of native aquatic plants were located in and around Long 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. The remaining eight native species were located visually during the survey, but not sampled on the rake. In addition, one non-native species was located visually on Long Lake - Eurasian watermilfoil (EWM). The EWM in Long Lake will be discussed in its own subsection at the end of the Aquatic Vegetation section. A whole-lake point-intercept (PI) survey was also completed on Long Lake in 2009 during the last management planning project. The species recorded during this survey are also displayed in Table 8.2.4-1 for comparison between the two years.

During the 2019 PI survey, aquatic plants were found growing to a depth of 7 feet. Of the 630 points on the sampling grid (Figure 8.3.4-1), 131 were littoral (within depths at which plants can grow), and only a total of 11 sites contained vegetation (Map 5). The absence of aquatic vegetation in the northern portion of Long Lake could be related to the heavy-metal contaminated sediment in upstream Elk Lake. Another contributing factor to the low incidence of aquatic vegetation is likely that much of Long Lake’s shoreline is steep and rocky, and also quite developed. Sediment data was collected at sampling points within the littoral zone and found that 33% of the substrate in Long Lake is hard sand which only select plant species can grow in, and 8% of the substrate is rock which plants cannot grow in alone. The remaining 59% consisted of soft organic sediments which many aquatic plants prefer. The darker water in the Phillips Chain also does not allow enough sunlight to support aquatic plant growth very deep in the lakes.

Table 8.3.4-1. Aquatic plant species located in Long Lake during the 2009 and 2019 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2009 Onterra	2019 Onterra
Emergent	*Acorus americanus*	Sweet-flag	7	I	
	Calla palustris	Water arum	9	I	
	Carex utriculata	Common yellow lake sedge	7	I	
	Carex vesicaria	Blister sedge	7	I	
	Eleocharis palustris	Creeping spikerush	6	I	
	Iris sp.	Iris sp.	N/A		I
	Pontederia cordata	Pickerelweed	9		I
	Sagittaria latifolia	Common arrowhead	3	I	
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Scirpus cyperinus	Wool grass	4		I
	Typha latifolia	Broad-leaved cattail	1	I	
	Typha spp.	Cattail spp.	1	X	I
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I	
	Sparganium sp.	Bur-reed sp.	N/A		I
FL	*Brasenia schreberi*	Watershield	7		I
	Nuphar variegata	Spatterdock	6	I	X
	Nymphaea odorata	White water lily	6	X	X
	Sparganium fluctuans	Floating-leaf bur-reed	10		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum heterophyllum	Various-leaved water milfoil	7	X	
	Myriophyllum spicatum	Eurasian water milfoil	Exotic/Invasive	X	I
	Myriophyllum verticillatum	Whorled water milfoil	8		X
	Nitella spp.	Stoneworts	7		X
	Najas flexilis	Slender naiad	6	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	
	Potamogeton berchtoldii	Slender pondweed	7		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	8	X	
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton vaseyi	Vasey's pondweed*	10	X	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	
FF	*Lemna trisulca*	Forked duckweed	6	X	
	Lemna minor	Lesser duckweed	5	X	
	Spirodela polyrhiza	Greater duckweed	5	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; * = species of concern in WI*

Aquatic plant rake fullness data (density of plants pulled up on the rake) was collected as well during the point-intercept survey. Only one of the vegetated sites contained a total rake fullness (TRF) of 3, the highest density rating (Figure 8.3.4-2). This was in a small protected bay near the southern end of the lake. Most of the vegetated sites contained the lowest density rating of TRF=1, indicating that where plants do occur in Long Lake, they are of low density.

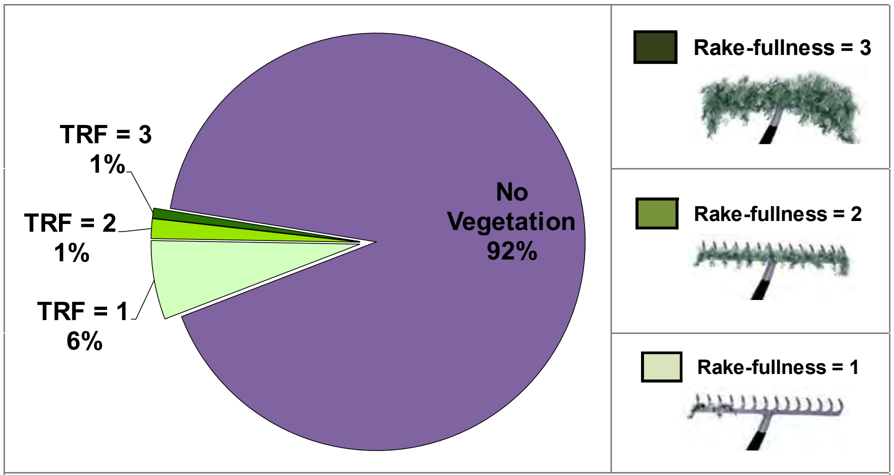


Figure 8.3.4-2. Total rake fullness ratings on Long Lake. Created using data from 2019 point-intercept survey.

Figure 8.3.4-3 shows the littoral frequency of occurrence of all species located in Long Lake during the 2009 and 2019 surveys. Between the two survey years, some species increased in frequency, while others decreased; although only one of these changes was statistically significant – slender naiad. Slender naiad and common waterweed were the two most frequently encountered species during the 2019 point-intercept survey.

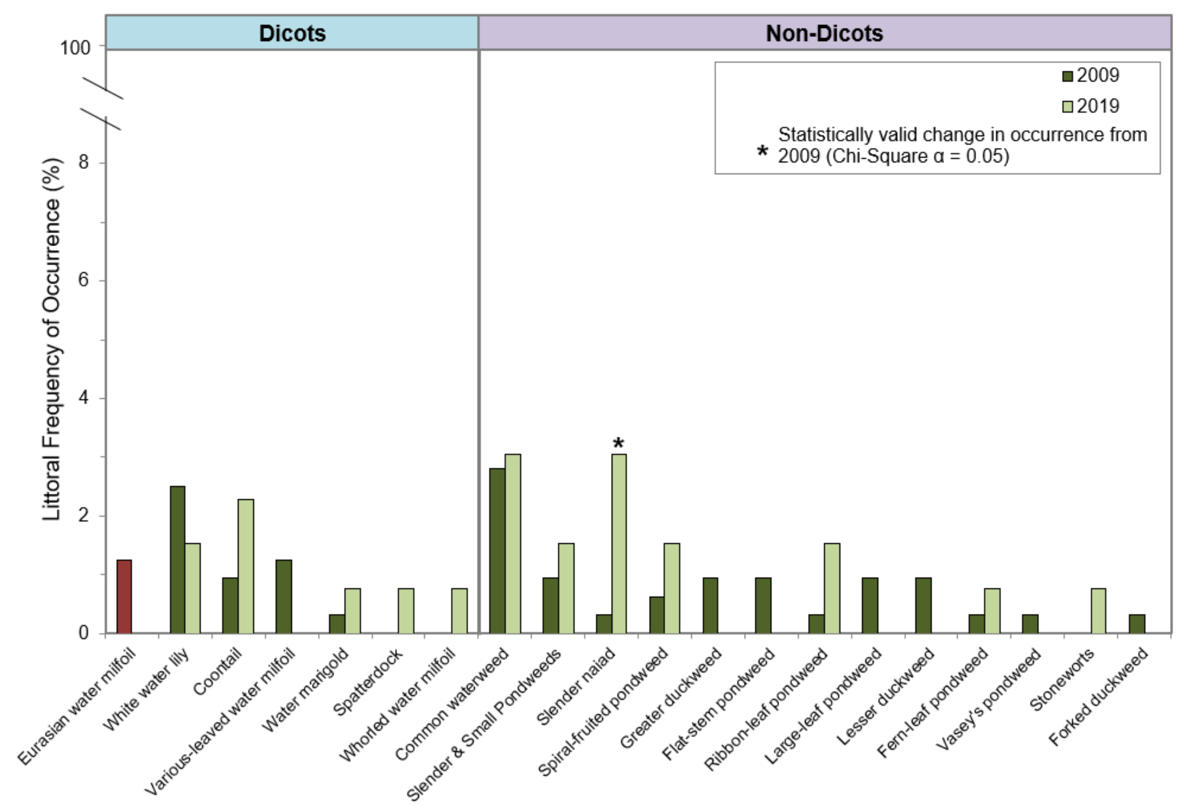


Figure 8.3.4-3. Long Lake aquatic plant littoral frequency of occurrence analysis. Created using data from the 2009 and 2019 point-intercept surveys.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, how evenly the species are distributed throughout the system also influence diversity. The diversity index for Long Lake's plant community (0.89 in 2019) falls just above the state and ecoregion medians, within the upper quartiles, making it near average (Figure 8.3.4-4). The Simpson's Diversity in 2009 had been just above that with a value of 0.91.

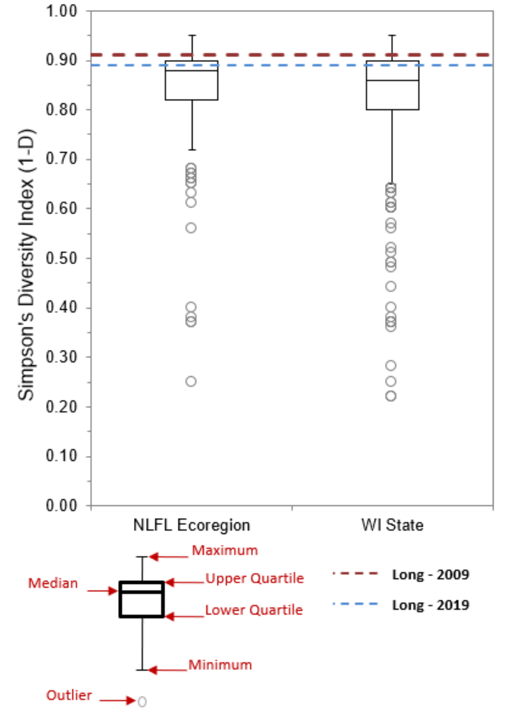


Figure 8.3.4-4. Simpson's diversity index for Long Lake.

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 slender naiad was found at only 3.1% of the littoral sampling locations in 2019, its relative frequency of occurrence is 17% because so few other species were located in the lake. Explained another way, if 100 plants were randomly sampled from Long Lake, 17 of them would be slender naiad. This distribution can be observed in Figure 8.3.4-5 where together 6 species account for about 71% of the population of plants within Long Lake, and the other 6 species account for the remaining 29%. Again, the incidentally located species are not included in this analysis.

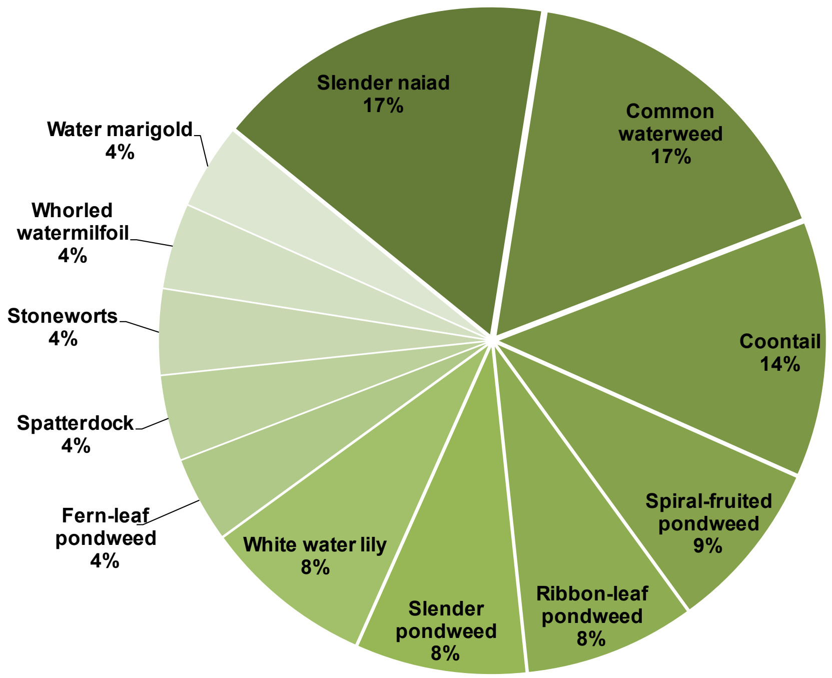


Figure 8.3.4-5. Long Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2019 point-intercept survey.

Long Lake's average conservatism value was below the ecoregion median for both surveys, but just above the state median (Figure 8.3.4-6). This indicates that the aquatic plant community in Long Lake is of near average quality. Long Lake's species richness value was below both the ecoregion and state medians. Combining Long Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 22.5 in 2019 which is below the median values for the ecoregion and state as well.

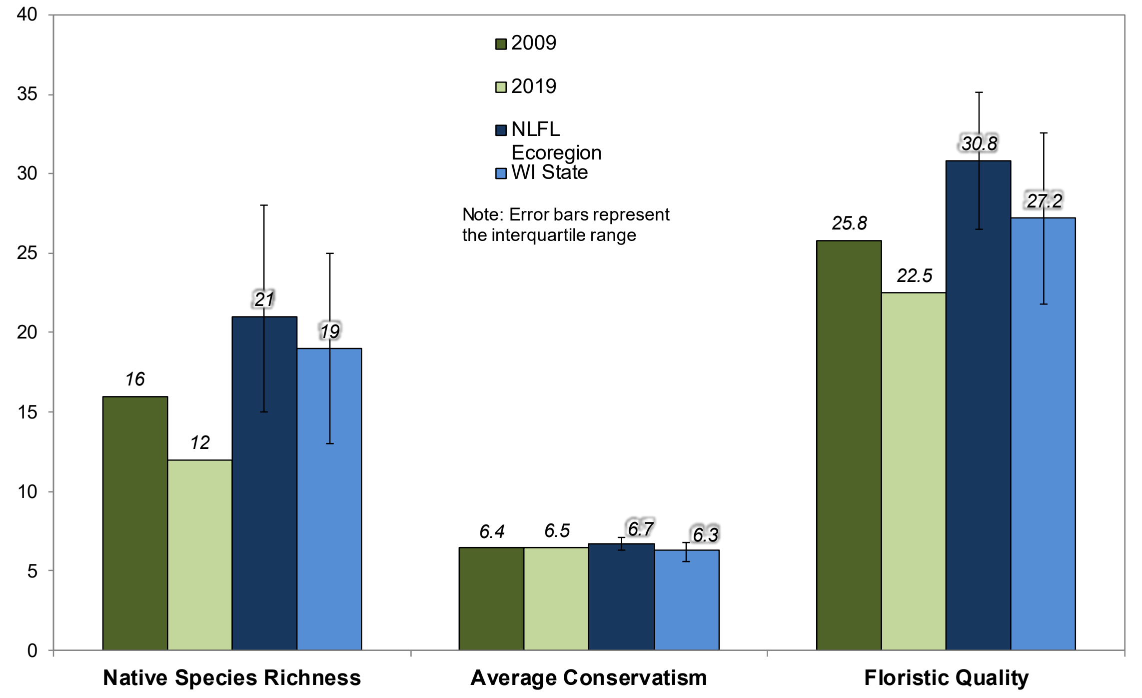


Figure 8.3.4-6. Long Lake Floristic Quality Analysis. Created using data from 2009 and 2019 point-intercept surveys.

The quality of Long Lake can also be assessed by the incidence of emergent and floating-leaf plant communities that occur around the lake. The 2019 community map indicates that approximately 1.7 acres of the lake contains these types of plant communities (Long – Map 3, Table 8.3.4-2). This is less than 1% of the lake which is comparatively quite low. During the 2009 survey, a total of 3 acres of emergent and floating-leaf plants had been mapped.

Table 8.3.4-2. Long Lake acres of emergent and floating-leaf plant communities from the 2019 community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-leaf	0.0
Mixed Emergent & Floating-leaf	1.7
Total	**1.7**

Pale-Yellow Iris

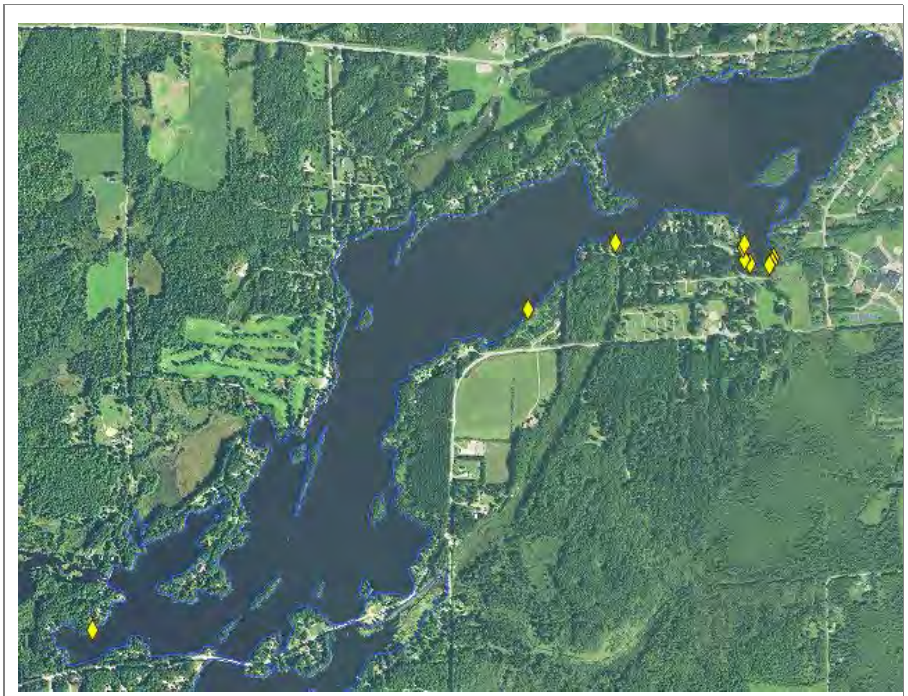


Figure 8.3.4-7. Possible locations of pale-yellow iris occurrences on Long Lake. Indicated by yellow diamonds. ID not confirmed.

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

Pale-yellow iris is typically in flower during the second half of June. During the June 2019 Early Season AIS Survey, the iris had not yet been in bloom. The foliage of pale-yellow iris and northern blue flag iris (valuable native species) is too similar to make a definitive identification based off of this alone. Positive ID really needs to come from the flowers or the seed pods, which come after the flower is pollinated. Figure 8.3.4-7 shows the location of where large iris foliage was located during the June 2019 survey and are suspected of being pale-yellow iris. Follow-up surveys would be required for positive identification.

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum;* EWM) was first verified in Long Lake in 2002. PCOLA has sponsored a number of AIS control projects aimed at managing the EWM population on the Phillips Chain, starting in 2011. As part of these projects, EWM Peak-Biomass surveys were completed annually from 2011-2016, in addition to the 2009 surveys completed as a part of the first management planning project (Figure 8.3.4-8). The EWM acreage mapped in 2019 as part of this updated planning project can be compared with these earlier years of data to see how the EWM population has changed over time in Long Lake. EWM is mapped in the same manner previously discussed in the CLP section. Note that these values only reflect the contiguous colonies of EWM mapped using polygons and does not include point-based occurrences.

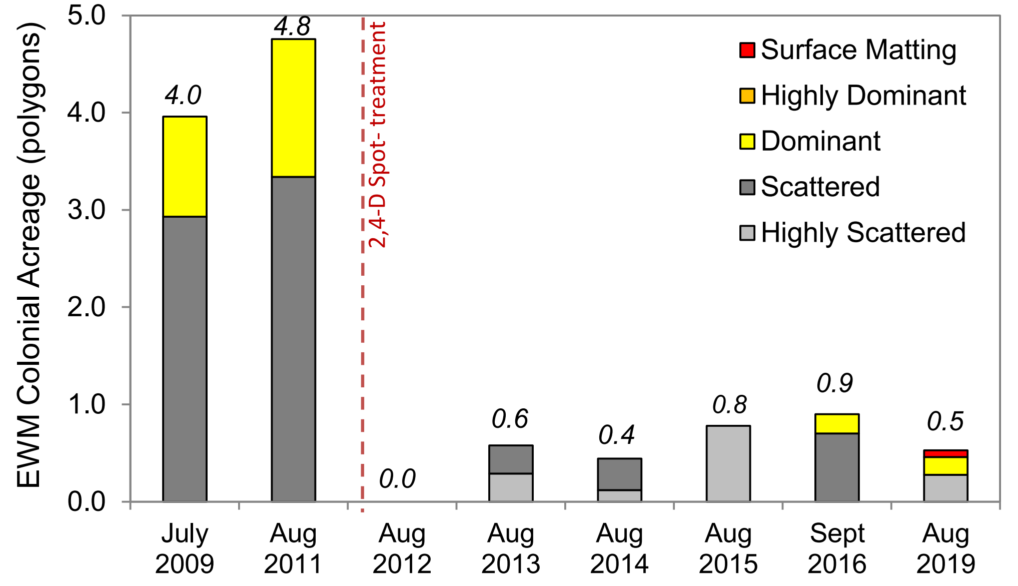


Figure 8.3.4-8. Acreages of EWM mapped in Long Lake. Created using data from EWM Peak-Biomass (Late-Season AIS) surveys.

During this timeframe, a single herbicide treatment occurred in Long Lake (Table 8.3.4-3). This treatment occurred within a relatively secluded bay south of the island in the upstream part of Long Lake. A liquid form of 2,4-D amine was used towards the top of their maximum application rate (3.0-ppm ae). This treatment was considered highly successful, with only low-density EWM occurrences being located for a few years following the treatment. A slight increase in the EWM population was noted in this area in 2019 (Long – Map 4). 2019 marked the first survey that located surface-matted EWM, the highest density rating, although it was only a small 0.1-acre area.

Table 8.3.4-3. Long Lake EWM treatment history.

Date	Acres	Product	Amount Applied		Pounds of Active Ingredient
4/25/2012	17.4	DMA 4 (amine)	150	gallons	570.0

Long Lake does have some Eurasian watermilfoil look-alikes which can be easily mistaken by the untrained eye as the non-native EWM (Photograph 8.3.4-1). Two of these include native milfoils: various-leaved watermilfoil (*Myriophyllum heterophyllum*) and whorled watermilfoil (*Myriophyllum verticillatum*). Another native look-alike is water marigold (*Bidens beckii*) which is actually a flowering herb from the daisy family.

Photograph 8.3.4-1. Three native aquatic plants with similar physical characteristics to EWM.

Glyceria maxima

Reed mannagrass (*Glyceria maxima*) is listed as prohibited species by the WDNR in this part of Wisconsin (Photograph 8.3.4-2). This invasive species can invade wetland areas and form monotypic stands which outcompete and crowd out native vegetation. In addition to destroying biodiversity, this species is not a good food source for wildlife and does not provide suitable nesting habitat like much of our native wetland vegetation would.

In October 2019, the Wisconsin DNR (Christopher Noll) located a population of reed manna grass near the Price County Airport. Shortly after this initial discovery, a botanist with the US Forest Service (Marjory Brzeskiewicz) completed a more thorough survey, noting the extents of the population as far as property boundaries would allow. During the summer of 2020, WDNR (Alan Wirt) conducted additional reconnaissance and confirmed reed mannagrass growing within the drainage ditch leading to Long Lake (Figure 8.3.4-9). The WDNR is currently working with local partners (BW Paper System and City of Phillips) as well as government partners (Department of Transportation and US Forest Service) to determine a management strategy.

Photograph 8.3.4-2. Reed mannagrass (Glyceria maxima). Photo credit WI State Herbarium

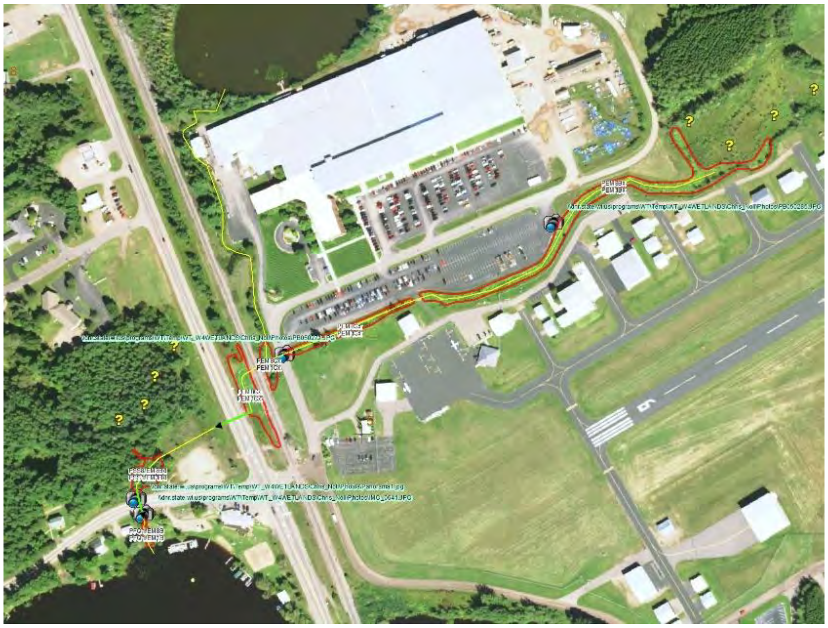
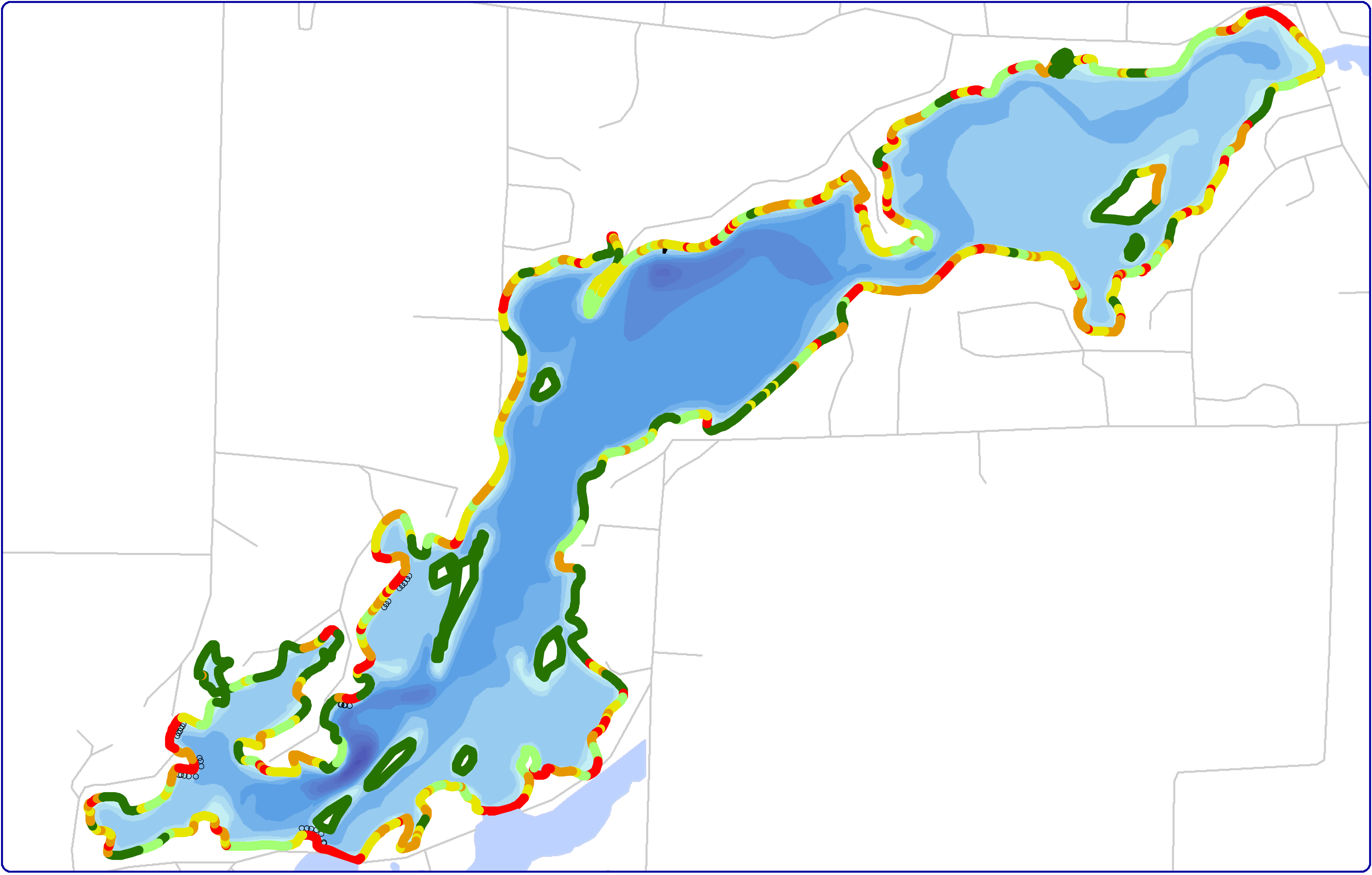


Figure 8.3.4-9. Reed managrass locations. Positive occurrences in red. Draft map created by WDNR (Alan Wirt – Summer 2020).



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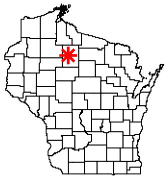
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 4, 2019 JMB
Filename: PhillipsChain_SA_2019_Long.mxd



Project Location in Wisconsin

Legend

- 🟩 Natural/Undeveloped
- 🟩 Developed-Natural
- 🟨 Developed-Semi-Natural
- 🟧 Developed-Unnatural
- 🟥 Urbanized

Seawall Modifier

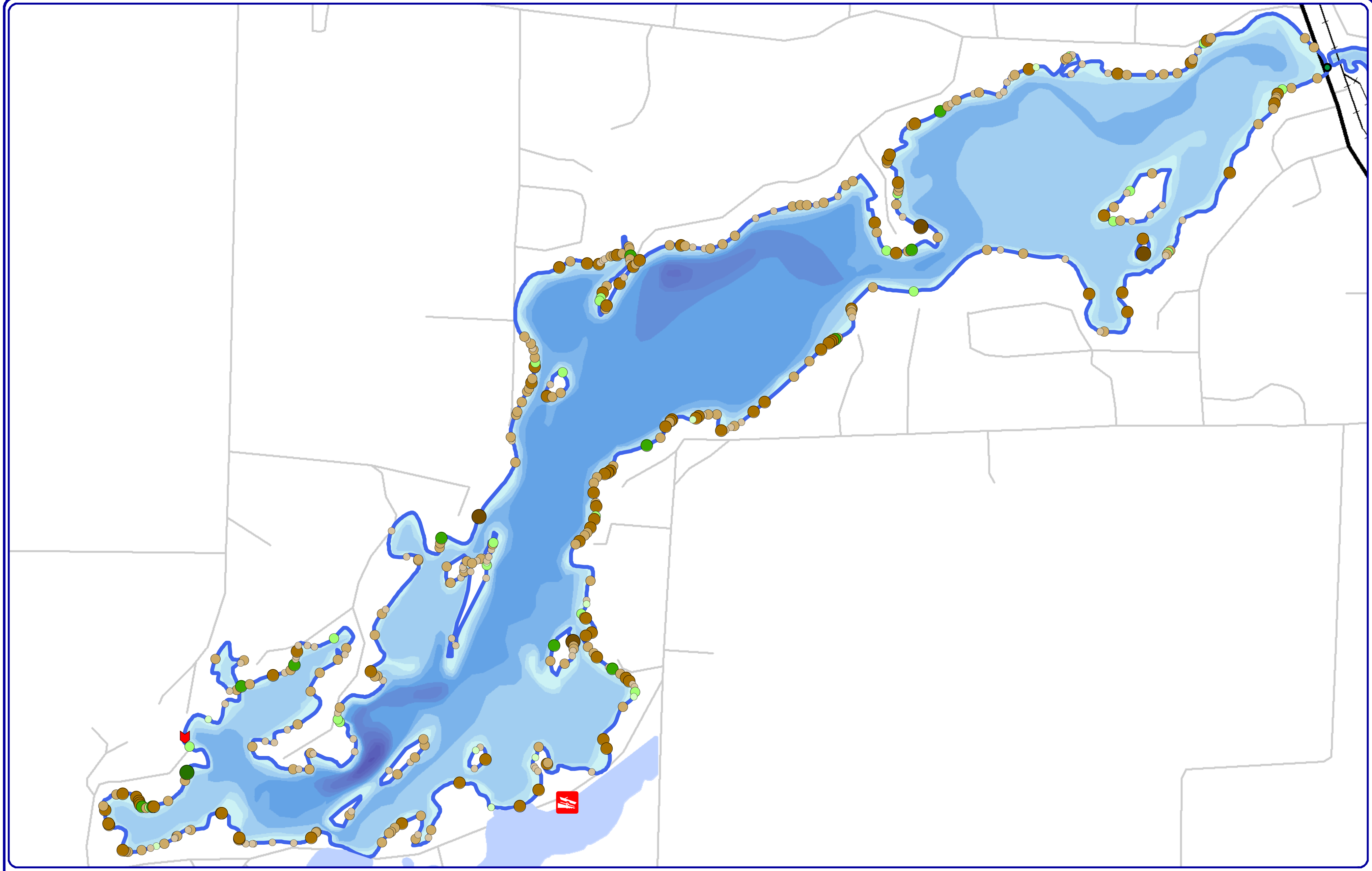
- ━ Masonary/Metal/Wood
- ○○○○ Rip-Rap/Placed Stone

Long - Map 1

Long Lake

Price County, Wisconsin

Shoreland Condition Assessment



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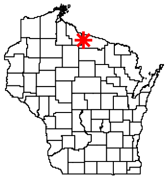
Sources
Hydro: WDNR
CWH Survey: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 3, 2019 JMB
Filename: Long_CWH_2019.mxd


Project Location in Wisconsin

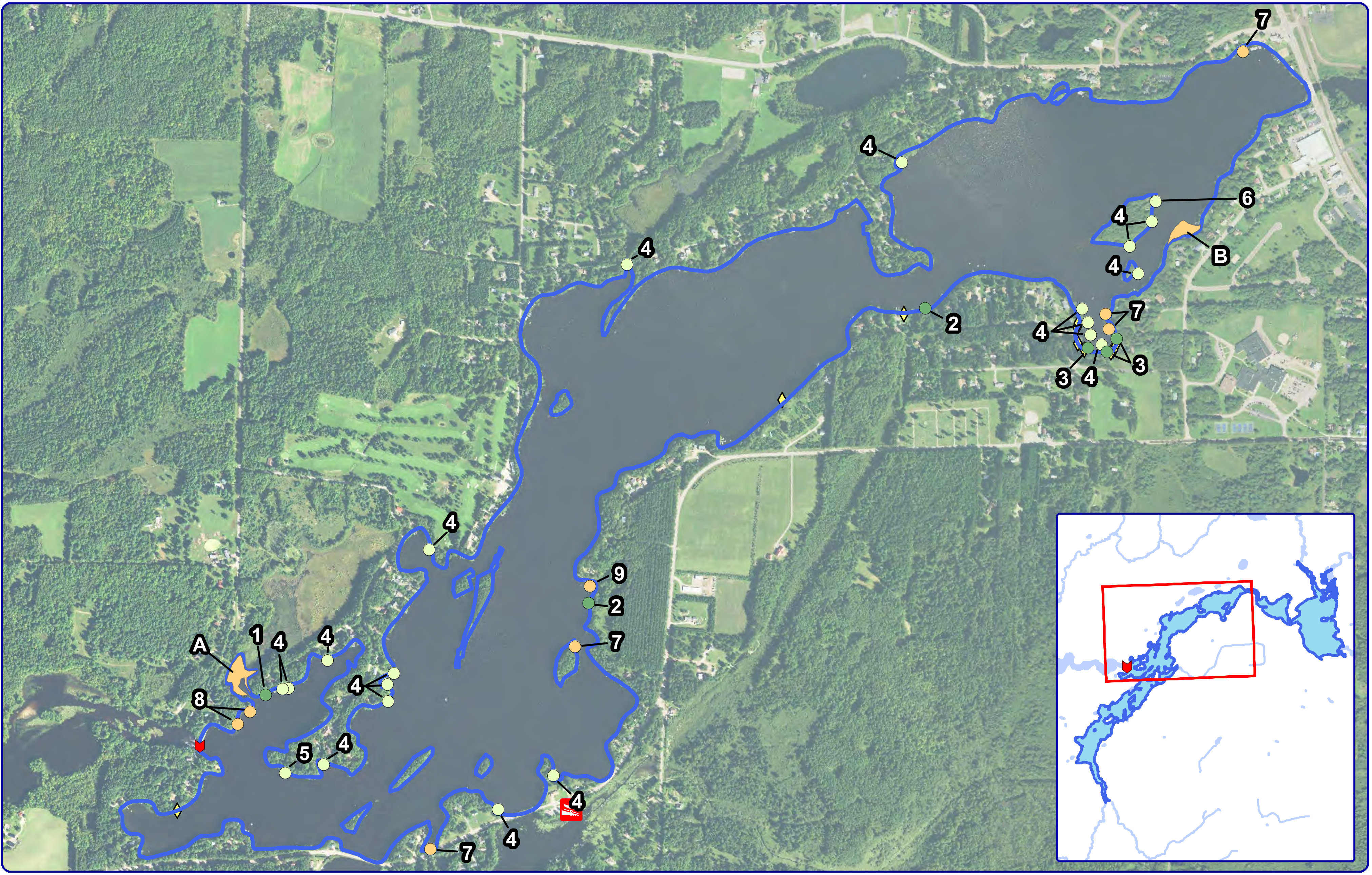
Legend

2-8 Inch Pieces	**8+ Inch Pieces**
● No Branches	● No Branches
● Minimal Branches	● Minimal Branches
● Moderate Branches	● Moderate Branches
● Full Canopy	● Full Canopy

Long - Map 2

Long Lake
Price County, Wisconsin

Coarse Woody Habitat



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Sources
Hydro: WDNR
CWH Survey: Onterra, 2019
Orthophotography: NAIP, 2015
Map date: December 19, 2019 AMS
Filename: PhillipsChain_Comm_2019_Long.mxd

Project Location in Wisconsin

Legend

Small Plant Communities
- ● Emergent
- ● Floating-leaf
- ● Mixed Floating-leaf & Emergent

Large Plant Communities
- ▨ Emergent
- ▨ Floating-leaf
- ▨ Mixed Floating-leaf & Emergent

Long - Map 3
Long Lake
Price County, Wisconsin

Aquatic Plant Communities

Long Lake 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Long - Map 3

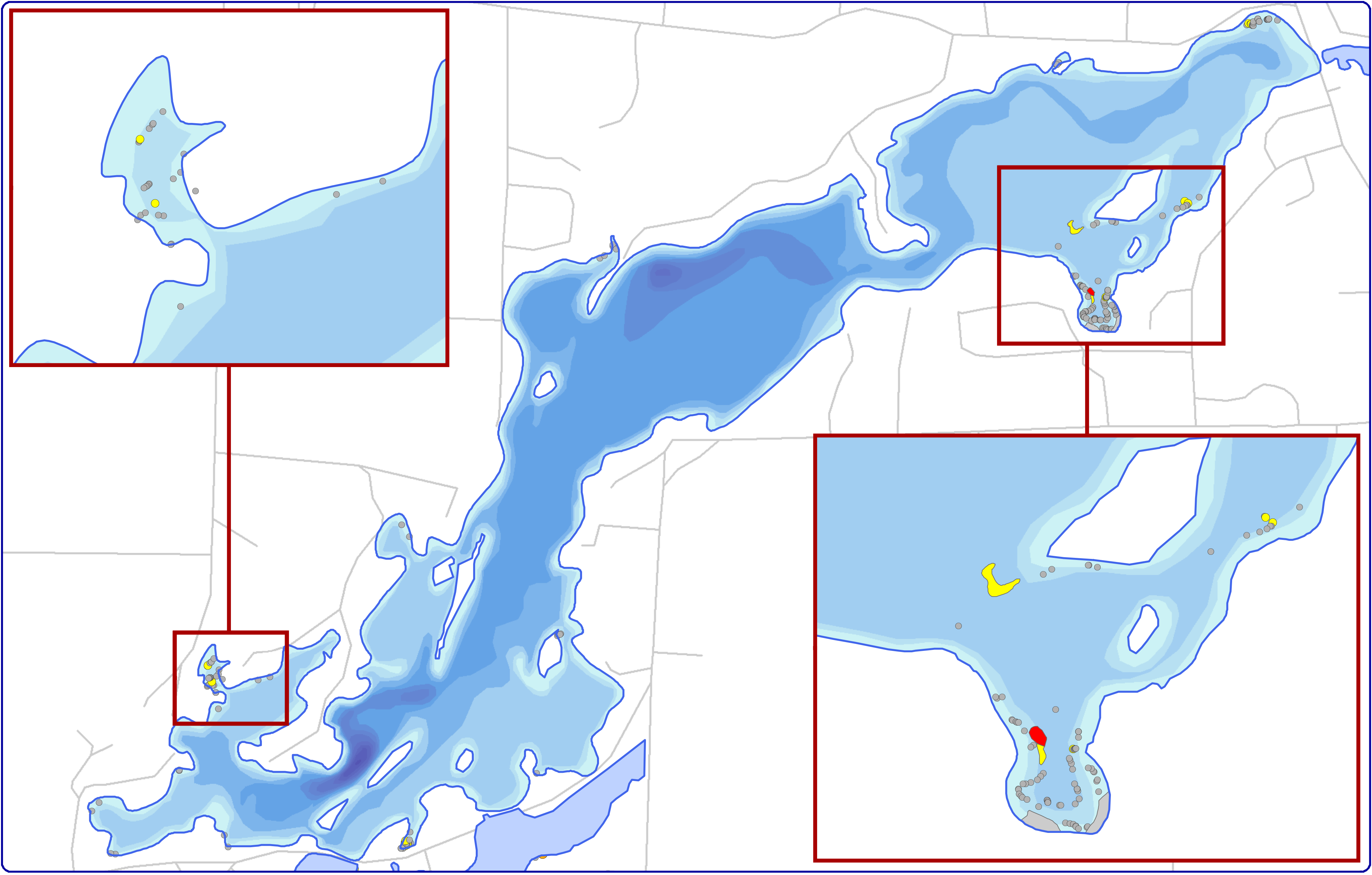
Large Plant Community (Polygons)

Floating-leaf & Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Acres
A	**White water lily**	**Spatterdock**	**Softstem bulrush**						1.02
B	**White water lily**	**Bur-reed sp. (Sterile)**	**Pickerelweed**	**Flaoting leaf bur-reed**					0.64

Small Plant Community (Points)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8
1	**Bur-reed sp. (sterile)**							
2	**Softstem bulrush**							
3	**Iris sp.**							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
4	**White water lily**							
5	**White water lily**	**Watershield**						
6	**White water lily**	**Wool-grass**	**Bur-reed sp.**					
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
7	**White water lily**	**Bur-reed sp. (sterile)**						
8	**Softstem bulrush**	**Bur-reed sp. (sterile)**	**White water lily**					
9	**White water lily**	**Cattail sp.**	**Bur-reed sp. (Sterile)**					
10	**White water lily**	**Softstem bulrush**						

Bolded species are considered most dominant within each community; Scientifc names can be found in the species list in Table 8.3.4-1



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Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 4, 2019 JMB
Filename: PhillipsChain_SA_2019_Long.mxd

Project Location in Wisconsin

Legend

- ⬜ Highly Scattered
- ▩ Scattered
- 🟨 Dominant
- 🟧 Highly Dominant
- 🟥 Surface Matting
- ● Single or Few Plants
- ● Clump of Plants
- ● Small Plant Colony

Long - Map 4
Long Lake
Price County, Wisconsin

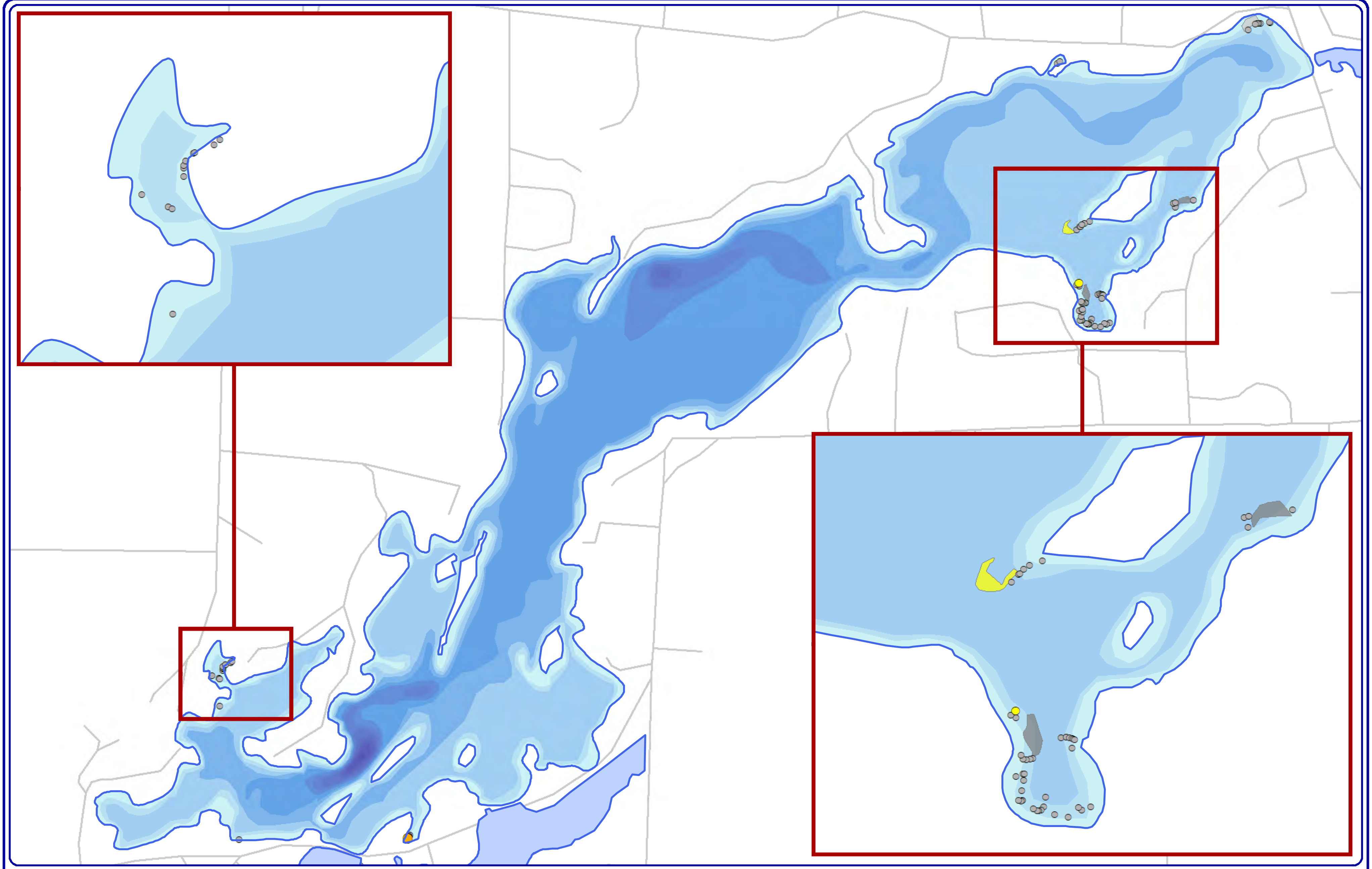
August 2019 EWM Survey Results

Long - Map 5

Long Lake

Price County, Wisconsin

August 2020 EWM Survey Results



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Legend

▨	Highly Scattered
▨	Scattered
🟨	Dominant
🟧	Highly Dominant
🟥	Surface Matting
●	Single or Few Plants
●	Clump of Plants
●	Small Plant Colony

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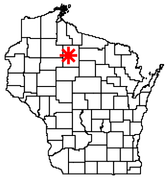


Project Location in Wisconsin

8.4.0 Wilson Lake Introduction

Wilson Lake, Price County, is a drainage lake with a maximum depth of 11 feet and a surface area of 348 acres. This eutrophic lake has an extremely large watershed when compared to the size of the lake. Wilson Lake contained 41 native plant species in 2019, of which small pondweed was the most common. Four exotic plant species were observed in Wilson Lake in 2019: Eurasian watermilfoil, purple loosestrife, reed canary grass, and narrow-leaved cattail.

Field Survey Notes

With its islands and large areas of undevleoped shoreline, Wilson Lake contains a lot of scenic beauty. Wilson Lake contains dense aquatic vegetation, with a portion of that vegetation being EWM. We encounter many fisherman while working on Wilson Lake.

Photograph 8.4.0-1. Wilson Lake, Price County.

Lake at a Glance* – Wilson Lake

Morphology	
Acreage	348
Maximum Depth (ft)	11
Mean Depth (ft)	6.0
Volume (acre-feet)	1,785
Shoreline Complexity	13.6
Vegetation	
Number of Native Species	41
Threatened/Special Concern Species	Vasey's pondweed
Exotic Plant Species	EWM, PL, RCG, NLC
Simpson's Diversity	0.89
Average Conservatism	6.3
Water Quality	
Wisconsin Lake Classification	Shallow lowland drainage lake
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	354:1

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

8.4.1 Wilson Lake Water Quality

Unlike the other three lakes, Wilson Lake is officially classified as a lake because its hydraulic residence time is greater than 14 days. That means that Wilson Lake's phosphorus standard is lower than the other lakes at 40µg/L. It also means that Wilson Lake's trophic parameters can be more accurately compared to similar lakes statewide and within the NLF ecoregion.

Water quality data was collected from Wilson Lake on six occasions in 2019/2020. 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) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. Wisconsin DNR staff monitored the lake in 1996 and 2000 for total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Unlike the other three waterbodies, the hydraulic residence time of Wilson Lake is long enough (about 51 days) that it is considered a lake by the Wisconsin Department of Natural Resources. However, the relatively short residence time of this lake means that in-lake processes will have a limited impact upon the lake's water quality. Instead the water quality will be most impacted by nutrients from Wilson and Unnamed streams that enter the lake at the southern end of the lake.

Wilson Lake Trophic Parameters

Near-surface total phosphorus data from Wilson Lake are available for 1998-2008 and 2019 (Figure 8.4.1-1). The weighted summer average total phosphorus concentration is variable ranging from 47 to 74 µg/L. The weighted summer average is 59.6 µg/L and falls into the *fair* category for shallow lowland drainage lakes in Wisconsin. Wilson Lake's summer average total phosphorus concentrations are much higher than the median values for both shallow lowland drainage lakes in the state and all lake types in the Northern Lakes and Forests (NLF) ecoregion. The elevated phosphorus levels are not surprising as the lake has such a short residence time.

Chlorophyll-*a* data are available from Wilson Lake for the same years as phosphorus, i.e. 1998-2008, and 2019 (Figure 8.4.1-2). Wilson Lake's summer average chlorophyll-*a* concentration is 23.6 µg/L and falls into the *fair* category for shallow lowland drainage lakes in Wisconsin. Unlike the other three lakes, phosphorus and chlorophyll-*a* categories are similar. This is because the hydraulic residence time is longer in Wilson Lake which allows algal growth to reach the level expected given the phosphorus concentration. The median value of summer chlorophyll-*a* in Wilson Lake is much higher than other shallow lowland drainage lakes in the state and the median value for all lake types in the NLF ecoregion.

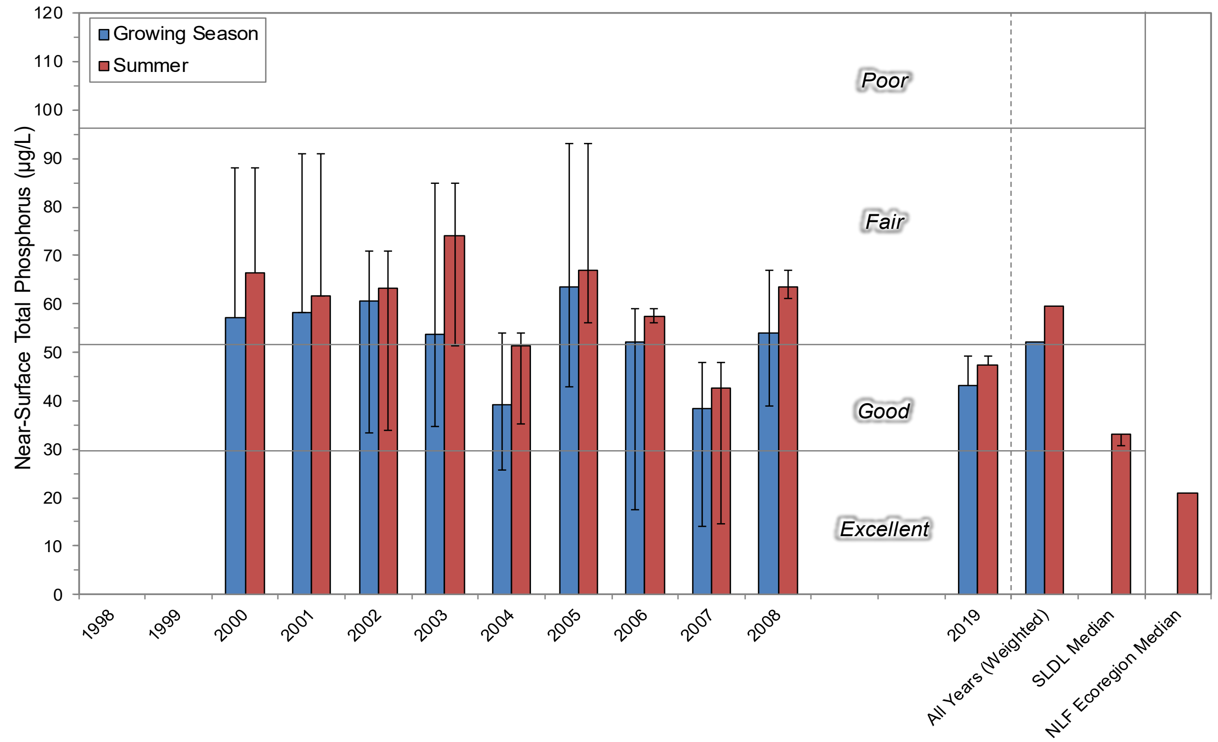


Figure 8.4.1-1. Wilson Lake, state-wide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

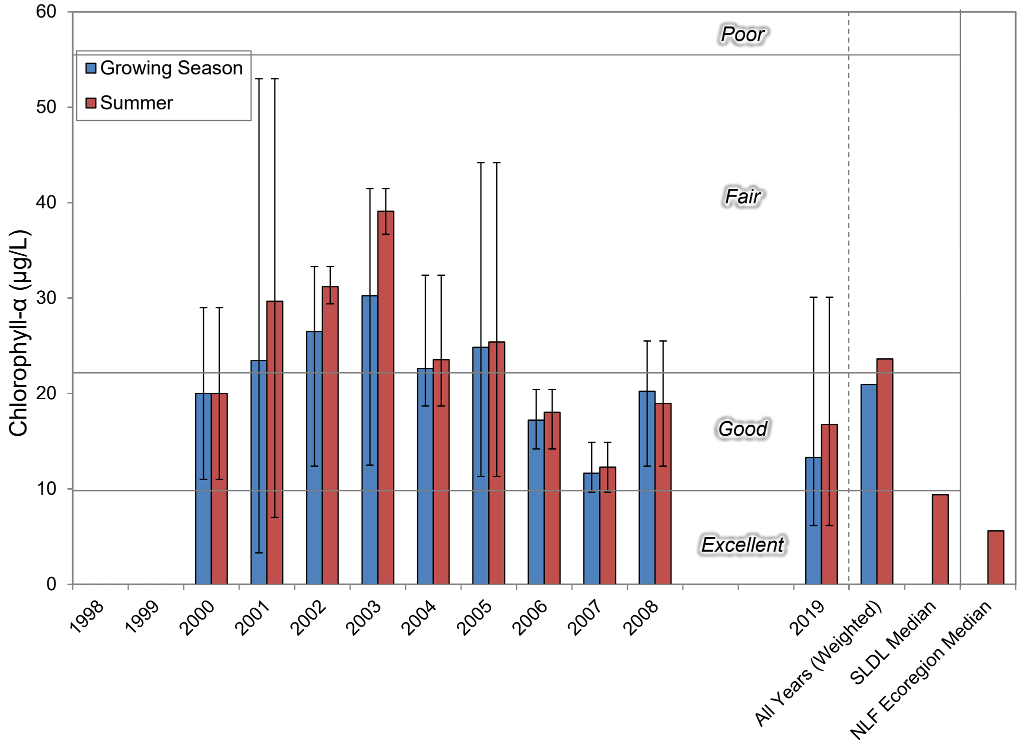


Figure 8.4.1-2. Wilson Lake, state-wide shallow, lowland drainage lakes, and regional chlorophyll-a concentrations. Mean values calculated with summer and growing season surface sample data. Water Quality Index values adapted from WDNR 2013.

Secchi disk transparency data are available from Wilson Lake for the same years as phosphorus and chlorophyll-*a*, as well as 1998 and 1999 (Figure 8.4.1-3). Like the weighted average summer phosphorus and chlorophyll-*a* concentrations, there is a range of Secchi disk transparencies, ranging from 1.7 to 4.0 feet. The weighted summer average Secchi disk depth is 2.8 feet and falls in *fair* category for shallow lowland drainage lakes in Wisconsin just like phosphorus and chlorophyll-*a.* Wilson Lake's weighted summer average Secchi disk depth transparency is much shallower than the median values for both shallow lowland drainage lakes in the state and for all lake types in the NLF ecoregion.

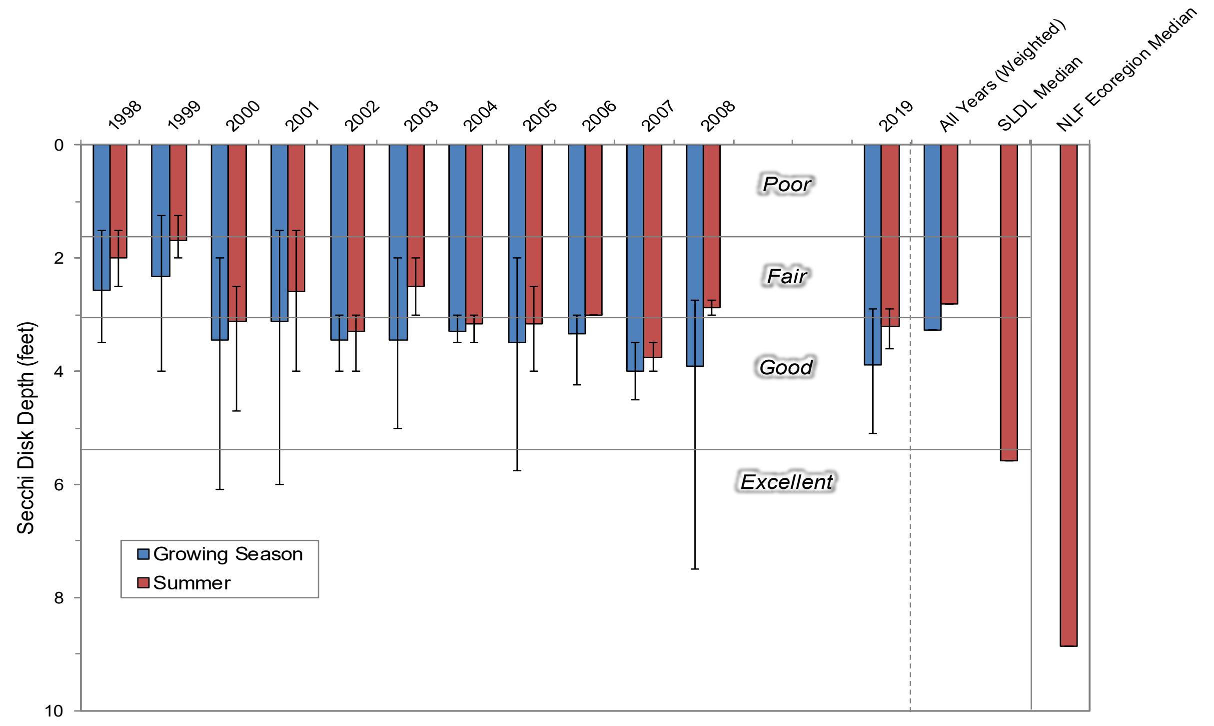


Figure 8.4.1-3. Wilson Lake, state-wide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR 2013.

Many lakes in the northern region of Wisconsin contain higher concentrations of natural dissolved organic acids that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Wilson Lake in 2019 averaged 70 SU (standard units) indicating the lake's water is *tea colored* and that the lake's water clarity is likely influenced by dissolved components in the water. The color of the water in Wilson Lake is lower than that in the other three lakes. This is likely the result in less runoff from wetlands in the Wilson Lake watershed.

Limiting Plant Nutrient of Wilson Lake

Using midsummer nitrogen and phosphorus concentrations from Wilson Lake, a nitrogen:phosphorus ratio of 19:1 was calculated. This finding indicates that Wilson Lake is phosphorus limited like most Wisconsin Lakes. In general, research has shown that cutting phosphorus inputs in these types of lakes will limit plant growth within the lake.

Wilson Lake Trophic State

Figure 8.4.1-4 contains the Trophic State Index (TSI) values for Wilson Lake. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values are for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in Wilson Lake indicate the lake is at present in a eutrophic state. Wilson Lake's productivity is higher when compared to both other shallow lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

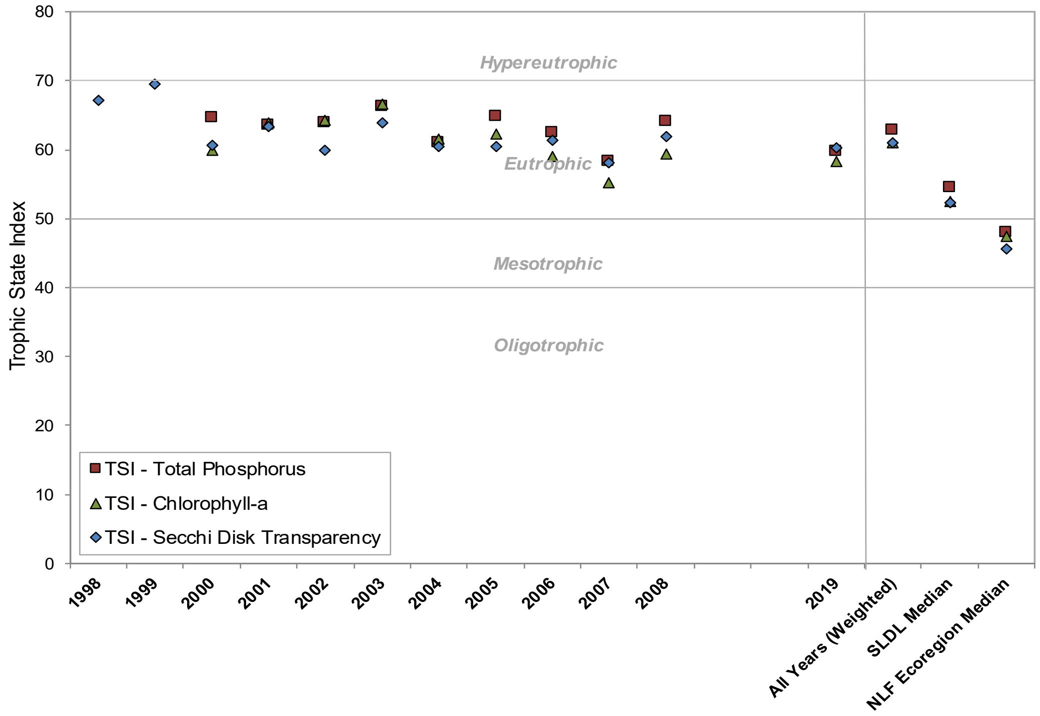


Figure 8.4.1-4. Wilson Lake, state-wide shallow, lowland drainage lakes, and regional Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using WDNR 2013.

Dissolved Oxygen and Temperature in Wilson Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Wilson Lake by Onterra staff. Graphs of those data are displayed in Figure 8.4.1-5 for all sampling events.

Wilson Lake is a polymictic lake meaning that it mixes frequently throughout the ice free season. The water column was completely mixed in April, August, and October. It was weakly stratified when sampled in June and July but the water column likely mixed during those months. This frequent mixing means that if the bottom waters become anoxic it is for a short duration. In February of 2020, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

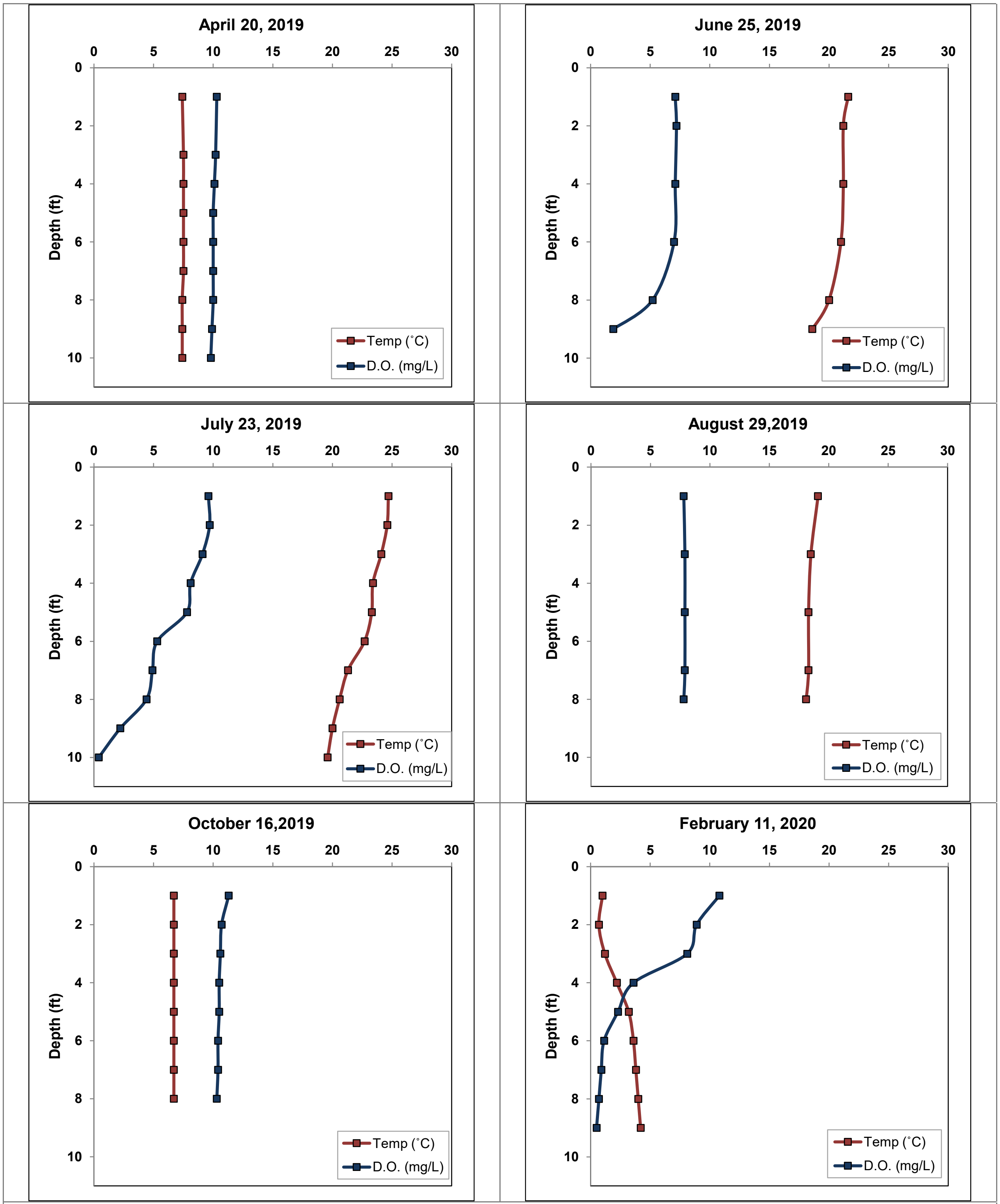


Figure 8.4.1-5. Wilson Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Wilson 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 Wilson 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. Values were much lower in April compared with the July samples. The low values in April reflect concentrations during snowmelt when chemicals are diluted. The concentrations reported below reflect concentrations during July. It is expected these concentrations will change from year to year depending upon precipitation and its impact on flows in the rivers.

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. Wilson Lake's surface water pH was measured at roughly 7.7 during summer 2019 (Figure 8.4.1-6). This value is near 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. The alkalinity in Wilson Lake during July 2019 was measured at 39.1 (mg/L as $CaCO_3$) (Figure, 8.4.1-7) 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 Wilson Lake during July 2019. 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 Wilson Lake's pH of 7.7 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 Wilson Lake was found to be 11.3 mg/L, which is below the optimal range for zebra mussels (Figure 8.4.1-8).

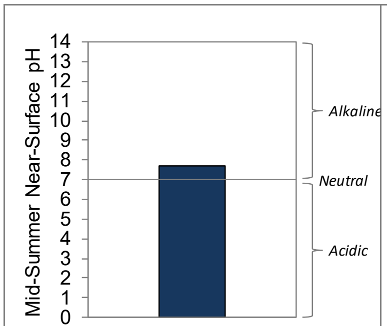


Figure 8.4.1-6. Wilson Lake mid-summer near-surface pH value.

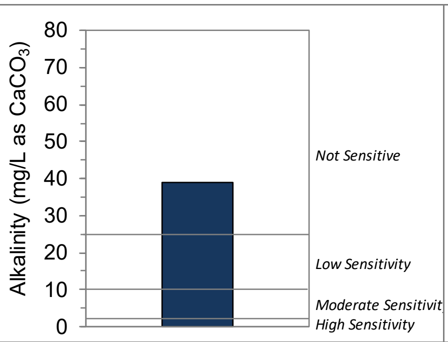


Figure 8.4.1-7. Wilson Lake summer total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

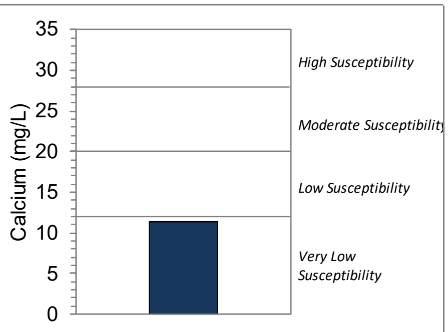


Figure 8.4.1-8. Wilson Lake summer calcium concentration and zebra mussel susceptibility. Samples collected from the near-surface.

8.4.2 Wilson Lake Watershed Assessment

Wilson Lake's watershed is 12,108 acres in size. Compared to Wilson Lake's size of 345 acres, this makes for an average watershed to lake area ratio of 35:1. The watershed is comprised of land cover types including wetlands (41%), forest (38%), pasture/grass/rural open space (15%), the lake surface itself (3%), row crops (2%), rural residential (1%), and urban land (<1%) (Figure 8.4.2-2). Wisconsin Lakes Modeling Suite (WiLMS) indicates that Wilson Lake's residence time is approximately 51 days, or the water within the lake is completely replaced seven times per year. Unlike the other three lakes, the phosphorus concentration in Wilson Lake will be determined by phosphorus loading from the direct watershed and internal lake processes.

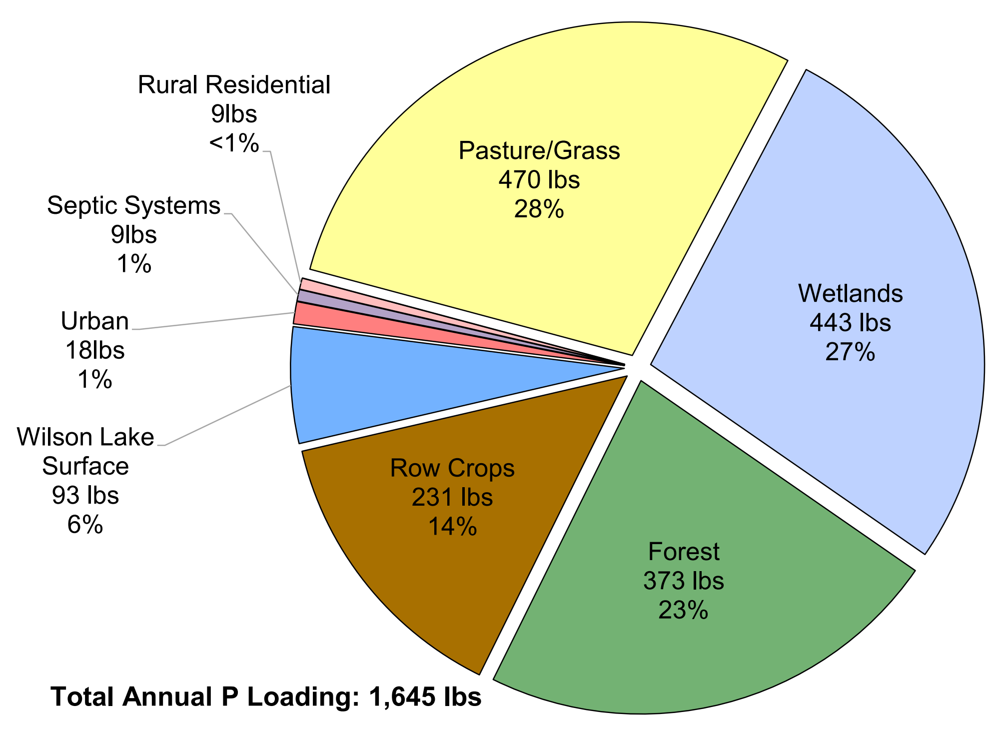


Figure 8.4.2-1. Wilson Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

As discussed in the chain-wide section (3.2), the Wilson Lake watershed does not contain any upstream waterbodies with sufficient water quality data to use as point sources. Due to this, the phosphorus load modeling was conducted solely based on the types of land covers within the Wilson Lake watershed (Map 2). Forested and wetland land cover types comprise 79% of the overall watershed. These land cover types provide the least amount of phosphorus inputs to a system. Row crop agriculture, urban and residential land cover types deliver the most amount of phosphorus to a system, with 3% of the overall watershed consisting of these land cover types and only a small fraction of the Wilson Lake watershed.

Using the information in Figure 8.1.2-1, WiLMS estimates 1,645 pounds of phosphorus being delivered to Wilson Lake on an annual basis. Comprising of only 2% of the overall landcover, row crop agriculture from the direct watershed contributes to 14% of the phosphorus budget.

Rotational agriculture likely changes the amount of phosphorus this land cover delivers each year. Also, conservational agriculture projects can reduce the amount of phosphorus and have a benefiting impact on the water quality of Wilson Lake and downstream waterbodies such as Long Lake.

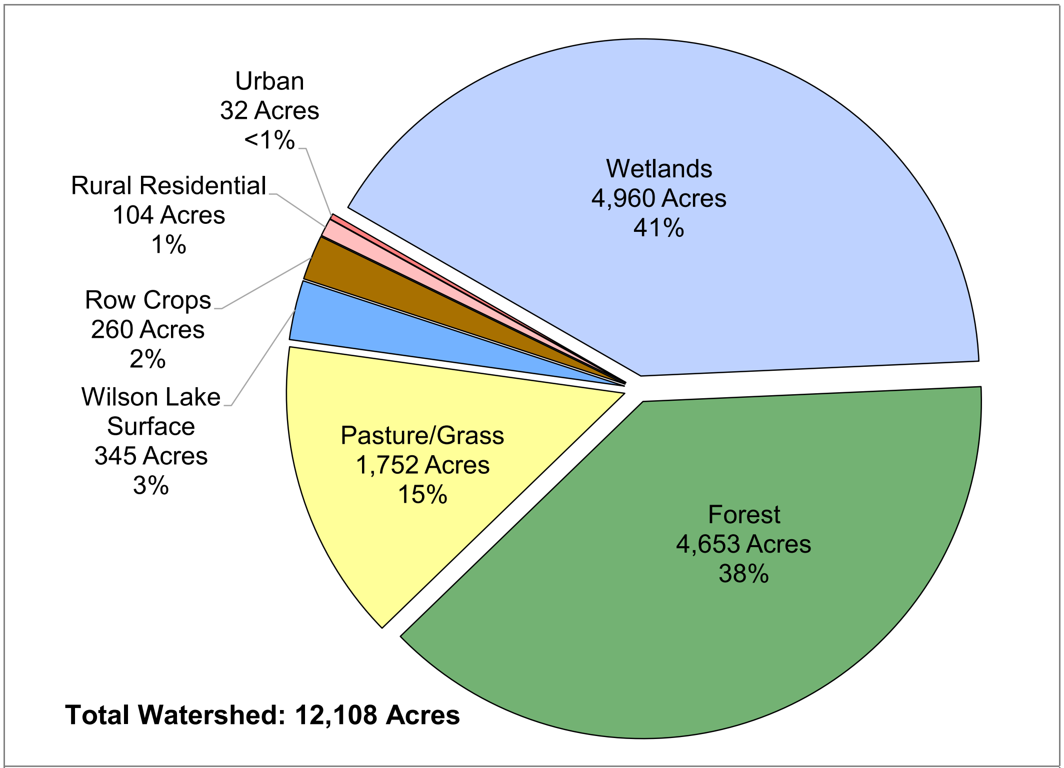


Figure 8.4.2-2. Wilson Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2016).

8.4.3 Wilson 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 Fall of 2019, Wilson Lake's immediate shoreline was assessed in terms of its development. Wilson Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 6.9 miles (70% of the total shoreline) of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.4.3-1). 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, 2.0 miles of urbanized and developed–unnatural shoreline (20% of the total shoreline) was observed. If restoration of the Wilson 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. Wilson – Map 1 displays the location of these shoreline lengths around the entire lake.

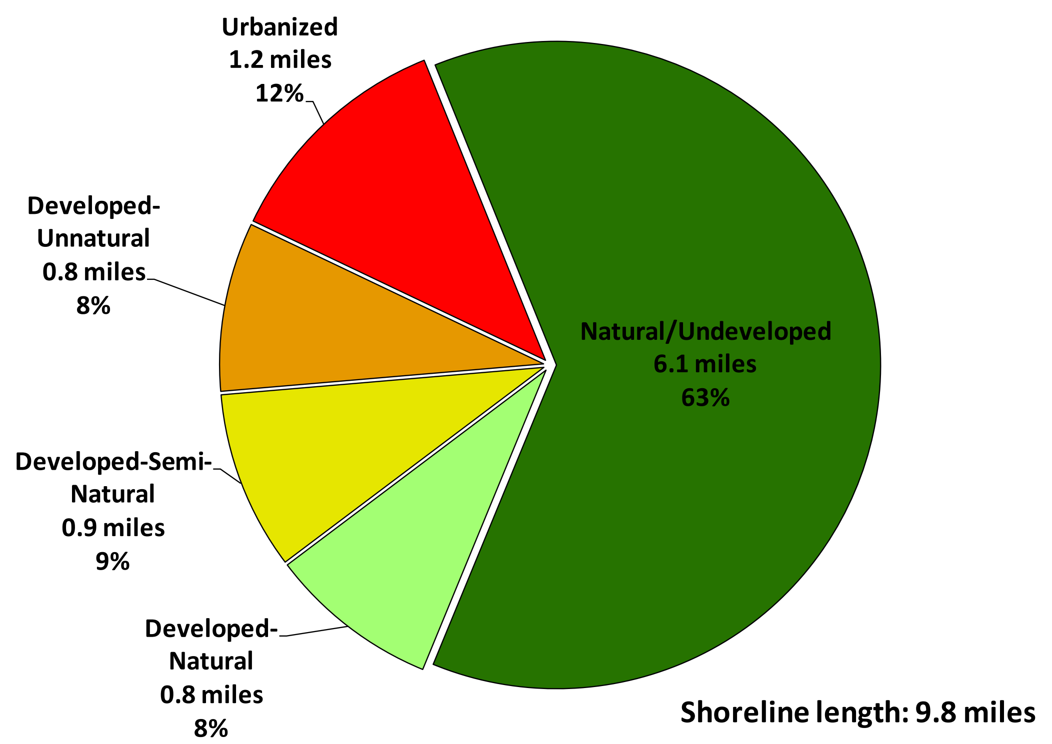


Figure 8.4.3-1. Wilson Lake shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on Wilson – Map 1.

Coarse Woody Habitat

Wilson Lake was surveyed in 2019 to determine the extent of its coarse woody habitat (Figure 8.4.3-2). 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 178 pieces of coarse woody habitat were observed along 9.8 miles of shoreline, which gives Wilson Lake a coarse woody habitat to shoreline mile ratio of 18:1. 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 coarse woody habitat are displayed on Wilson – Map 2.

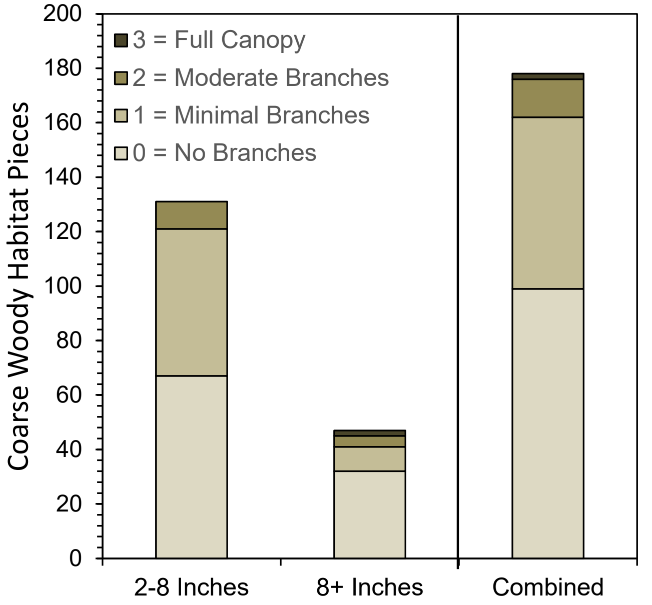


Figure 8.4.3-2. Wilson Lake coarse woody habitat survey results. Based upon a Fall 2019 survey. Locations of Wilson Lake coarse woody habitat can be found on Wilson – Map 2.

8.4.4 Wilson Lake Aquatic Vegetation

Figure 8.4.4-1. Wilson Lake whole-lake aquatic point-intercept survey sampling locations. Indicated by '+' (n=225).

The aquatic plant point-intercept survey was conducted on Wilson Lake on July 24, 2019 by Onterra (Figure 8.4.4-1). The floating-leaf and emergent plant community mapping survey was completed on August 26 to create the aquatic plant community map. During these 2019 surveys, a total of 41 species of native aquatic plants were located in and around Wilson Lake (Table 8.4.4-1). Twenty-nine of these species were sampled directly on the rake during the point-intercept survey and are used in the analysis that follows. The remaining 12 native species were located visually during the survey, but not sampled on the rake. In addition, four non-native species were located on Wilson Lake: Eurasian watermilfoil (EWM), purple loosestrife, reed canary grass, and narrow-leaved cattail. These presence of EWM will be discussed in further detail at the end of the Aquatic Plants Section. Whole-lake point-intercept (PI) surveys were also completed on Wilson Lake in previous years: 2007 by the WDNR to gain information about a potential drawdown; 2011, 2012 and 2014 by Onterra as part of an herbicide treatment project; and in 2015 by the WDNR to increase long-term understanding of the treatment. The species recorded during these surveys are included in Table 8.4.4-1.

During the 2019 PI survey, aquatic plants were found growing to a depth of 6 feet. As discussed later within this section, many of the plants found during this survey indicate that the overall community is healthy, diverse, and in the case of one species, somewhat rare. Vasey's pondweed (*Potamogeton vaseyi*) is listed by the Natural Heritage Inventory (NHI) Program as a species of special concern in Wisconsin, and was found in Wilson Lake. The special concern listing means it is suspected that there is a low abundance of the species within the state, and attention should be focused to help prevent it from becoming threatened or endangered.

Of the point-intercept locations sampled within the littoral zone in 2019, approximately 70% of them contained aquatic vegetation, with the majority being in the southern half of the lake (Map 5). A similar amount of littoral vegetation was documented in 2007, with lower amount of vegetation in the years between.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations can be driven by a combination of natural factors including variations in temperature, ice and snow cover (winter light availability), nutrient availability, water levels and flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul and Freedman 2006). Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition (Asplund and Cook 1997) (Lacoul and Freedman 2006). The use of herbicides to manage EWM have occurred on Wilson Lake, and will be discussed in the subsequent sub-section. Within many of the following charts, green shading indicates years in which an herbicide spot-treatment occurred, and blue shading indicates the year in which a whole-lake herbicide treatment occurred.

Aquatic plant rake fullness data was also collected during each of the point-intercept surveys beginning in 2011. The 2019 survey had the highest littoral frequency of occurrence of vegetation out of all survey years, as well as the highest proportion of the highest density rating of TRF=3 (Figure 8.4.4-2). Approximately 84% of the point-intercept sampling locations where sediment data was collected contained fine organic substrate which is conducive for supporting lush aquatic plant growth, 13% consisted of sand, and the remaining 3% was rocky substrate.

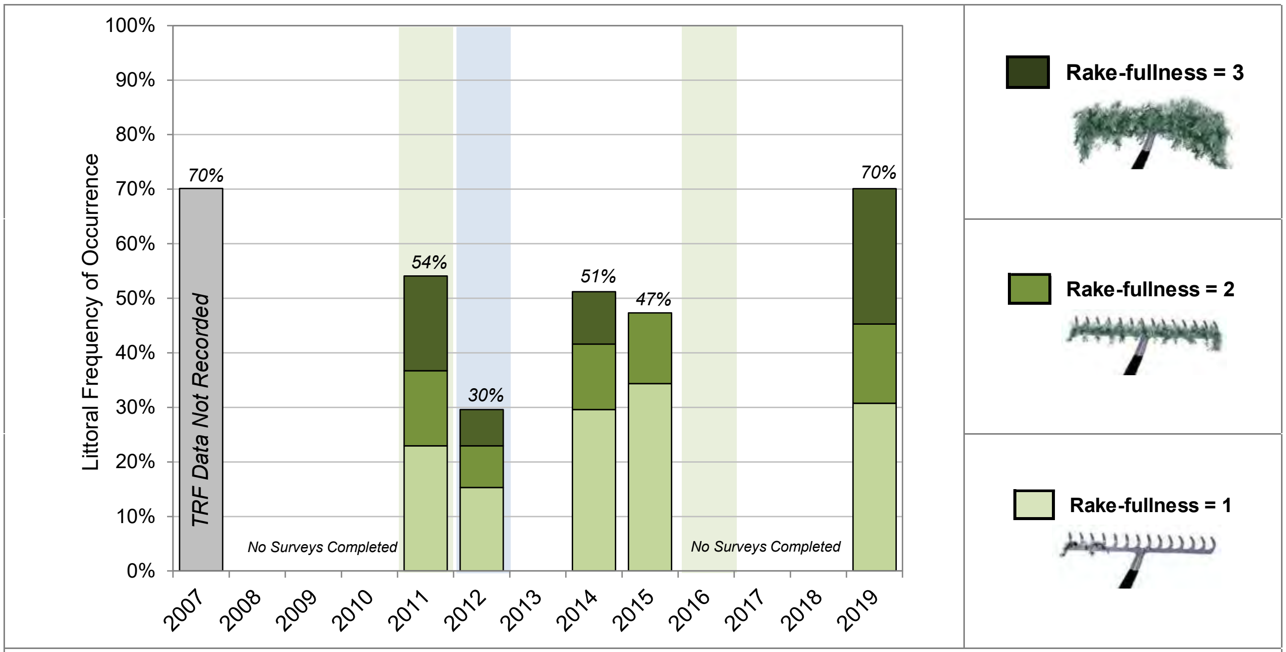


Figure 8.4.4-2. Total rake fullness ratings on Wilson Lake. Created using data from the point-intercept surveys. Green shading indicates year of herbicide spot-treatment. Blue shading indicates year of whole-lake treatment.

Table 8.4.4-1. Aquatic plant species located in Wilson Lake during the aquatic plant surveys.

Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	Growth Form	Wilson					
					2007	2011	2012	2014	2015	2019
Brasenia schreberi	Watershield	Native	7	FL		X	X		X	X
Calla palustris	Water arum	Native	9	E						I
Carex comosa	Bristly sedge	Native	5	E	X					
Carex utriculata	Common yellow lake sedge	Native	7	E						I
Ceratophyllum demersum	Coontail	Native	3	S	X	X	X	X	X	X
Ceratophyllum echinatum	Spiny hornwort	Native	10	S						X
Chara spp.	Muskgrasses	Native	7	S		X		X	X	X
Eleocharis acicularis	Needle spikerush	Native	5	S/E		X				
Eleocharis palustris	Creeping spikerush	Native	6	E	I	X				I
Elodea canadensis	Common waterweed	Native	3	S	X	X	X	X	X	X
Elodea nuttallii	Slender waterweed	Native	7	S				X		X
Equisetum fluviatile	Water Horsetail	Native	7	E	I					
Glyceria canadensis	Rattlesnake grass	Native	7	E						I
Lemna minor	Lesser duckweed	Native	5	FF	X				X	
Lemna trisulca	Forked duckweed	Native	6	FF	X	X	X	X	X	
Lemna turionifera	Turion duckweed	Native	2	FF			X			I
Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	E						I
Myriophyllum heterophyllum	Various-leaved watermilfoil	Native	7	S	I					X
Myriophyllum sibiricum	Northern watermilfoil	Native	7	S	X	X		X		
Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	S	X	X	I	X	X	X
Myriophyllum verticillatum	Whorled watermilfoil	Native	8	S	X					
Najas flexilis	Slender naiad	Native	6	S	X	X		X		X
Nitella spp.	Stoneworts	Native	7	S	X			X	X	X
Nuphar variegata	Spatterdock	Native	6	FL	I	X	X	X		X
Nymphaea odorata	White water lily	Native	6	FL	X		X	X	X	X
Phalaris arundinacea	Reed canary grass	Non-Native - Invasive	N/A	E						I
Potamogeton amplifolius	Large-leaf pondweed	Native	7	S	X	X	X	X	X	X
Potamogeton berchtoldii	Slender pondweed	Native	7	S				X		X
Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	S	X	X	X	X	X	X
Potamogeton foliosus	Leafy pondweed	Native	6	S				X	X	X
Potamogeton natans	Floating-leaf pondweed	Native	5	S	X	X	X	X	X	X
Potamogeton obtusifolius	Blunt-leaved pondweed	Native	9	S	X			I	X	X
Potamogeton pusillus	Small pondweed	Native	7	S	X	X	X	X		X
Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	S						
Potamogeton robbinsii	Fern-leaf pondweed	Native	8	S	X	X	X	X	X	X
Potamogeton spirillus	Spiral-fruited pondweed	Native	8	S	X	X				
Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	S						X
Potamogeton zosteriformis	Flat-stem pondweed	Native	6	S	X	X	X	X		X
Riccia fluitans	Slender riccia	Native	7	FF						X
Sagittaria latifolia	Common arrowhead	Native	3	E						I
Sagittaria rigida	Stiff arrowhead	Native	8	E	I	X				I
Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	S						X
Schoenoplectus acutus	Hardstem bulrush	Native	5	E			X			
Schoenoplecus subterminalis	Water bulrush	Native	9	S	I					
Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	E	I			X	X	X
Scirpus cyperinus	Wool grass	Native	4	E						I
Sparganium eurycarpum	Common bur-reed	Native	5	E	I					I
Sparganium fluctuans	Floating-leaf bur-reed	Native	10	FL	I					I
Sparganium sp.	Bur-reed sp.	Native	N/A	FL/E	X					I
Spirodela polyrhiza	Greater duckweed	Native	5	FF	X	X	X	X	X	X
Stuckenia pectinata	Sago pondweed	Native	3	S					X	X
Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A	E						I
Typha latifolia	Broad-leaved cattail	Native	1	E	I					
Typha spp.	Cattail spp.	N/A	N/A	E						I
Utricularia gibba	Creeping bladderwort	Native	9	S	I					
Utricularia vulgaris	Common bladderwort	Native	7	S	I		X		X	X
Vallisneria americana	Wild celery	Native	6	S	I	X				X
Zizania palustris	Northern wild rice	Native	8	E	I					I

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

Of the native species in Wilson Lake in 2019, the most common was small pondweed. Because of their very similar morphological characteristics which make it difficult to differentiate them from one another in the field, some species were combined together for this analysis. In this case, small pondweed and slender pondweed were combined. Their collective littoral frequency of occurrence (LFOO) was 38.5 (Figure 8.4.4-3). This represented a statistically significant increase from the previous survey in 2015 which did not locate either of these species. Small pondweeds are particularly sensitive to whole-lake 2,4-D treatments, which likely reduced the population from 5.6% in 2011 to less than 2% from 2012-2015. It is unclear what conditions caused the large increase in small pondweeds in 2019.

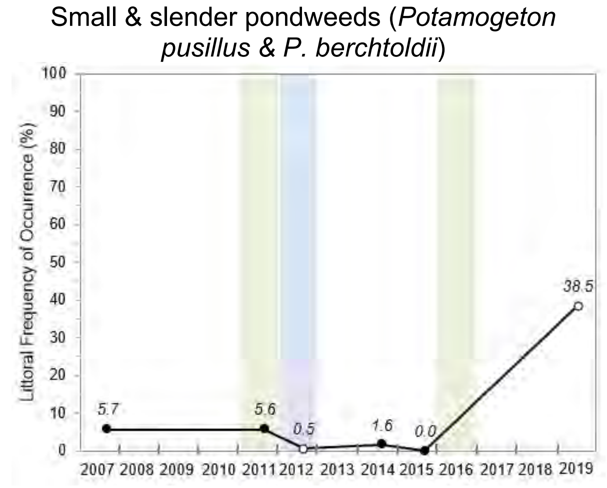


Figure 8.4.4-3. Littoral frequency of occurrence of the most common species in Wilson Lake in 2019. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Coontail was the second most frequently encountered native aquatic plant in Wilson Lake in 2019 (Figure 8.4.4-4) and waterweed was the third most frequent species. Both these species are largely non-rooted, becoming wrapped in taller vegetation and can sometimes cause nuisance conditions that hampers boat traffic and recreation.

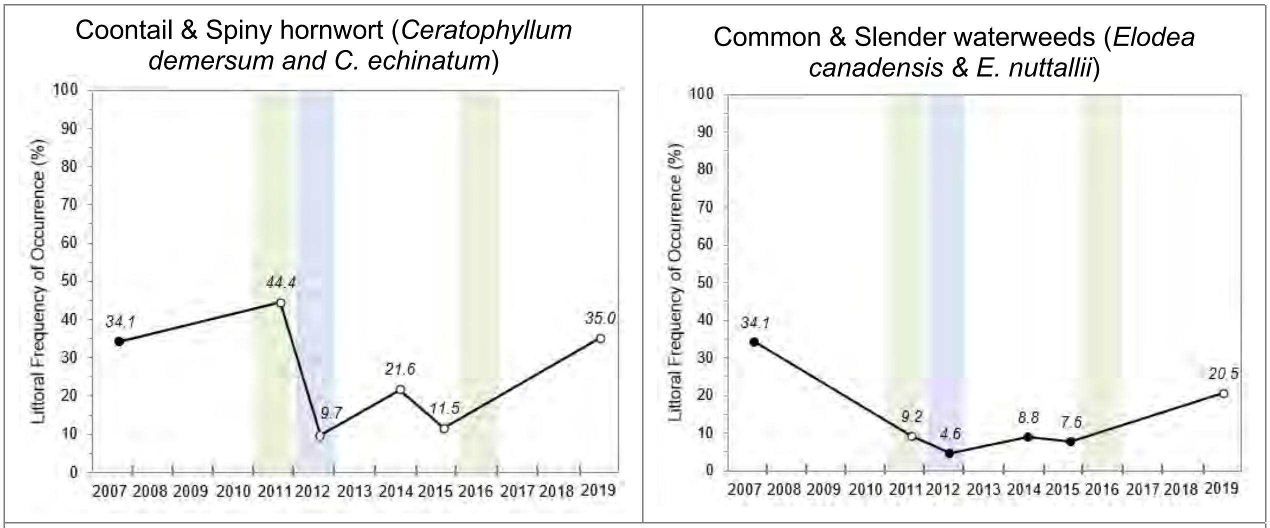


Figure 8.4.4-4. Littoral frequency of select common species in Wilson Lake during 2019. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.4.4-1. Fern pondweed (left) and slender naiad (right).

Fern pondweed (*Potamogeton robbinsii*) and slender naiad (*Najas flexilis*) were tied for the fourth most common species in 2019 (Photograph 8.4.4-1). Fern-leaf pondweed is generally found growing in thick beds over soft substrates where it stabilizes bottom sediments and provides a dense network of structural habitat for aquatic wildlife. As its name indicates, this plant resembles a terrestrial fern frond in appearance and is often a dominant species in plant communities of northern Wisconsin lakes. This plant often goes without being noticed, as it grows low within the water column and rarely causes conditions that interfere with recreation and navigation. Fern-leaf pondweed survives mostly as an evergreen plant throughout the winter when many other native plants are dormant. Slender naiad is an annual that produces many seeds and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman, Korth and Temte 1997).

Because of the high number of native species of plants (species richness) found in Wilson Lake, one may assume that the lake would also have high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence diversity. The diversity index for Wilson Lake's plant community has ranged from 0.84 to 0.92 over the survey years and was 0.89 in 2019, falling above the Northern Lakes and Forests Lakes ecoregion median value (0.88), as well as the state median (0.86), indicating the lake holds just above average diversity (Figure 8.4.4-5).

Figure 8.4.4-5. Simpson's diversity for Wilson Lake from 2007-2019.

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 small pondweed was found at approximately 36% of the littoral sampling locations, its relative frequency of occurrence is just under 17%. Explained another way, if 100 plants were randomly sampled from Wilson Lake, 17 of them would be small pondweed. This distribution can be observed in Figure 8.4.4-6 where together 6 species account for 70% of the population of plants within Wilson Lake, and the other 24 species account for the remaining 30%. As a reminder, the incidentally located species are not included in this analysis.

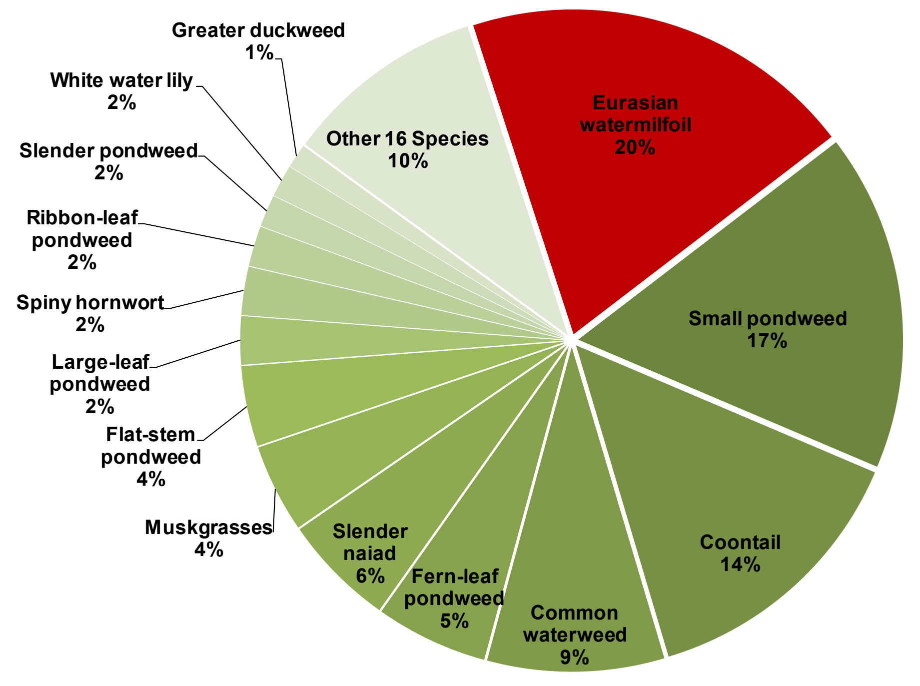


Figure 8.4.4-6. Wilson Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2019 point-intercept survey.

Wilson Lake's average conservatism value in 2019 (6.3) was below the Northern Lakes and Forests ecoregion median and matched the state median (Figure 8.4.4-7). This indicates that the aquatic plant community in Wilson Lake is of somewhat average quality. Wilson Lake's species richness value (29) however exceeded the ecoregion (21) and state (19) medians (Figure 8.4.4-7). Combining Wilson Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 33.8 in 2019 which is above the median values for the ecoregion and state as well (Figure 8.4.4-7). The charts in Figure 8.4.4-7 also include the green shading to indicate the 2011 herbicide spot-treatment, and the blue shading for the 2012 whole-lake herbicide treatment. Although the 2012 survey had the lowest average conservatism value, overall Floristic Quality was lowest during the 2015 survey in which year no treatments occurred in the lake. As discussed in the chainwide section, aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time.

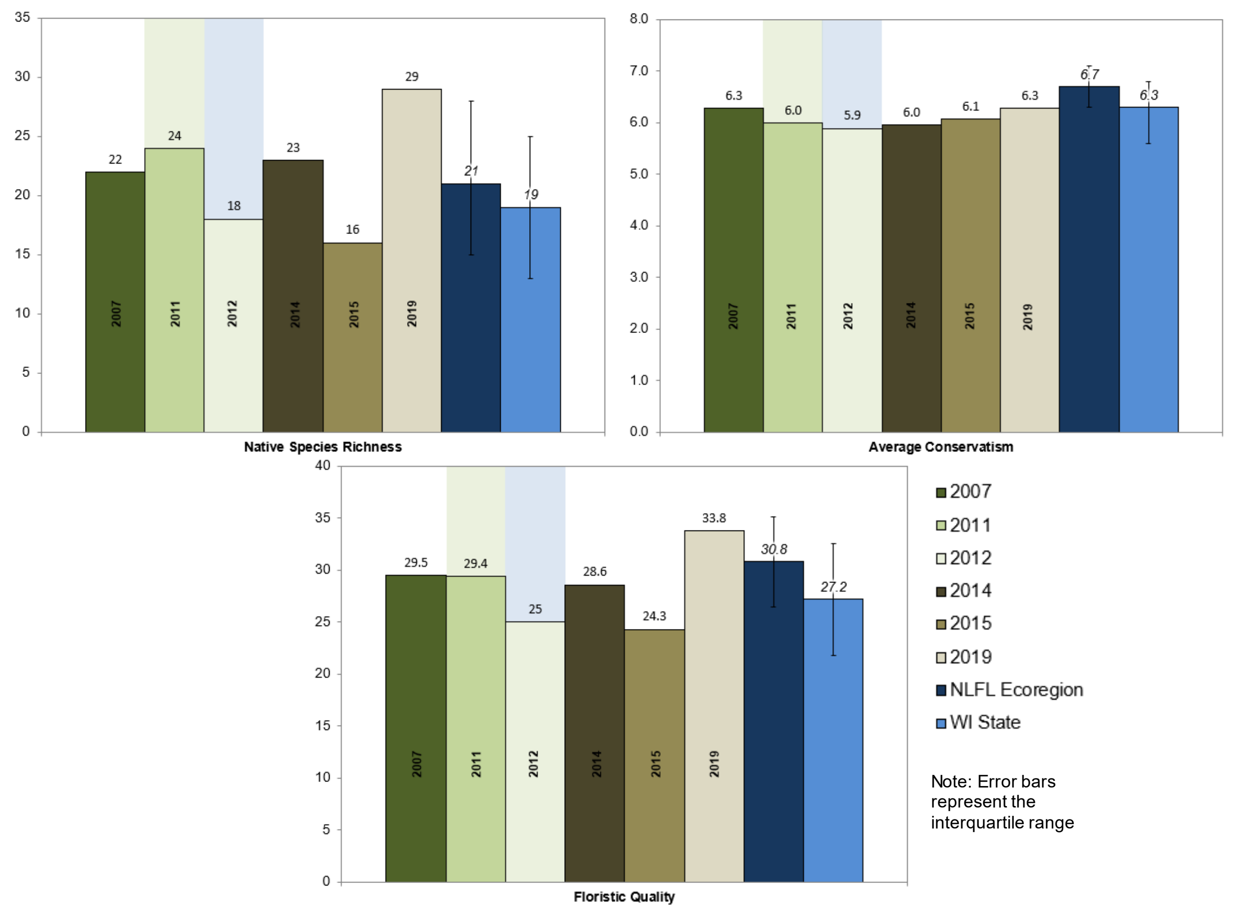


Figure 8.4.4-7. Wilson Lake Floristic Quality Analysis. Created using data from point-intercept surveys.

The quality of Wilson Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas around the lake. The 2019 community map indicates that approximately 92.6 acres of the lake contains these types of plant communities (Wilson – Map3, Table 8.4.4-2). Sixteen native floating-leaf and emergent species were located in and around Wilson Lake in 2019, providing valuable wildlife habitat.

Table 8.4.4-2. Wilson Lake acres of emergent and floating-leaf plant communities from the 2019 community mapping survey.

Plant Community	Acres
Emergent	1.8
Floating-leaf	87.1
Mixed Emergent & Floating-leaf	3.7
Total	**92.6**

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum;* EWM) was first verified in Wilson Lake in 2002. EWM has an affinity for softer sediments, which as displayed previously, makes up 84% of Wilson Lake's bottom substrate, making it an ideal place for EWM to thrive.

PCOLA has sponsored a number of AIS control projects aimed at managing the EWM population on the Phillips Chain, starting in 2011. As part of these projects, EWM Peak-Biomass surveys were completed annually from 2011-2016, in addition to the 2009 surveys completed as a part of the first management planning project. The EWM acreage mapped in 2019 as part of this updated planning project can be compared with these earlier years of data to see how the EWM population has changed over time in Wilson Lake. EWM is mapped in the same manner previously discussed in the CLP section. Note that these values only reflect the contiguous colonies of EWM mapped using polygons and does not include point-based occurrences.

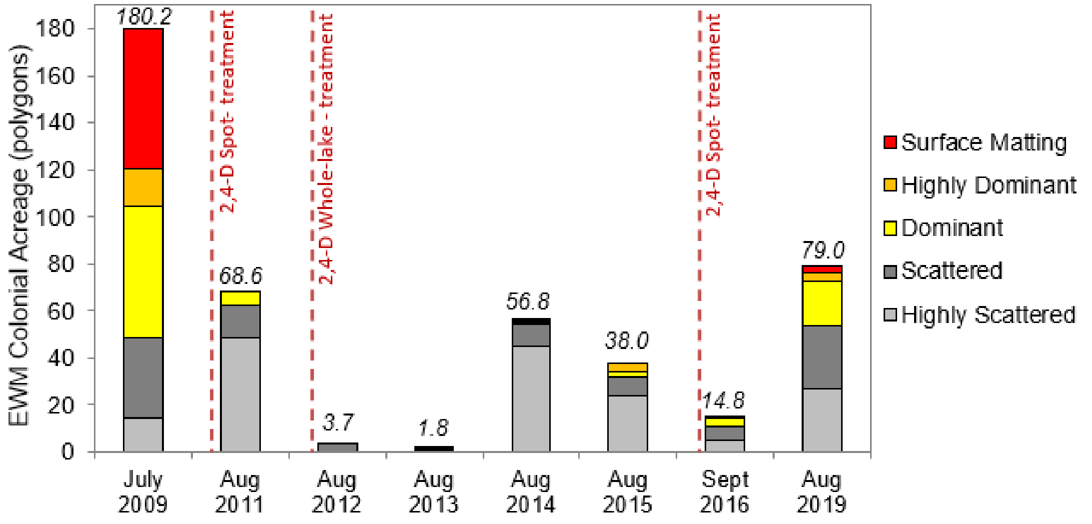


Figure 8.4.4-8. Acreages of EWM mapped in Wilson Lake. Created using data from EWM Peak-Biomass (Late-Season AIS) surveys.

During this timeframe, herbicide spot treatments occurred in 2011 and 2016, with a whole-lake treatment occurring in 2012 (Table 8.4.4-3). During all treatments, a liquid form of 2,4-D amine was used. The whole-lake 2,4-D treatment targeted a lake-wide concentration of approximate 0.325 ppm ae. Volunteer-based water testing indicated that the mean concentration of the lake was only slightly below target (0.315 ppm ae), with concentrations exceeding targets in the southern half of Wilson Lake, and being lower than targets in the northern half. Herbicide concentrations were below detection by 28 days after treatment. While no EWM was recorded during 2012 on the point-intercept survey, remnant populations were identified in the northern half of the lake where concentrations were lower. EWM populations were reduced for approximately three years following this management action (Figure 8.4.4-8). In 2019, EWM

Table 8.4.4-3. Wilson Lake EWM treatment history.

Date	Acres	Product	Amount Applied		Pounds of Active Ingredient
6/7/2011	9.6	Weedestroy (amine)	76.5	gallons	290.7
4/24/2012	110.9	DMA 4 (amine)	432.5	gallons	1643.5
6/1/2016	7.8	Aligare (amine)	89.25	gallons	339.2

Wilson Lake does have some Eurasian watermilfoil look-alikes which can sometimes be mistaken as the non-native EWM (Photograph 8.4.4-2). Two of these include native Northern watermilfoil (*Myriophyllum sibiricum*) and common bladderwort (*Utricularia vulgaris*). Northern watermilfoil is often falsely identified as Eurasian watermilfoil, especially since it is known to take on the reddish appearance of Eurasian watermilfoil as the plant reacts to sun exposure as the growing season progresses. The feathery foliage of northern watermilfoil traps filamentous algae and detritus, providing valuable invertebrate habitat. Because northern watermilfoil prefers high water clarity, its populations are declining state-wide as lakes are becoming more eutrophic. Common bladderwort is arguably the most common bladderwort species in Wisconsin. Bladderworts are insectivorous, meaning they supplement their nutrient demand by trapping and digesting small insects and crustaceans. These plants possess small sac-like bladders containing small hairs, which when touched by unsuspecting prey trigger a door on the trap to open rapidly drawing in water and the insect. Trapped within the bladder, the insect is slowly digested. Bladderworts are free-floating and non-rooted species that are often found entangled on floating-leaf vegetation like water lilies.

Photograph 8.4.4-2. Two native aquatic plants with similar physical characteristics to EWM.

Purple Loosestrife

Onterra located purple loosestrife in several locations along shore in the southern half of Wilson Lake during their 2019 surveys (Figure 8.1.4-9). No purple loosestrife was located in these areas during the 2009 assessment.

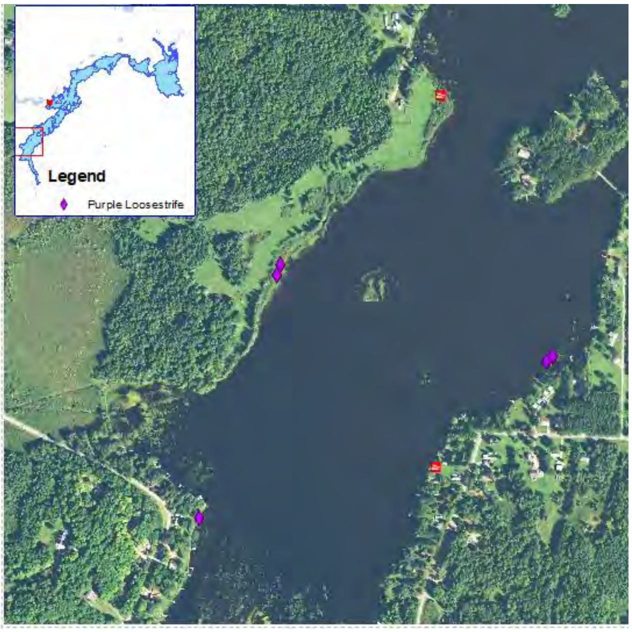
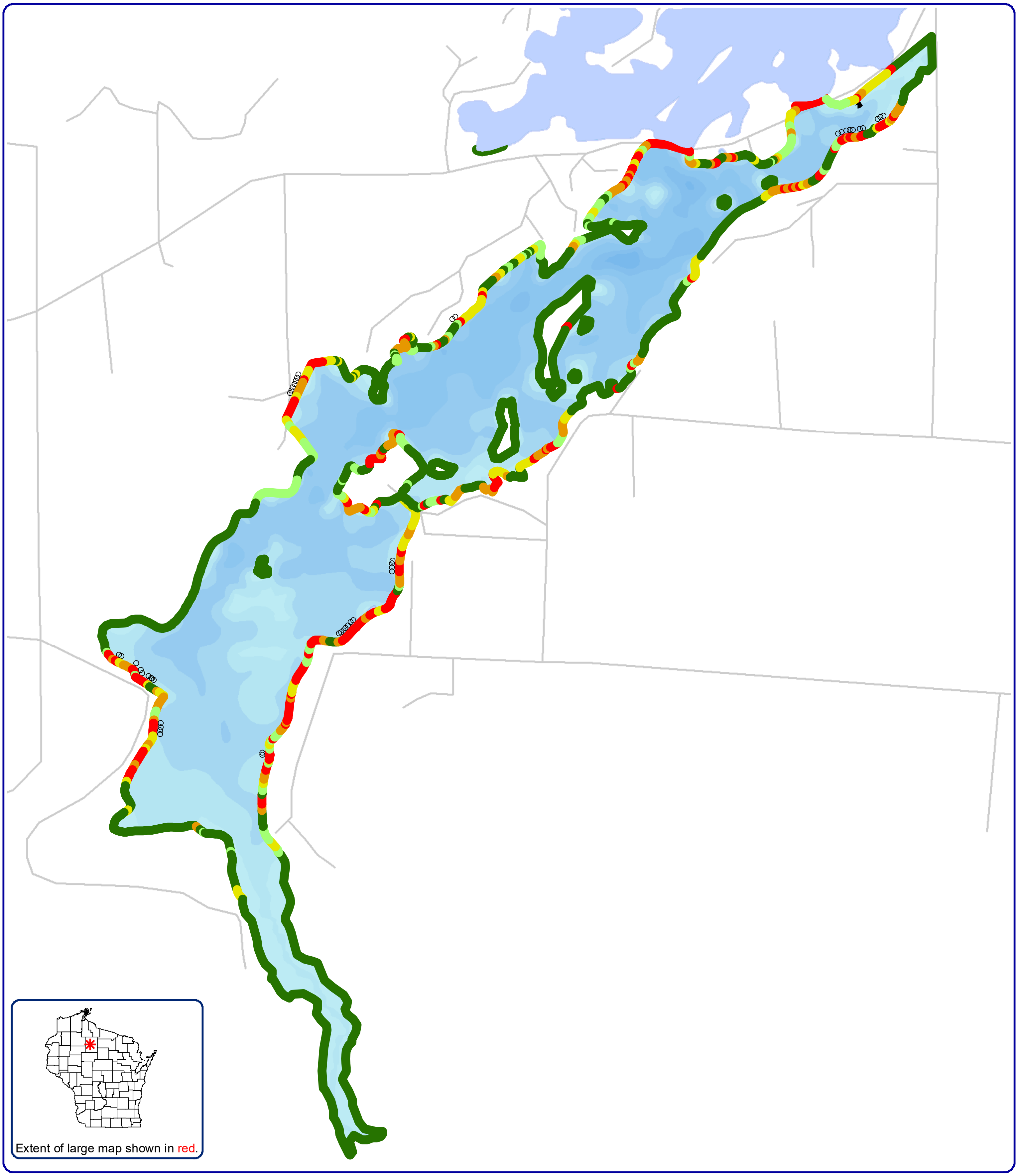


Figure 8.4.4-9. Purple loosestrife locations around Wilson Lake in August 2019.



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Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 2019
Orthophotography: NAIP, 2017
Map date: December 4, 2019 JMB
Filename: PhillipsChain_SA_2019_Wilson.mxd

Legend

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall Modifier

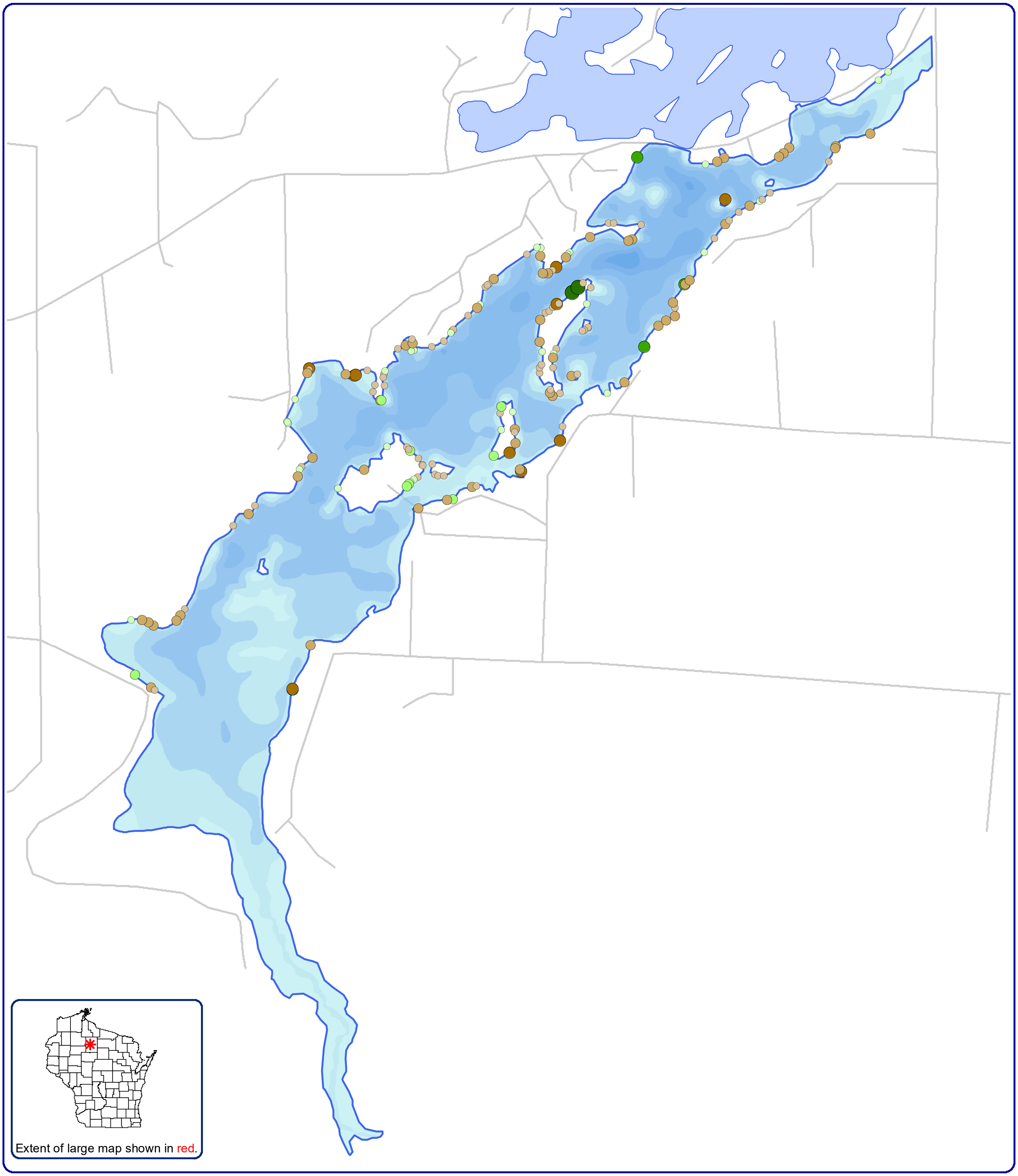
- Masonary/Wood Seawall
- Rip-Rap/Placed Stone

Wilson - Map 1

Wilson Lake

Price County, Wisconsin

Shoreland Condition Assessment



1,150

Feet

Legend

2-8 Inch Pieces	8+ Inch Pieces
● No Branches	● No Branches
● Minimal Branches	● Minimal Branches
● Moderate Branches	● Moderate Branches
● Full Canopy	● Full Canopy

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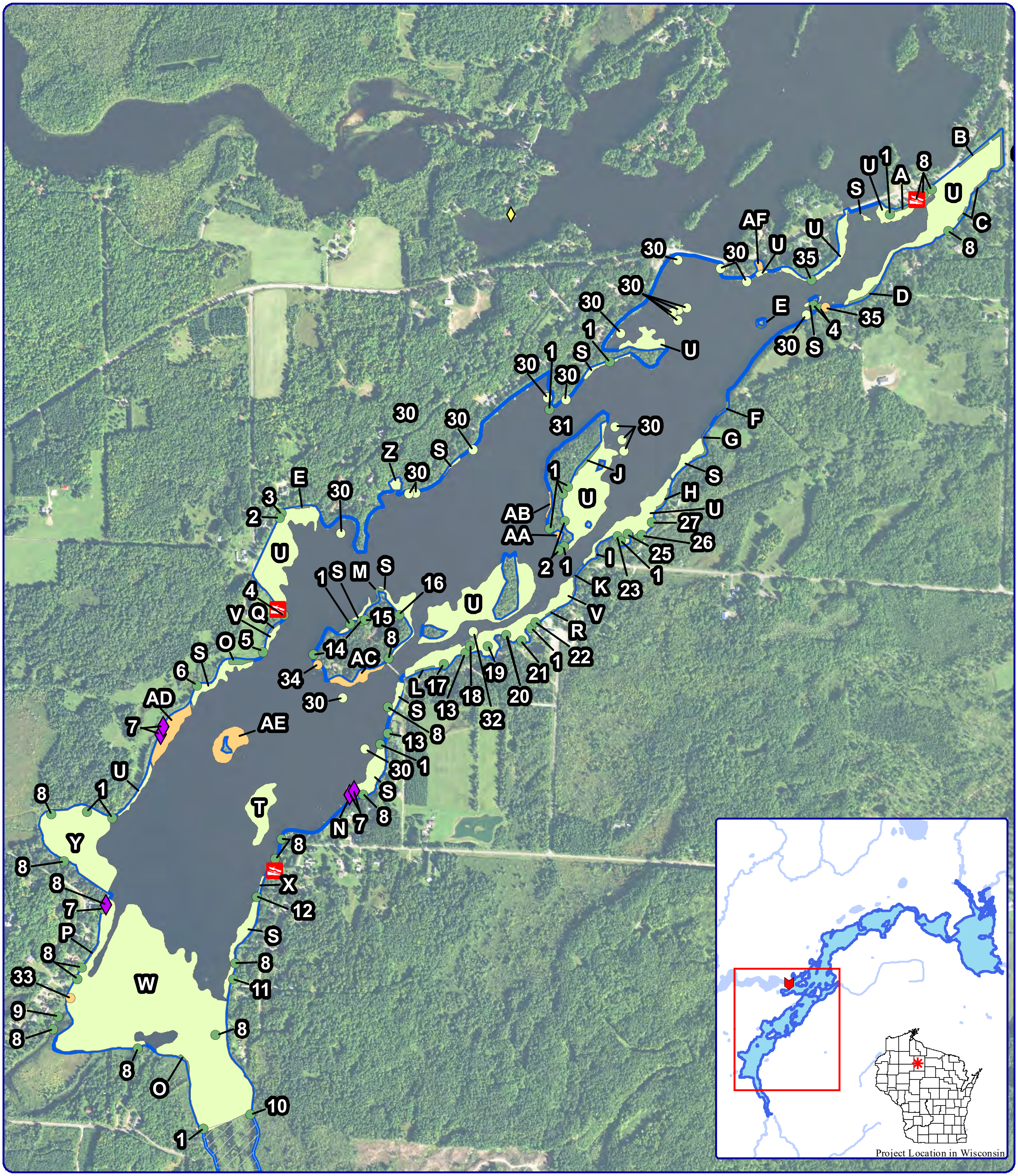
Orthophotography: NAIP, 2017
Map date: December 4, 2019 JMB
Filename: PhillipsChain_SA_2019_Wilson.mxd

Wilson - Map 2

Wilson Lake

Price County, Wisconsin

Coarse Woody Habitat



N W E S

1,100

Feet

Onterra, LLC
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Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: December 20, 2019 AMS

Legend

Small Plant Communities
- ● Emergent
- ○ Floating-leaf
- ● Mixed Floating-leaf & Emergent
- ◆ Purple Loosestrife

Large Plant Communities
- 🟩 Emergent
- ▨ Floating-leaf
- 🟧 Mixed Floating-leaf & Emergent
- ▨ Unnaviagable Area; Not Able to Survey

Wilson - Map 3

Wilson Lake
Price County, Wisconsin

Aquatic Plant Communities

Wilson Lake 2019 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Wilson - Map 3

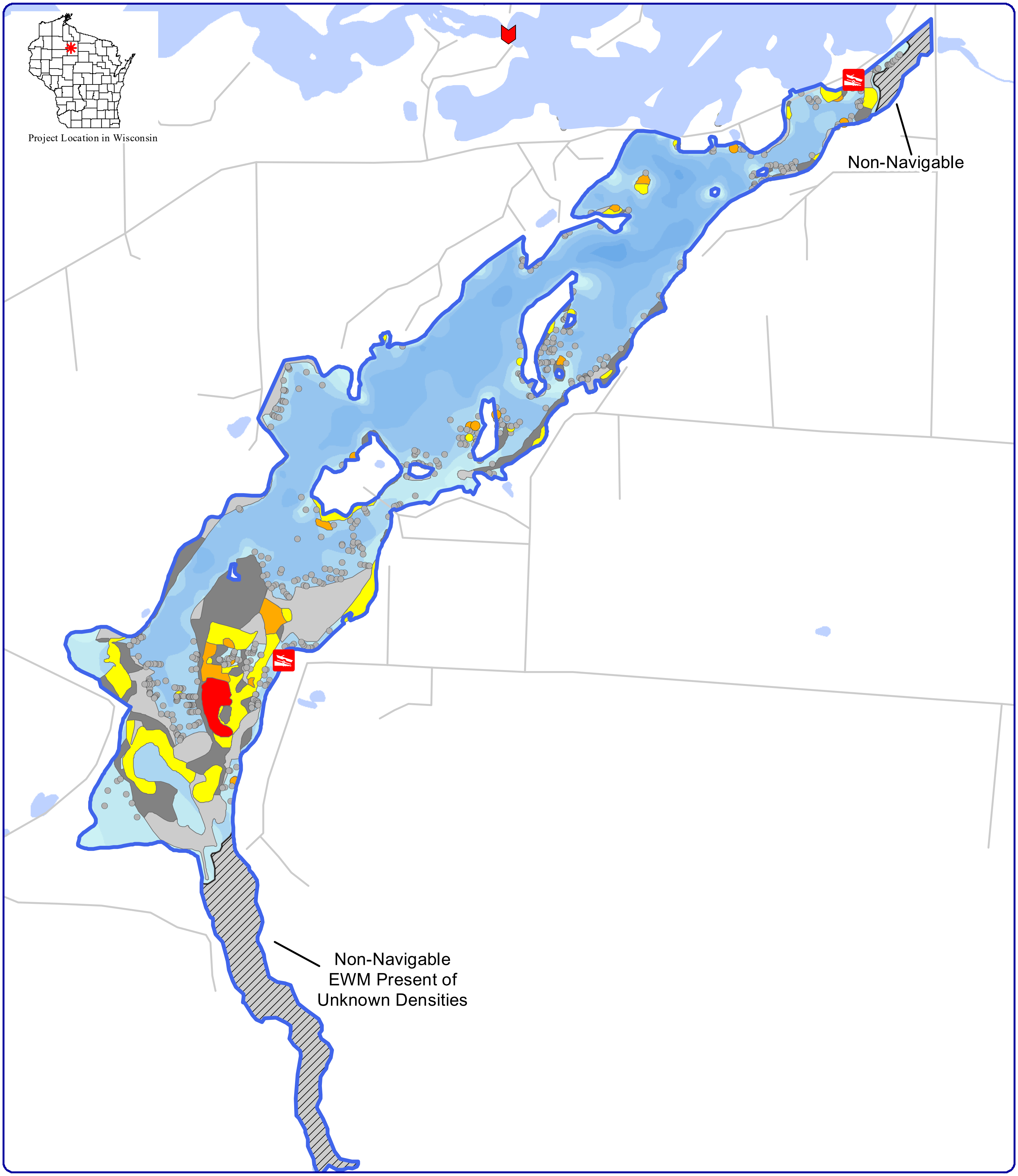
Large Plant Community (Polygons)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8	Acres
A	**Cattail sp.**	**Softstem bulrush**	**Creeping spikerush**	Common arrowhead					0.06
B	**Cattail sp.**	**Unbranched bur-reed**	Creeping spikerush						0.12
C	**Cattail sp.**								0.34
D	**Common beaked sedge**	**Softstem bulrush**	**Common arrowhead**						0.13
E	**Softstem bulrush**	**Common beaked sedge**							0.02
F	**Cattail sp.**	**Softstem bulrush**							0.04
G	**Common beaked sedge**	**Softstem bulrush**							0.10
H	**Common beaked sedge**	**Cattail sp.**	**Softstem bulrush**						0.07
I	**Softstem bulrush**	**Common beaked sedge**							0.05
J	**Floating-leaf bur-reed**								0.16
K	**Softstem bulrush**	**Common beaked sedge**	**Creeping spikerush**	**Cattail sp.**					0.06
L	**Cattail sp.**	**Creeping spikerush**	**Softstem bulrush**	Stiff arrowhead					0.06
M	**Cattail sp.**	**Creeping spikerush**	**Softstem bulrush**	**Common beaked sedge**	Common arrowhead				0.08
N	**Sedge sp.**	**Cattail sp.**	**Softstem bulrush**	Common beaked sedge					0.16
O	**Stiff arrowhead**								0.25
P	**Cattail sp.**	**Creeping spikerush**	**Common arrowhead**						0.03
Q	**Creeping spikerush**	**Softstem bulrush**	**Common beaked sedge**						0.03
R	**Cattail sp.**	**Softstem bulrush**	**Common beaked sedge**						0.03
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
S	**White water lily**								6.70
T	**White water lily**	Spatterdock							1.99
U	**White water lily**	**Spatterdock**							29.84
V	**White water lily**	**Spatterdock**	**Watershield**						4.77
W	**White water lily**	**Spatterdock**	**Watershield**	Floating-leaf bur-reed					36.53
X	**White water lily**	**Watershield**							0.09
Y	**Spatterdock**	**White water lily**	**Watershield**						6.98
Z	**Spatterdock**	**White water lily**							0.17
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
AA	**Common beaked sedge**	**Cattail sp.**	**Softstem bulrush**	**Spatterdock**	Creeping spikerush				0.09
AB	**Softstem bulrush**	**Spatterdock**	**White water lily**						0.09
AC	**White water lily**	**Cattail sp.**	Creeping Spikerush	Softstem bulrush	Sedge sp.	Watershield			0.63
AD	**Stiff arrowhead**	**White water lily**	**Creeping spikerush**	**Common beaked sedge**	Softstem bulrush	Watershield	Spatterdock		1.44
AE	**White water lily**	**Stiff arrowhead**	Softstem bulrush						1.38
AF	**White water lily**	**Spatterdock**	**Sedge sp. (sterile)**	Common arrowhead	Cattail sp.	Water arum			0.10

Small Plant Community (Points)

Emergent	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6	Species 7	Species 8
1	**Softstem bulrush**							
2	**Creeping spikerush**							
3	**Common beaked sedge**	**Creeping spikerush**						
4	**Common beaked sedge**							
5	**Creeping spikerush**	**Softstem bulrush**						
6	**Common bur-reed**	**Stiff arrowhead**						
7	**Purple loosestrife**							
8	**Cattail sp.**							
9	**Cattail sp.**	**Water arum**	**Creeping spikerush**	**Stiff arrowhead**				
10	**Cattail sp.**	**Sedge sp. (sterile)**						
11	**Common arrowhead**	**Creeping spikerush**						
12	**Wild rice sp.**							
13	**Sedge sp. (sterile)**							
14	**Reed canary grass**							
15	**Softstem bulrush**	**Sitff arrowhead**	Water arum	Reed canary grass				
16	**Common beaked sedge**	**Softstem bulrush**	Common arrowhead	Common bur-reed				
17	**Stiff arrowhead**	**Softstem bulrush**						
18	**Creeping spikerush**	**Softstem bulrush**	Common arrowhead					
19	**Common beaked sedge**	**Stiff arrowhead**						
20	**Common bur-reed**	**Softstem bulrush**	Common beaked sedge	Common arrowhead				
21	**Softstem bulrush**	**Stiff arrowhead**	Unbranched bur-reed					
22	**Common beaked sedge**	**Common arrowhead**						
23	**Common beaked sedge**	**Softstem bulrush**	Common bur-reed					
24	**Softstem bulrush**	**Creeping spikerush**	Stiff arrowhead					
25	**Narrow-leaved cattail**							
26	**Stiff arrowhead**							
27	**Common beaked sedge**	**Softstem bulrush**	Cattail sp.					
28	**Softstem bulrush**	**Cattail sp.**	Reed canary grass					
29	**Creeping spikerush**	**Cattail sp.**						
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
30	**White water lily**							
31	**Spatterdock**	**White water lily**						
32	**Spatterdock**							
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
33	**Cattail sp.**	Common beaked sedge	Softstem bulrush					
34	**White water lily**	Softstem bulrush						
35	**Common beaked sedge**	White water lily						

Bolded species are considered most dominant within each community; Scientifc names can be found in the species list in Table 8.4.4-1



Legend

- ⬜ Highly Scattered
- ⬛ Scattered
- 🟨 Dominant
- 🟧 Highly Dominant
- 🟥 Surface Matting
- ● Single or Few Plants
- 🟡 Clumps of Plants
- 🟠 Small Plant Colony

Wilson - Map 4

Wilson Lake

Price County, Wisconsin

August 2019 EWM Survey Results

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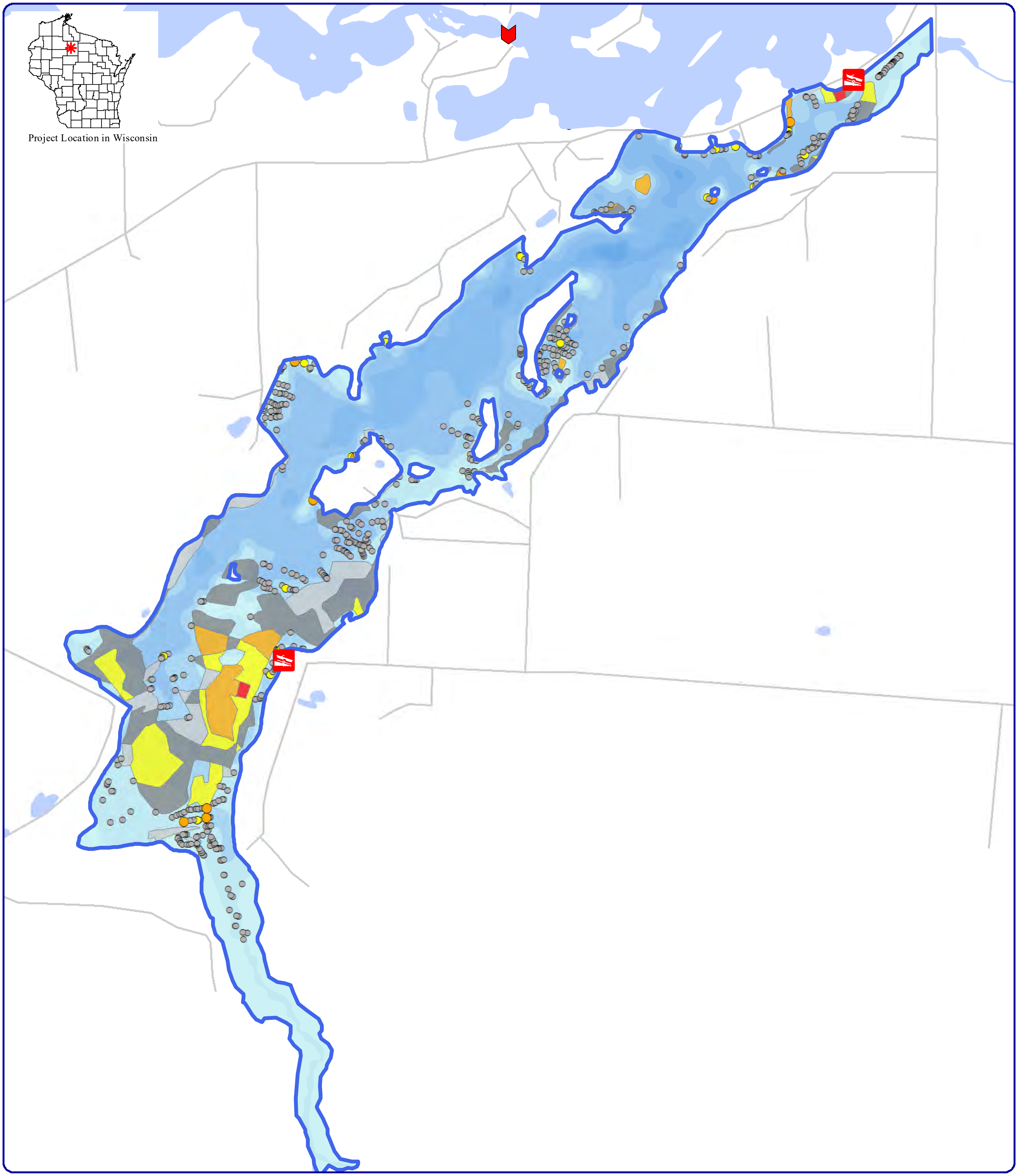
Sources:
Roads & Hydro: WDNR
Bathymetry: WDNR, digitized by Onterra
Map date: October 14, 2019 JMB
Filename: PhillipsChain_EWM_PB_Aug19_Wilson.mxd



Legend

- ▨ Highly Scattered
- ▨ Scattered
- 🟨 Dominant
- 🟧 Highly Dominant
- 🟥 Surface Matting
- ● Single or Few Plants
- ● Clumps of Plants
- ● Small Plant Colony

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Wilson - Map 5

Wilson Lake

Price County, Wisconsin

August 2020 EWM Survey Results