Town of Winchester Lakes
Comprehensive Management Plan – Phase III

Vilas County, Wisconsin

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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:

Town of Winchester Lakes Planning Committee

The Planning Committee was comprised of riparian property owners from the following lakes:

Harris Lake
Hiawatha Lake
Birch Lake
Tamarack Lake
Rainbow Lake
Rock Lake
North Turtle Lake
South Turtle Lake

North Lakeland Discovery Center
Emily Heald
John Heusinkveld

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Onterra LLC
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Will be included in the final phase report (Phase IV).

1.0 INTRODUCTION

Note: This town-wide management plan and individual lake plans will serve as the deliverable for Phase III town-wide project. As additional lakes are studied over the course of the remaining phases, their individual lake plans will be included to this report and the town-wide section will be updated appropriately. Updates from previous phases (e.g. monitoring of curly-leaf pondweed in Harris Lake) will be included in future reports.

The Town of Winchester is located in northwest Vilas County along the Wisconsin-Michigan border, and as of 2010 held a population of 383 residents. This remote area of Vilas County is heavily forested, and contains a number of natural lakes which have seen minimal human development. However, these remote lakes are popular tourist destinations during the summer months, which elevates the risk for the introduction of aquatic invasive species. The discovery of the non-native aquatic plant curly-leaf pondweed in Harris Lake in 2008 incited greater interest in assessing other lakes within the town. In 2013, the Town of Winchester Lakes Committee approached the North Lakeland Discovery Center (NLDC) about conducting surveys for aquatic invasive species as well as baseline studies to assess the health of the town's lakes. Many of these lakes have minimal ecosystem-related data, and a project was initiated in 2015 to collect baseline data and assess the overall health of 12 lakes within the township.

This project was designed to systematically conduct studies on 12 lakes within the township over the course of four years, with two to four lakes being studied each year (Table 1 and Map 1). Developing management plans for subsets of lakes within the town each year allows for financial savings to be realized in overall project costs while creating a manageable process that allows for sufficient attention to be applied to each lakes' needs. This is opposed to completing all plans simultaneously, which would facilitate great cost savings, but only produce generic plans for each lake and the town as a whole. Financial assistance was obtained through the Wisconsin Department of Natural Resources (WDNR) Lake Management Grant Program for each phase of the project.

Beyond the issue of assessing these lakes for aquatic invasive species, the Town of Winchester Lakes Committee wanted to move forward with a town-wide lake management plan in order to ensure the preservation of the town's lakes for future generations. Through the development of a town-wide lake management plan, the town wants to assure that they are working to preserve the lakes as ecosystems, not solely recreational resources. Overall, the Town of Winchester Lakes Committee recognizes the value of gaining a better understanding of their lake ecosystems and their current condition.

This report discusses the study results from the Phase I, II, and III study lakes. These studies included an assessment of each lakes' water quality, watershed, shoreline habitat, and aquatic plant community. Acoustic surveys were also completed on each lake to obtain an up-to-date and accurate bathymetric map. In addition, anonymous stakeholder surveys were distributed to riparian property owners for each lake to gauge stakeholder perceptions and concerns. The results are presented first from a town-wide perspective where the results from each lake are compared to one another. This section is followed by the Town-Wide Implementation Plan, which will include management goals that the Town of Winchester Lakes Committee will use to guide future management actions. The Town-Wide Implementation Plan will be developed in later phases of the project as common challenges all of the lakes share become more evident. Following the town-wide sections, the study results from each lake are discussed in detail within the individual lake sections. Each individual lake section also contains a lake-specific implementation plan which was developed by members of the respective lake's planning committee, Onterra ecologists, and NLDC and WDNR staff.

Table 1.0-1. Town of Winchester Lake Management Planning Project study lakes. The location of these lakes can be found on Map 1.

	Phase I 2015		Phase II 2016			Phase III 2017			Phase IV 2018			
	Harris Lake	Hiawatha Lake	Birch Lake	Tamarack Lake	Rainbow Lake	Rock Lake	North Turtle Lake	South Turtle Lake	Circle Lily Lake	Lake Adelaide	Lake Helen	Pardee Lake
Morphometry												
LakeType	DHDL	DHDL	DLDL	DLDL	DLDL	SLDL	DLDL	DLDL*				
Surface Area (acres)	536	38	528	63	148	126	368	488				
Max Depth (ft)	57	58	52	27	39	20	51	40				
Mean Depth (ft)	24	32	18	7	9	9	21	14				
Perimeter (miles)	5.8	1.4	6.5	1.7	3.5	3.9	5.6	7.7				
Shoreline Complexity	3.2	2.6	4.1	2.1	4.0	6.0	4.4	6.1				
Watershed Area (acres)	2,348	819	4,178	5,109	6,731	3,624	12,901	15,356				
Watershed to Lake Area Ratio	3:1	21:1	7:1	77:1	43:1	28:1	34:1	4:1				
Water Quality												
Trophic State	OM	M	M	ME	ME	E	M	E				
Limiting Nutrient	P	P	P	P	P	P	P	P				
Avg Summer TP (µg/L)	12	17	19	32	24	26	16	22				
Avg Summer Chl-α (µg/L)	2.4	4.6	5.4	5.6	10.3	12	5	9				
Avg Summer Secchi Depth (ft)	16.1	5.7	7.8	5.9	6.6	5.7	8.4	7.4				
Summer pH	8.1	7.2	7.7	7.3	7.5	7.6	7.6	7.7				
Alkalinity (mg/L as $CaCO_3$)	39	15	37	32	30	31	30	36				
Aquatic Vegetation												
Number of Native Species	56	26	37	32	45	42	35	39				
NHI-Listed Species	UTR	None	None	None	PVA	PVA	PVA	PVA				
Exotic Species	CLP	None	None	None	None	PYI	PYI	PYI				
Average Conservatism	7.0	7.2	7.1	7.3	7.2	6.9	6.8	6.6				
Floristic Quality	44.3	25.8	31.8	34.1	40.7	35.6	27.0	32.8				
Simpson's Diversity (1-D)	0.91	0.87	0.80	0.83	0.93	0.92	0.86	0.90				

DHDL = Deep Headwater Drainage Lake
SLDL = Shallow Lowland Drainage Lake
DLDL = Deep Lowland Drainage Lake
OM = Oligo-mesotrophic
M = Mesotrophic
E = Eutrophic
ME = Meso-eutrophic

TP = Total Phosphorus
Chl-α = Chlorophyll-α
NHI = WDNR Natural Heritage Inventory
UTR = Northeastern bladderwort (Utricularia resupinata)
CLP = Curly-leaf pondweed (Potamogeton crispus)
PVA = Vasey's pondweed (Potamogeton vaseyi)
PYI = Pale-yellow iris (Iris pseudacorus)
** = Treated as a DHDL; see individual water quality 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, the completion of stakeholder surveys, and updates within the lake group's newsletter and/or website. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

Project Planning Process

Kick-off Meetings

Project Kick-off Meetings were held for each phase to introduce the management planning project to the general public. The Kick-off Meetings for the Phase I and II lakes were held at the Town of Winchester Town Hall on June 20, 2015 and June 25, 2016, respectively. The Kick-off Meeting for the Phase III lakes was held at the Winchester Public Library on May 20, 2017. The attendees observed a presentation by an Onterra ecologist which started with an educational component regarding general lake ecology and ended with a detailed description of the Town of Winchester project including opportunities for stakeholder involvement. The presentation was followed by a questions and answer session.

Stakeholder Survey

During each phase of the project, a 29-question web-based survey was provided to lake property owners around each lake. The data from the returned surveys were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full results from each stakeholder survey can be found in Appendix B, while applicable survey results are discussed within the results sections of the report.

Planning Committee Meetings

Planning meetings were conducted periodically during the town-wide study, with meetings being held that focus upon the lakes involved during each phase of the project. During these meetings, Onterra lakes ecologist Brenton Butterfield met with representatives from each lake during each phase. During these meetings, Mr. Butterfield presented the study results from the lakes for each respective phase. All project components including water quality analyses, watershed assessments, shoreland assessments, and aquatic plant surveys were presented and discussed in detail. During these planning meetings, Onterra and NLDC staff worked with the planning committee for each lake to develop the framework for the Implementation Plan. This included the development of management goals that the Town of Winchester would implement to continue the protection and enhancement of the town's lakes.

Project Wrap-up Meetings

A project Wrap-up Meeting for the Phase I lakes was held at the Winchester Public Library on May 20, 2017. At this meeting, Onterra ecologist Brenton Butterfield presented the study results from the Phase I lakes along, the management goals and actions that were developed as part of their Implementation Plans, and the current status of the multi-phased project and how it is moving forward. The Wrap-up Meeting for the Phase II lakes was completed on May 19, 2018. The wrap-up meeting for the Phase III lakes is scheduled for June 29, 2019.

Management Plan Review and Adoption Process

Prior to the first Planning Committee Meeting for each lake, the result sections (both Town-Wide and Individual Lake) were sent to all planning committee members for their review and preparation for the meeting. Following discussions at the planning meetings, Onterra staff drafted the Implementation Plan and sent it to the Planning Committee for their review. Their comments were integrated into the plan, and the first official draft of the Phase I management plan was sent to the WDNR for review in December 2016. The WDNR provided comments on the report, and the final Phase I report was created in February 2017. The final version of the Phase II report was created in April of 2018. The first official draft of the Phase III project was provided to the WDNR during June 2019.

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 Town of Winchester Lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the Southeast Wisconsin Till Plains ecoregion (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 Town of Winchester lakes' 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 phytoplankton 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 phytoplankton 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 widely used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are almost always correlated with one another. In most instances, phosphorus controls phytoplankton abundance, and when phosphorus concentrations increase, so do chlorophyll-*a* concentrations. As phytoplankton abundance (and chlorophyll-*a* concentrations) increase, water clarity measured by Secchi disk transparency declines. Secchi disk transparency is directly affected by the suspended particulates within the water. In the majority of Wisconsin lakes, the primary source of these suspended particulates is phytoplankton, and the abundance of phytoplankton directly affects water clarity. In addition, studies have shown that water clarity is the parameter the majority of lake users use to judge a lake's water quality (Canter et al. 1994, Dinius 2007, and Smith et al. 1991).

Trophic State

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

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

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a 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 phytoplankton 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 phytoplankton. 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

Lake stratification occurs when temperature and density gradients are developed with depth in a lake. During stratification, the lake can be broken into three layers: The *epilimnion* is the surface layer with the lowest density and has the warmest water in the summer months and the coolest water in the winter months. The *hypolimnion* is the bottom layer the highest density and has the coolest water in the summer months and the warmest water in the winter months. The *metalimnion*, often called the thermocline, is the layer between the epilimnion and hypolimnion where temperature changes most rapidly with depth.

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 may periodically transition between periods of stratification and mixing.

Dissolved oxygen is essential in the metabolism of nearly every organism that exists within a lake. For instance, fishkills are often the result of insufficient amounts of dissolved oxygen. However, dissolved oxygen's role in lake management extends beyond this basic need by living organisms. In fact, its presence or absence impacts many chemical process that occur within a lake, including one process termed internal nutrient loading which is discussed 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 phytoplankton and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can 'pump' phosphorus from the sediments to the water column throughout the growing season. In lakes that mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season phytoplankton blooms and even last through the winter to support early algae blooms the following spring.

Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add large loads of phosphorus to the water column during spring turnover that may support phytoplankton blooms long into the summer. This cycle continues year after year and is termed *internal nutrient loading*, a phenomenon that can support nuisance phytoplankton blooms decades after external sources of phosphorus are controlled. The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of Town of Winchester project lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into ten natural communities (Figure 3.1-1).

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

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

The eight lakes studied to date in the Phase I – III lakes fall within one of three classifications: deep headwater drainage lakes, shallow lowland drainage lakes, or deep lowland drainage lakes (Table 3.1-1). Harris and Hiawatha lakes are classified as deep headwater drainage lakes, Birch, Tamarack, Rainbow, North Turtle, and South Turtle lakes are classified as deep lowland drainage lakes, and Rock Lake is classified as a shallow lowland drainage lake. However, as is discussed in more detail in the South Turtle Lake Individual Report Section (Section 8.8), it is believed that South Turtle Lake functions more like a deep headwater drainage lake. For this reason, the water quality from South Turtle Lake is compared against other deep headwater drainage lakes in Wisconsin. The water quality of the other lakes are compared to their respective lake classification.

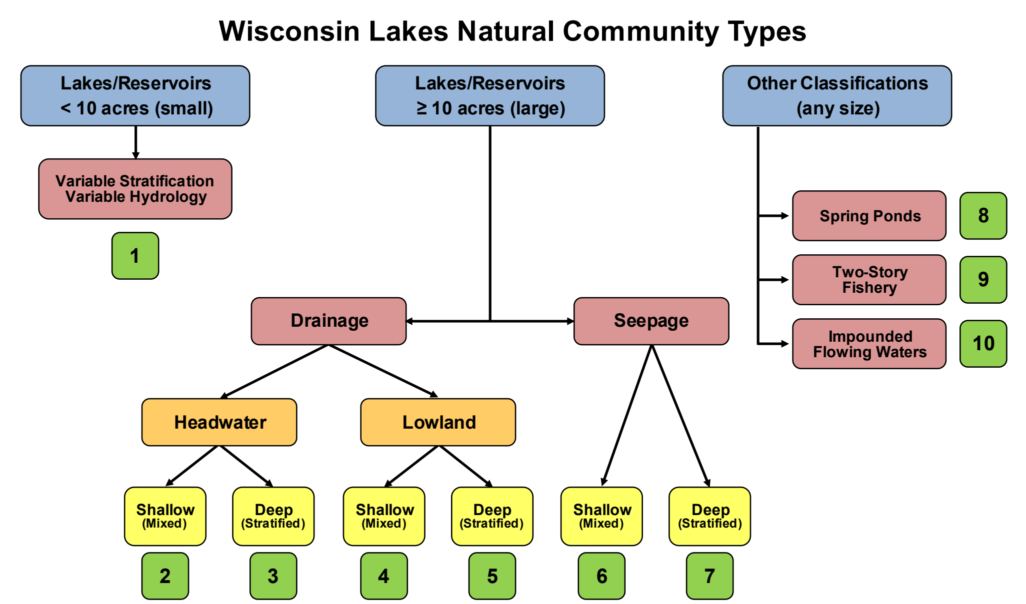

Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

Table 3.1-1. Community classification of project lakes within the Town of Winchester. Created using equations from WDNR 2013A.

Project Phase	Lake	Lake Classification
Phase I	Harris Lake	Deep Headwater Drainage
	Hiawatha Lake	Deep Headwater Drainage
Phase II	Birch Lake	Deep Lowland Drainage
	Rainbow Lake	Deep Lowland Drainage
	Tamarack Lake	Deep Lowland Drainage
Phase III	North Turtle Lake	Deep Lowland Drainage (Two-Story)
	South Turtle Lake	Deep Lowland Drainage
	Rock Lake	Shallow Lowland Drainage
Phase IV	Circle Lily Lake	*Available in Phase IV*
	Lake Adelaide	*Available in Phase IV*
	Lake Helen	*Available in Phase IV*
	Pardee Lake	*Available in Phase IV*

Garrison, et. al (2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the ten lake classifications. While 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 Town of Winchester and its lakes fall within the Northern Lakes and Forests (NLF) ecoregion, and the water quality of the town's lakes will be compared to other lakes within the NLF ecoregion. (Figure 3.1-2).

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

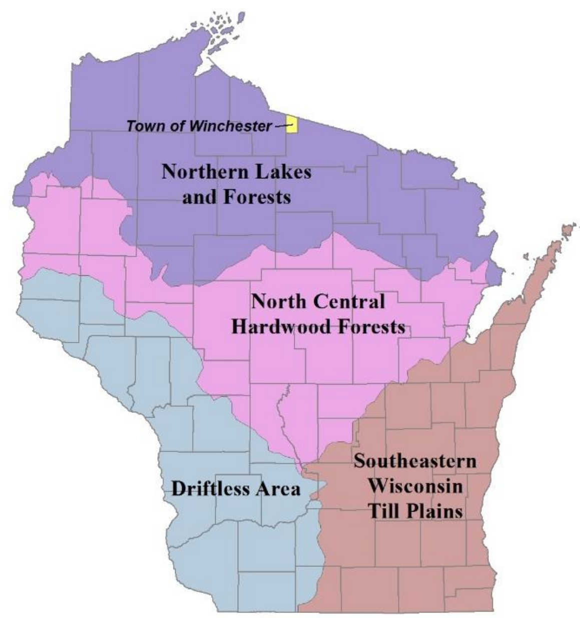

Figure 3.1-2. Location of the Town of Winchester within the ecoregions of Wisconsin. After Nichols 1999.

Water quality data from the Town of Winchester project lakes is 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.

Town of Winchester Lakes Water Quality Analysis

Town of Winchester Lakes Nutrients, Phytoplankton, and Water Clarity

This draft of the Town of Winchester Comprehensive Lake Management Plan contains water quality data from the Phase I, II, and III project lakes. Monitoring occurred during the summer and winter of each respective phase. The Phase IV lakes are scheduled to be sampled in 2018/19. The individual lake sections provide in-depth discussions of each respective lake's water quality. The data presented in this section will serve to compare the lakes within the township. While these lakes are in close proximity to one another, their morphology and watershed size/composition differ which results in variations in water quality. These differences in water quality in turn lead to differences in each lakes' flora and fauna. Within this section, the lakes' total phosphorus concentrations, chlorophyll-*a* concentrations, and water clarity are compared.

Total Phosphorus

As discussed previously, phosphorus is the primary nutrient controlling the growth of 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. Using mid-summer total phosphorus and total nitrogen concentrations from the Town of Winchester project lakes indicates that all eight lakes studied to date are phosphorus-limited (Figure 3.1-3). The mid-summer nitrogen to phosphorus ratios ranged from 48:1 in Hiawatha Lake to 23:1 in South Turtle Lake. These ratios indicate that all eight of these lakes are phosphorus-limited, and that increases in phosphorus inputs would likely result in increased phytoplankton production.

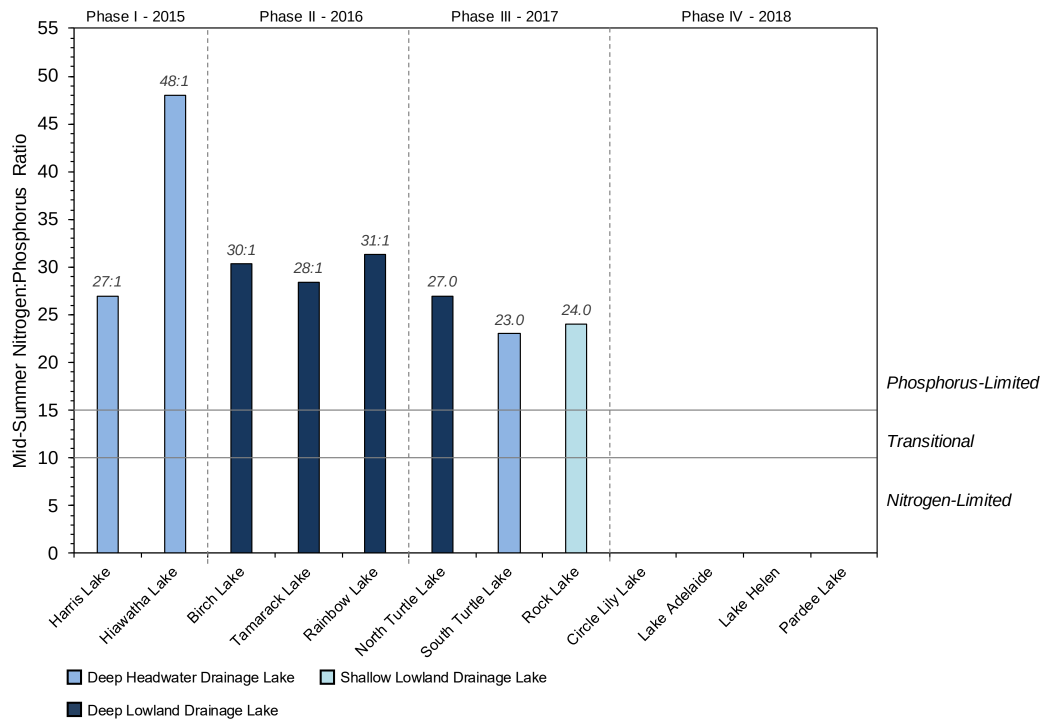

Figure 3.1-3. Town of Winchester project lakes mid-summer total nitrogen to total phosphorus ratios. Data represent surface samples collected during mid-summer during each respective project phase.

The average summer near-surface total phosphorus concentration was calculated for each lake using data collected as part of this project along with any available historical data. Near-surface summer total phosphorus concentrations ranged from 12.2 µg/L in Harris Lake to 32.2 in Tamarack Lake (Figure 3.1-4). In general, more voluminous (deep) lakes with smaller watersheds (headwater) tend to have naturally lower phosphorus concentrations as they receive lesser amounts of phosphorus from their watersheds and they are better able to dilute incoming phosphorus. In contrast, lakes that are less voluminous (shallow) with larger watersheds (lowland) tend to have naturally higher phosphorus concentrations as they receive higher amounts of phosphorus from the watershed and are less able to dilute incoming phosphorus. As illustrated in Figure 3.1-3, the median phosphorus concentration for deep headwater drainage lakes in Wisconsin is 17 µg/L compared to 33 µg/L for shallow lowland drainage lakes.

Pearson correlation analysis indicated that the best predictor of average summer total phosphorus concentrations in the Winchester project lakes is the watershed area to lake volume ratio (Figure 3.1-5). This analysis shows that phosphorus concentrations tend to be higher in lakes which have a higher watershed area to lake volume ratio, or lakes that have greater watershed acreage relative to lake volume. Harris Lake, which has the lowest measured phosphorus concentrations, also has the lowest watershed area to lake volume ratio. In contrast, Tamarack Lake which had the highest phosphorus concentrations also has the highest watershed are to lake volume ratio. In other words, Harris Lake has approximately 0.2 acres of watershed draining to every acre-foot of water while

Tamarack Lake has approximately 11 acres of watershed draining to every acre-foot of water. The influence of these lakes' watersheds on water quality is discussed further within the Watershed Assessment Section (section 3.2).

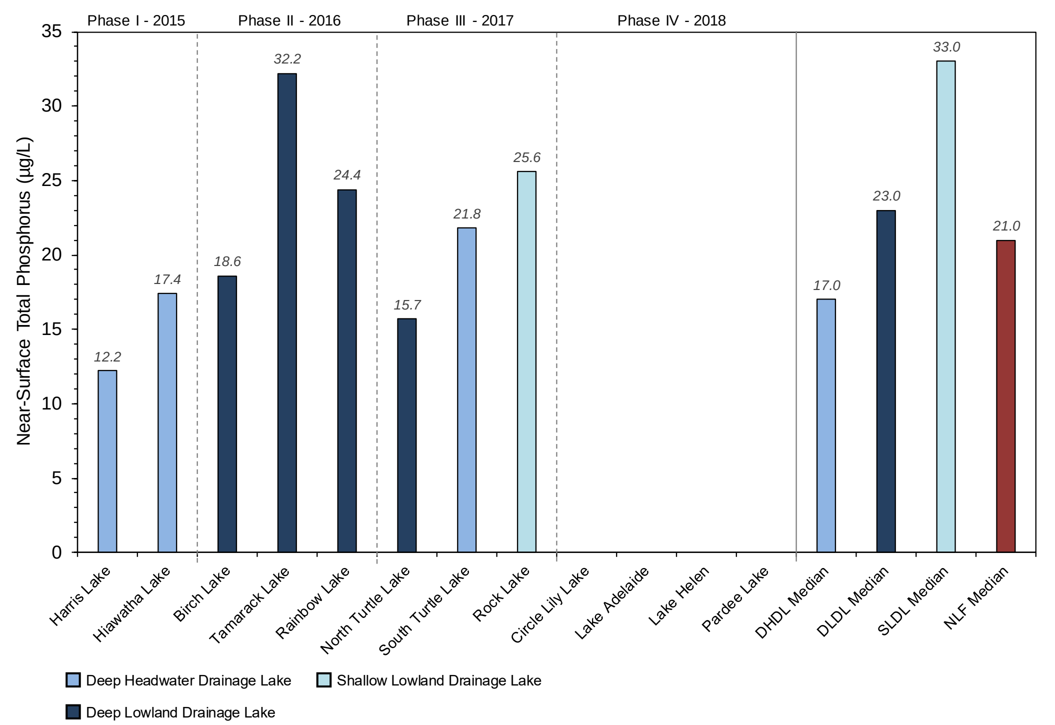

Figure 3.1-4. Town of Winchester project lakes summer average near-surface total phosphorus concentrations and median summer near-surface total phosphorus concentrations from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; SLDL = Shallow Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion Lakes.

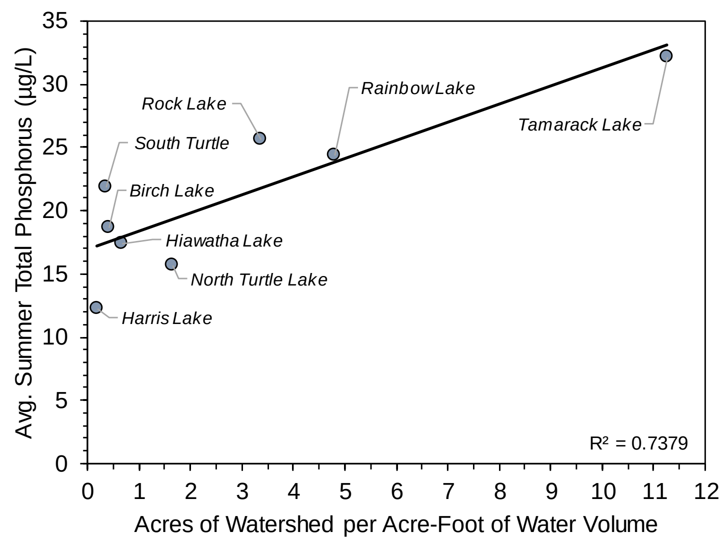

Figure 3.1-5. Town of Winchester project lakes average summer total phosphorus plotted against acres of watershed per acre-foot of water volume.

Chlorophyll-α

Summer average chlorophyll-*a* concentrations measured within the eight Phase I, II, and III project lakes ranged from 2.4 µg/L in Harris Lake to 11.8 µg/L in Rainbow Lake (Figure 3.1-6). Chlorophyll-*a* concentrations for all eight lakes are considered to be *excellent* to *good* for their respective lake type, and no lakes were found to have concentrations approaching 20 µg/L, the concentration which is considered to create *nuisance algal blooms*.

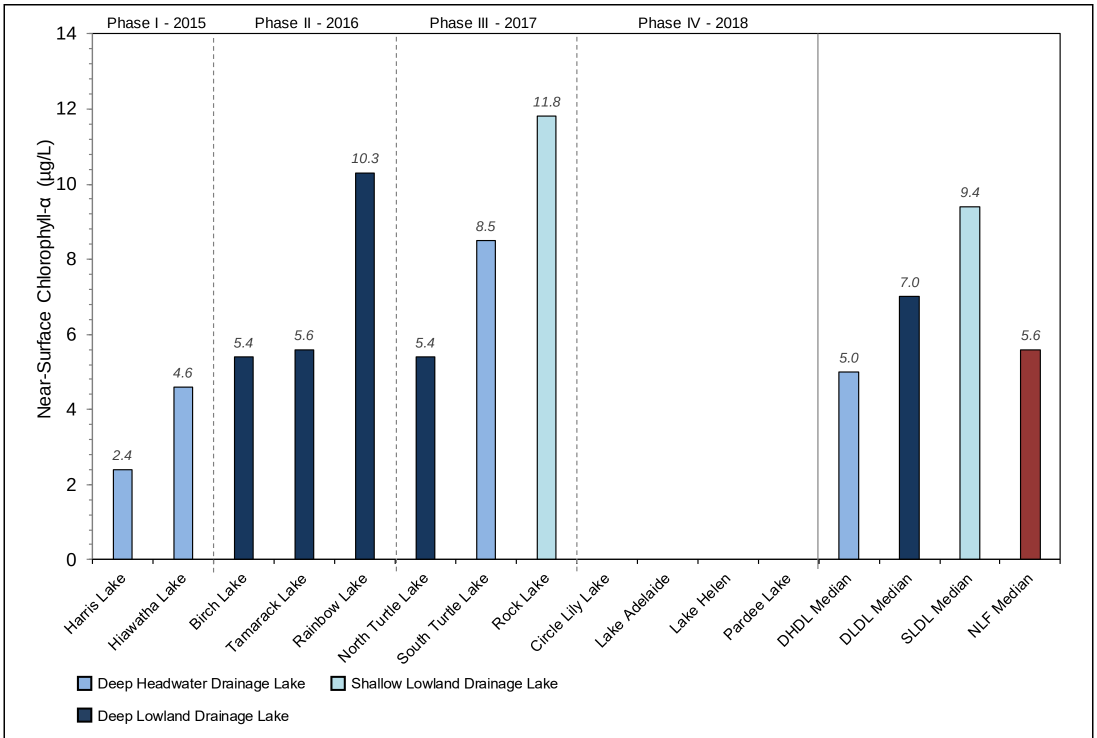

Figure 3.1-6. Town of Winchester project lakes summer average chlorophyll-α concentrations and median summer chlorophyll-α concentrations from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; SLDL = Shallow Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion Lakes.

As discussed previously, all eight lakes were found to be phosphorus-limited, meaning that algal production is going to be regulated largely by phosphorus availability. Figure 3.1-7 illustrates that average chlorophyll-*a* concentrations were positively correlated with average summer phosphorus concentrations, with the exception of Tamarack Lake. Tamarack Lake had an average summer phosphorus concentration of 32 µg/L, and based on the relationship between phosphorus and chlorophyll-*a* in the other seven lakes, Tamarack Lake was predicted to have a chlorophyll-*a* concentration of 16 µg/L. However, the measured average summer chlorophyll-*a* concentration in Tamarack Lake was considerably lower at 5.6 µg/L. It is not clear why algal production in Tamarack Lake is lower than expected, but it could be related to the lake's high aquatic plant abundance and/or food web dynamics.

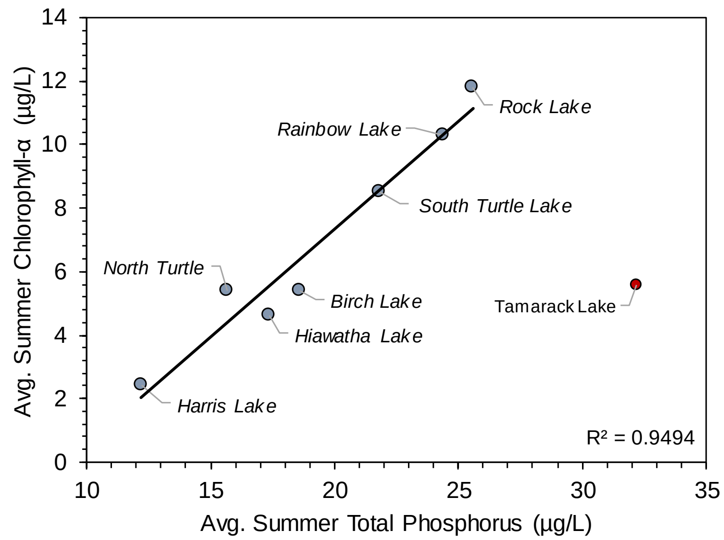

Figure 3.1-7. Town of Winchester project lakes average summer chlorophyll-α concentrations plotted against average summer total phosphorus concentrations. Phosphorus is a good predictor of chlorophyll in all project lakes except Tamarack Lake. It is not clear why algal production in Tamarack is lower despite higher concentrations of phosphorus.

Water Clarity

Average summer Secchi disk depth measured within the eight Phase I, II, and III study lakes ranged from 5.7 feet in Hiawatha and Rock lakes to 16.1 in Harris Lake (Figure 3.1-8). These Secchi disk values fall within the *excellent* to *good* categories for their respective lake types. While the amount of algae within the water largely regulates water clarity in Wisconsin's lakes, analysis of the data from the Winchester lakes indicates that chlorophyll concentrations explain only 50% of the variation in water clarity among these lakes. This is an indication that another factor(s) other than algal levels is influencing water clarity in the Winchester lakes.

As discussed previously, water clarity in Wisconsin's lakes is primarily influenced by suspended particulates within the water, mainly phytoplankton. Abiotic suspended particulates, such as sediment, can also affect water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water were near or below the limit of detection in all of the project lakes indicating minimal amounts of suspended material within the water.

Apart from suspended material within the water, water clarity in Wisconsin's lakes, particularly in northern Wisconsin, can also be affected by dissolved compounds within the water. Many lakes in northern Wisconsin contain higher concentrations of dissolved humic substances and organic acids that originate from decomposing plant material within wetlands and coniferous forests in the lakes' watersheds. In higher concentrations, these dissolved compounds give the water a brown or tea-like color, decreasing water clarity. In addition, the underlying geology of northern Wisconsin is largely low in calcium, and lower concentrations of calcium within the water inhibit the breakdown of these organic compounds by bacteria allowing concentrations to be higher (Cole and Weihe 2016).

A measure of water clarity, once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and indicates the level of dissolved material within the water. Average true color values measured from the five Phase I and II lakes ranged from 30 SU (standard units), or *lightly tea-colored* in Harris Lake to 175 SU, or *highly tea-colored* in Hiawatha Lake (Figure 3.1-9). Birch, Tamarack, Rainbow, North Turtle, and Rock Lake had similar true color values ranging from 60-70 SU, while true color in South Turtle Lake was slightly lower at 40 SU.

When the true color data from the Winchester lakes was taken into account along with chlorophyll-*a* concentrations, these two variables explained 87% of the variation in water clarity between the lakes (Figure 3.1-10). In other words, phytoplankton production and dissolved organic compounds are the most significant factors influencing water clarity in these lakes. Lakes with low chlorophyll-*a* and true color (i.e. Harris Lake) had the highest water clarity, while lakes with higher chlorophyll-*a* and true color (i.e. Rock Lake) had the lowest water clarity. Like total phosphorus concentrations, the differences in true color values between these lakes is a result of a combination of each lake's morphometry and watershed size/composition. The lakes with higher true color values receive a larger proportion of surface water which has passed through wetlands within their watersheds. While the water clarity is lower as a result of these dissolved compounds, the origin of these compounds is natural and are not an indication of degraded water quality.

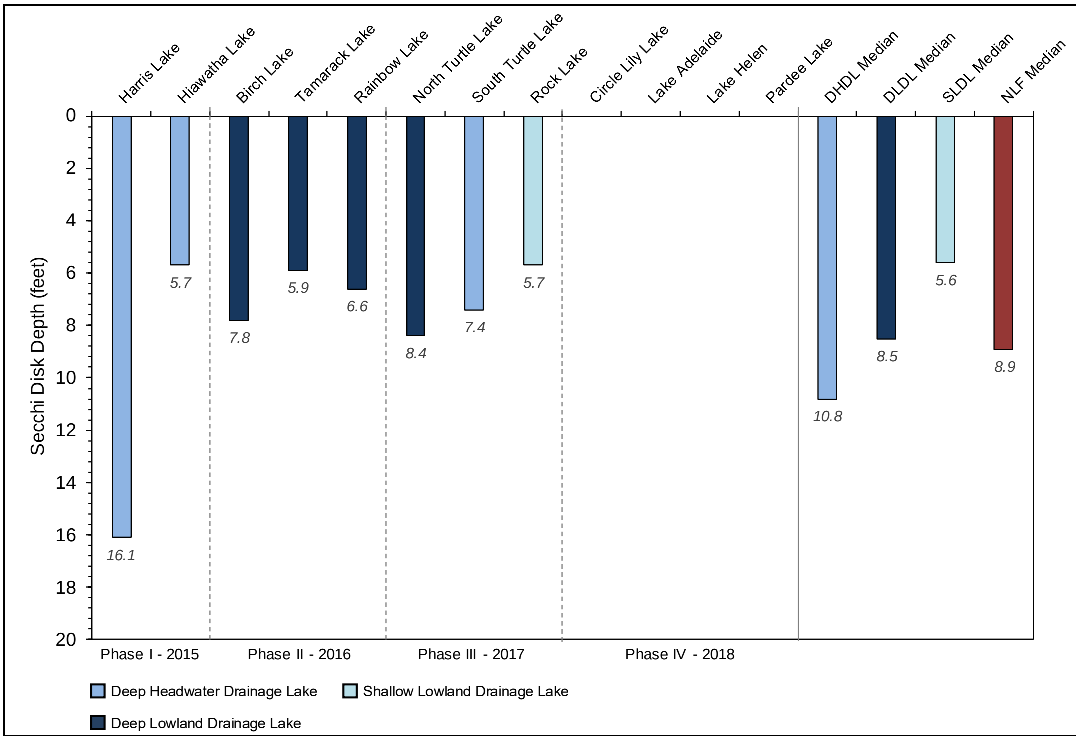

Figure 3.1-8. Town of Winchester project lakes summer average Secchi disk transparency and median summer Secchi disk transparency from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; SLDL = Shallow Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion Lakes.

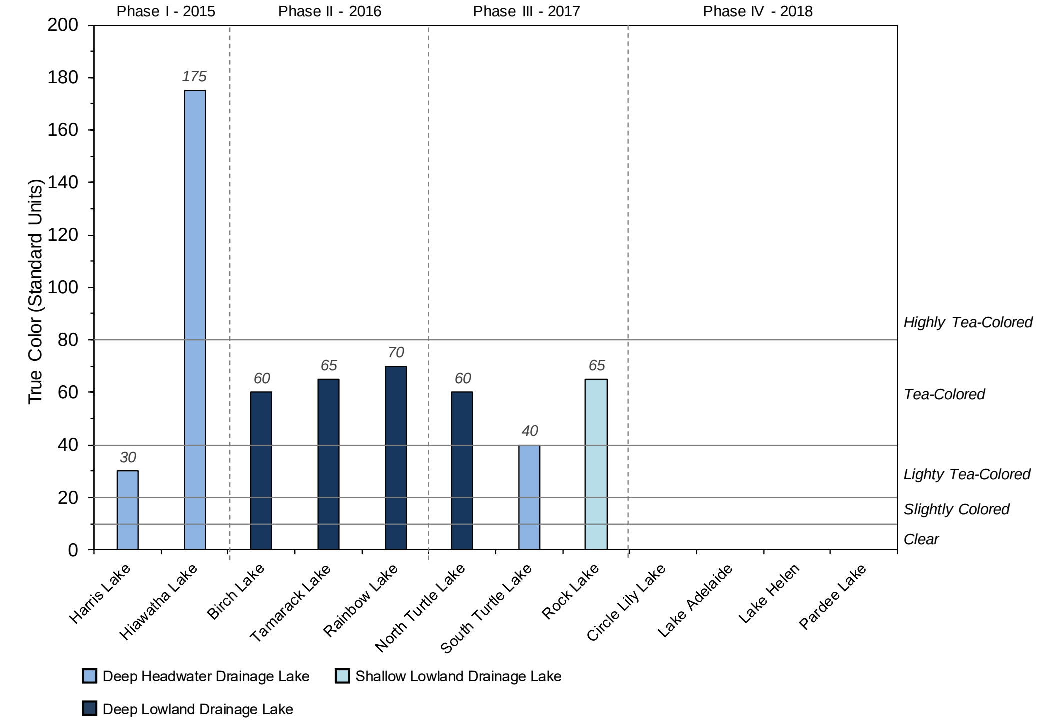

Figure 3.1-9. Town of Winchester project lakes average growing season true color values. Samples collected from the near-surface. Color range adapted from UNH Center for Freshwater Biology (2014).

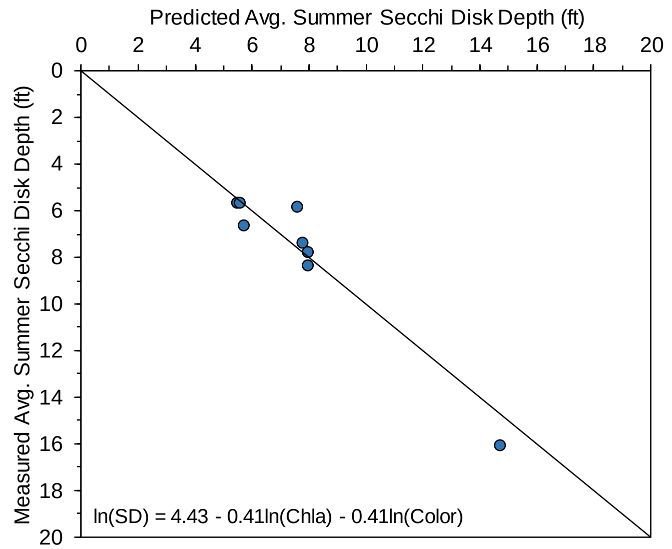

Figure 3.1-10. Town of Winchester project lakes predicted Secchi disk depth using chlorophyll and true color versus measured Secchi disk depth. Chlorophyll and true color explained 87% of the variation in water clarity among the Winchester project lakes.

Town of Winchester Lakes Trophic State

Figure 3.1-11 contains the weighted average Trophic State Index (TSI) values for each of the Town of Winchester 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 closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

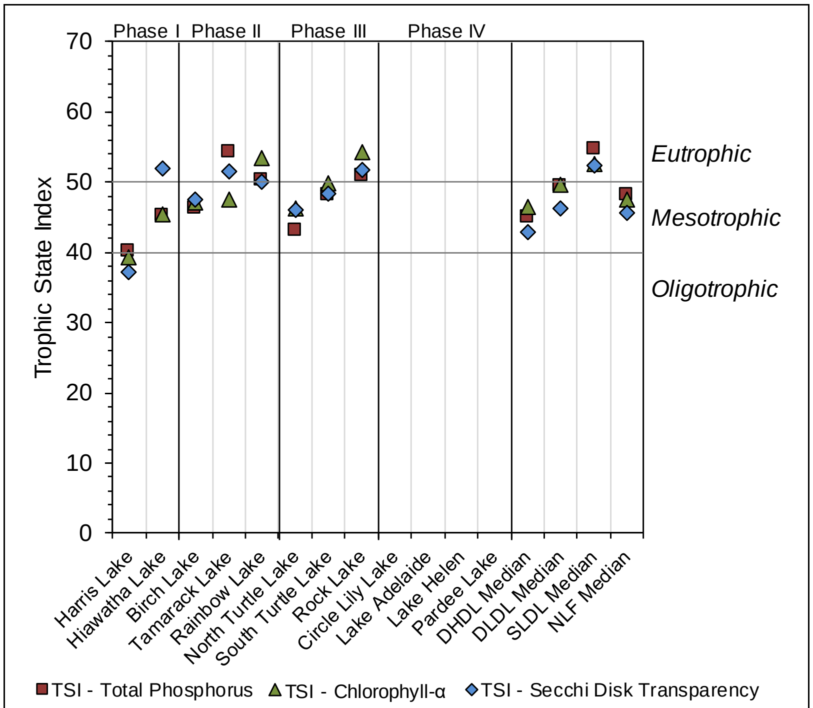

Figure 3.1-11. Town of Winchester project lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193. DHDL = Deep Headwater Drainage Lake; DLDL = Deep Lowland Drainage Lake; SLDL = Shallow Lowland Drainage Lake; NLF = Northern Lakes and Forests Ecoregion.

The weighted TSI values for total phosphorus and chlorophyll-*a* in the eight Phase I, II, and III project lakes indicate these lakes range in productivity from oligo-mesotrophic to lower eutrophic. Harris Lake is oligo-mesotrophic, Hiawatha, Birch, North Turtle, and South Turtle lakes are mesotrophic, and Tamarack, Rainbow, and Rock lakes are lower eutrophic. It should be noted that Tamarack, Rainbow, and Rock lakes were likely naturally eutrophic prior to Euro-American settlement, and their current eutrophic status is not believed to be due to human activity (cultural eutrophication).

Additional Water Quality Data Collected on the Town of Winchester Lakes

The previous sections were largely focused on lake eutrophication. However, parameters other than nutrients, chlorophyll-*a*, and water clarity were collected as part of the project. These other parameters were collected to increase the understanding of the Town of Winchester 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 variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology within the lake's surficial and groundwatershed. On a smaller scale within a lake or between similar lakes, photosynthesis by phytoplankton and macrophytes can impact pH because the process uses dissolved carbon dioxide, which forms carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. In the Phase I, II, and III project lakes, summer near-surface pH values ranged from 7.2 in Hiawatha Lake to 8.1 in Harris Lake indicating the pH of all the project lakes are slightly alkaline (Figure 3.1-12). The pH values of the Winchester lakes fall within the normal range for Wisconsin's lakes.

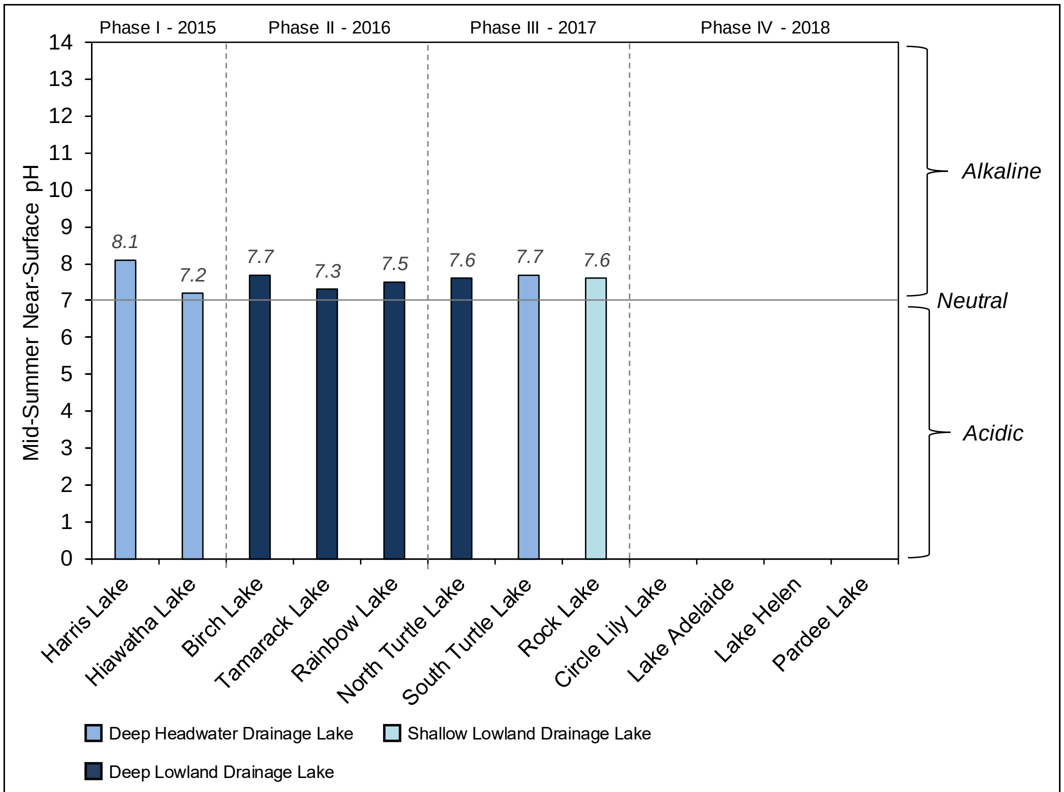

Figure 3.1-12. Town of Winchester project lakes mid-summer near-surface pH values. Data for each lake collected during the respective project phase.

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 due to their inability to buffer against acid inputs. Within the Phase I, II, and III project lakes, alkalinity ranged from 14.6 mg/L as $CaCO_3$ in Hiawatha Lake to 38.7 mg/L as $CaCO_3$ in Harris Lake (Figure 3.1-13). Given the alkalinity in these five lakes, none are sensitive to inputs from acid rain.

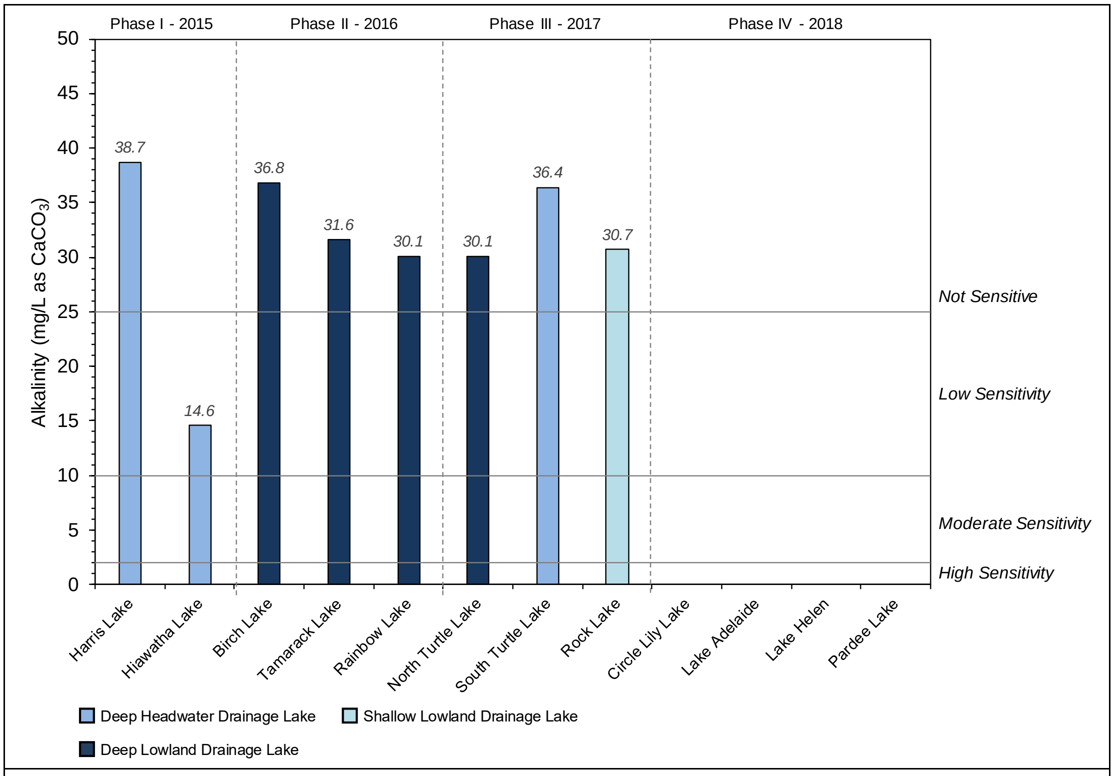

Figure 3.1-13. Town of Winchester project lakes average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and the pH of the Phase I and II 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 Phase I, II, and III project lakes ranged from 6.1 mg/L in Hiawatha Lake to 12.2 mg/L in Harris Lake (Figure 3.1-14). Calcium concentrations in Harris Lake fall within the *low susceptibility* category for zebra mussel establishment, while calcium concentrations in the remaining seven lakes fall within the *very low susceptibility* category. The calcium concentrations in these lakes indicate zebra mussels have a low probability of establishment if they were to be accidentally introduced.

Within each project lake, Onterra ecologists collected three plankton tows from three different locations that underwent analysis to check for the presence of zebra mussel veligers, the planktonic larval stage of the zebra mussel. Analysis of these samples were negative for the presence of zebra mussel veligers in all lakes studied to date, and no adult zebra mussels were observed during any of the surveys. It is believed that zebra mussels are currently not present in any of the Phase I, II, or III study lakes.

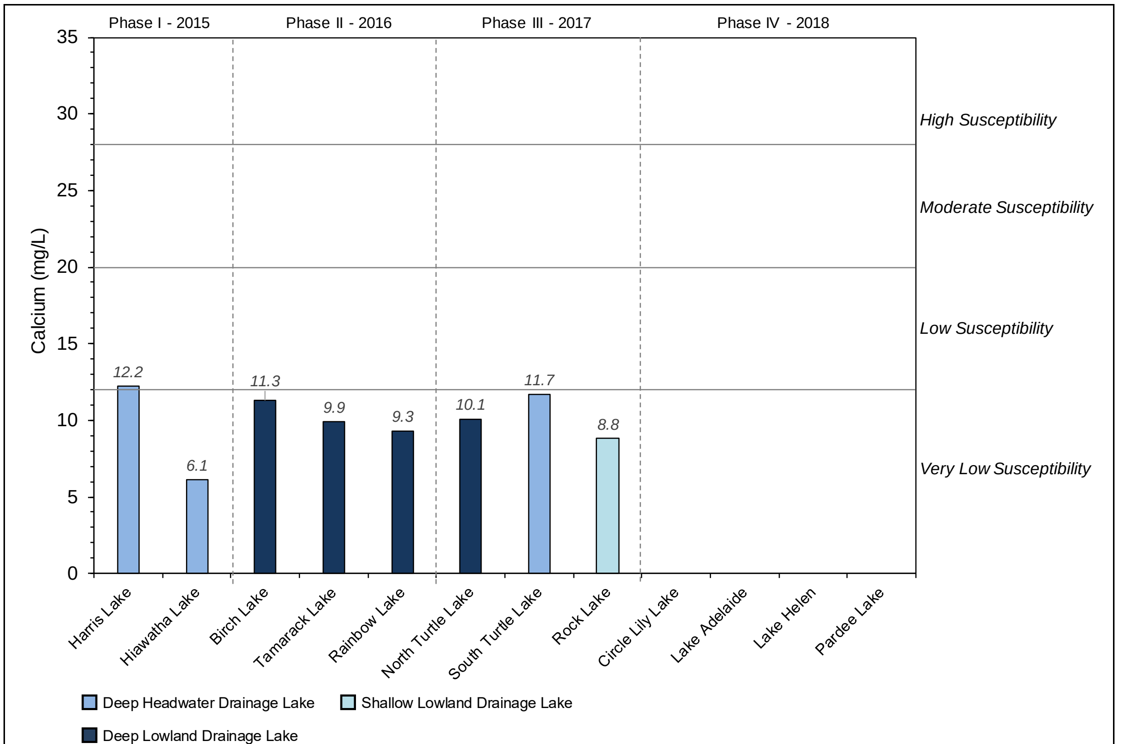

Figure 3.1-14. Town of Winchester project lakes average growing season calcium concentrations and susceptibility to zebra mussel establishment. Samples collected from the near-surface.

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 produce less surface runoff. On the other hand, agricultural areas, particularly row crops and 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 phytoplankton blooms, increased sedimentation, and/or overabundant macrophyte populations.

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

In systems with high WS:LA ratios, like those 10-15:1 or higher, the impact of land cover may be tempered by the sheer amount of land draining to the lake. Situations actually occur where lakes with completely forested watersheds have sufficient phosphorus loads to support high rates of plant production. In other systems with high ratios, the conversion of vast areas of row crops to vegetated areas (grasslands, meadows, forests, etc.) may not reduce phosphorus loads sufficiently to see a change in primary 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 – Panuska, 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface.

WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the potential impact of shoreland septic systems.

Town of Winchester Lakes Watershed Assessment

As is discussed within the Lake Water Quality Section (section 3.1), the differences in water quality among the Phase I, II, and III project lakes are largely the result of differences in lake morphometry (water volume) and watershed size. The watershed sizes among these eight project lakes range in size of 819 acres for Hiawatha Lake to 12,901 acres for North Turtle Lake (Figure 3.2-1). The watershed area to lake area ratios range from 3:1 in Harris Lake to 77:1 in Tamarack Lake (Figure 3.2-1). The majority of the land cover within the Winchester lakes' watersheds is forests and wetlands, while smaller portions are comprised of pasture/grass, rural residential areas, and the surfaces of the lakes (Figure 3.2-2). No agricultural land or urban areas are located within the watersheds of these lakes. Maintaining the natural land cover found within the watersheds of these lakes will ensure preservation of their water quality.

Watershed modeling indicated that the estimated annual phosphorus loading delivered to these lakes varies widely, ranging from 76 lbs/year in Hiawatha Lake to 1,011 lbs/year in North Turtle Lake (Figure 3.2-4). However, as discussed, lake size and volume also have to be taken into consideration when discussing phosphorus loading. Using the estimated annual phosphorus loads and the estimated volume of each lake, the annual phosphorus load per acre-foot of lake was calculated (Figure 3.2-5). This analysis shows, for example, that while Birch Lake receives an estimated 474 lbs more phosphorus per year than Hiawatha Lake, the phosphorus loading relative to each respective lakes' volume is the same at 0.06 lbs/acre-feet/year. Despite differences in watershed size, the phosphorus loading relative to lake volume is similar between these two lakes and thus their phosphorus concentrations within the lake are relatively similar. Annual phosphorus loading per acre-feet ranged from 0.02 lbs/acre-feet/year in Harris Lake to 1.16 lbs/acre-foot/year in Tamarack Lake.

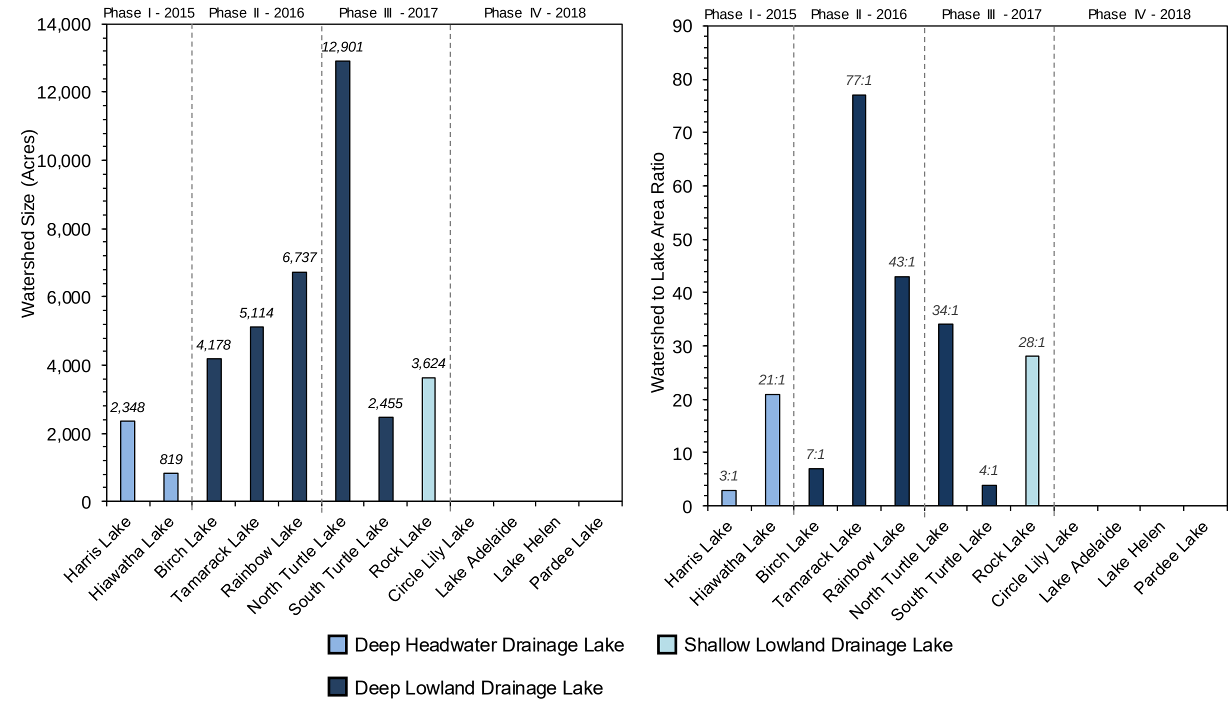

Figure 3.2-1. Town of Winchester lakes watershed size (left) and watershed to lake area ratios (right). Maps displaying watershed boundaries can be found within the individual lake report sections.

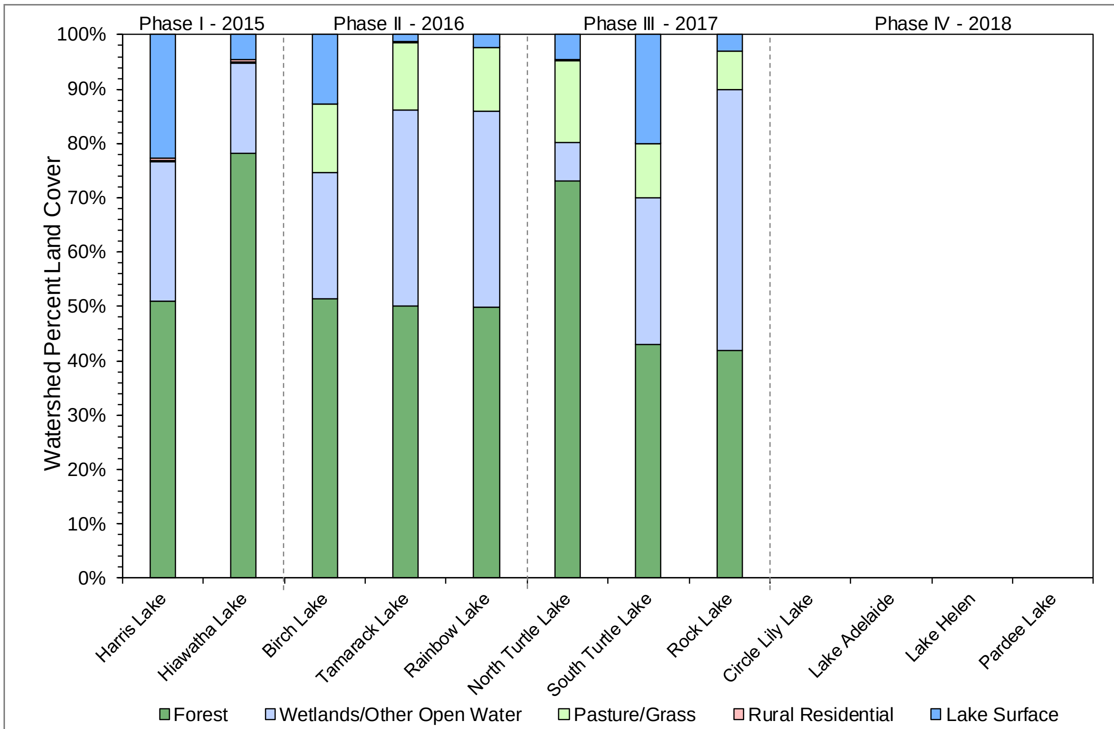

Figure 3.2-2. Town of Winchester lakes watershed land cover composition. Maps displaying watershed boundaries can be found within the individual lake report sections.

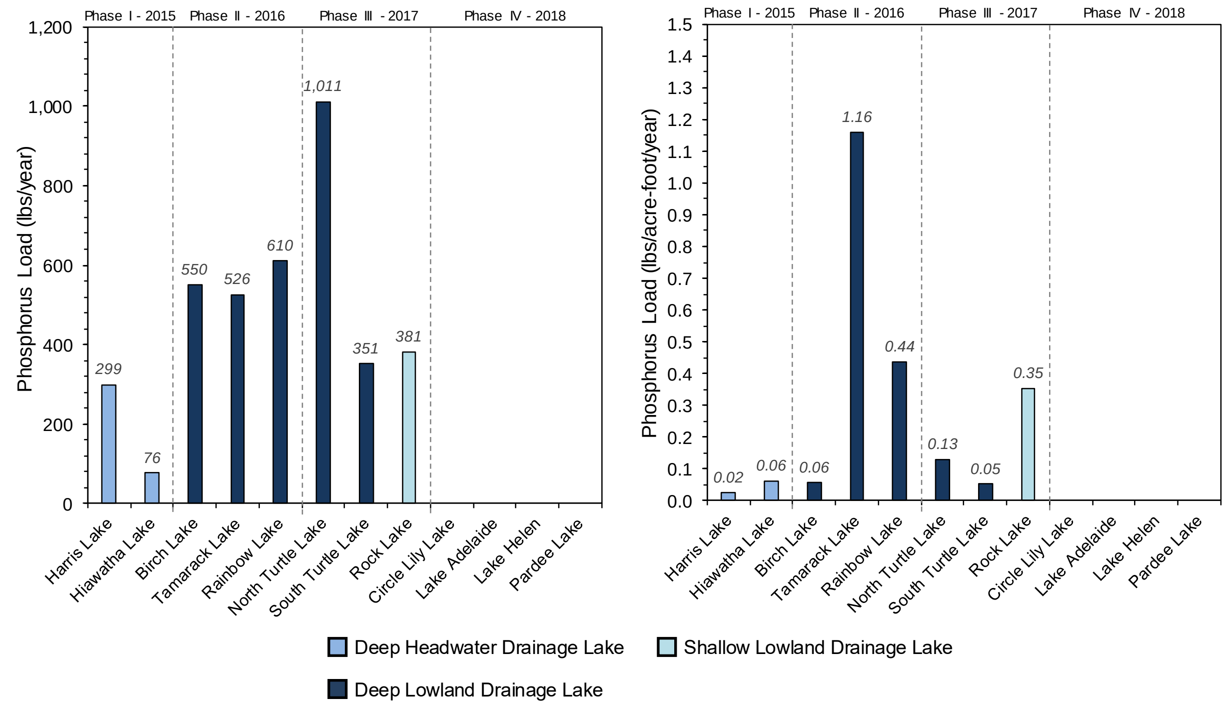

Figure 3.2-3. Town of Winchester lakes WiLMS estimated annual phosphorus loading in pounds (right) and calculated annual phosphorus loading in pounds/acre-feet/year. Maps displaying watershed boundaries can be found within the individual lake report sections.

In addition to estimating the annual amount of phosphorus delivered to each lake, WiLMS also provides a predicted growing season total phosphorus concentration for each lake. The predicted phosphorus concentrations are compared against measured concentrations collected from each lake. If the measured phosphorus concentrations are higher than the model predictions, it is an indication that phosphorus may be entering the lake from a source that was unaccounted for within the model. If the measured and predicted phosphorus concentrations are relatively similar, it is an indication that the watershed was modeled accurately and there are likely no significant sources of unaccounted phosphorus entering the lake.

Figure 3.2-4 displays the measured growing season (April-October) near-surface total phosphorus concentrations compared to WiLMS predicted concentrations from the Phase I, II, and III project lakes. Measured and predicted phosphorus concentrations were relatively similar in all lakes within the exception of Tamarack Lake. Measured total phosphorus concentrations in Tamarack Lake were approximately 37% higher than the concentration predicted by WiLMS, indicating that approximately 200 lbs of phosphorus is being loaded to Tamarack Lake on an annual basis that was not accounted for within the model.

As mentioned within the Lake Water Quality Section (section 3.1), when measured phosphorus concentrations are higher than predicted in a lake which has a watershed largely comprised of natural land cover, internal nutrient loading is often the source of the unaccounted phosphorus. Internal nutrient loading involves the release of phosphorus (and other nutrients) from anoxic bottom sediments into the overlying water. Measured dissolved oxygen in 2016 showed that Tamarack Lake develops anoxia in bottom waters in summer; however, phosphorus concentrations measured in near-bottom waters were only slightly higher than those measured at the surface indicating internal nutrient loading does not appear to be a significant source of phosphorus to the lake. In addition, no mixing events occurred during summer of 2016 that would mobilize phosphorus in near-bottom waters to the surface. The data collected on Tamarack Lake in 2016 indicate that internal nutrient loading is likely not the source of the unaccounted phosphorus.

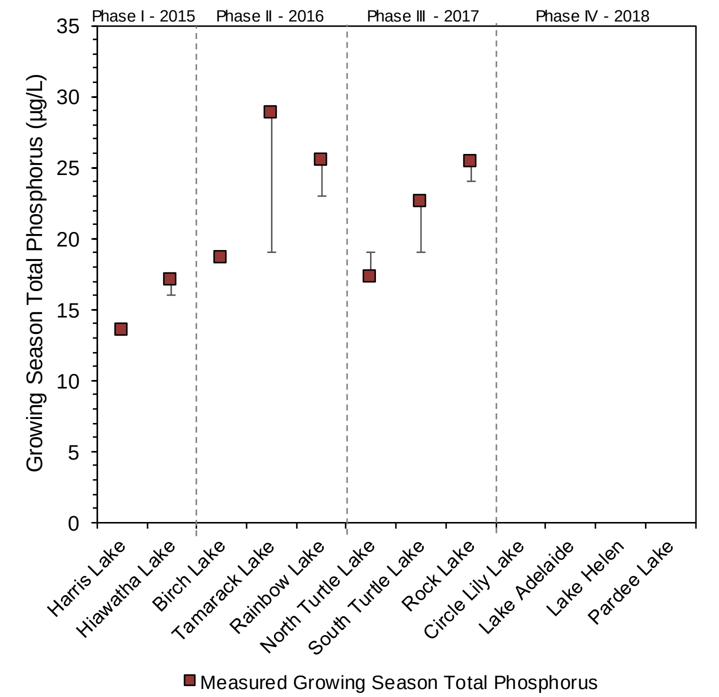

Figure 3.2-4. Town of Winchester lakes measured versus WiLMS-predicted growing season total phosphorus concentrations. Error bar represents WiLMS-predicted concentration.

Given the unaccounted phosphorus in Tamarack Lake is likely not originating internally, it is most likely originating from external sources within its watershed. Near-surface total phosphorus concentrations measured in 2016 tended to increased following larger precipitation events, indicating increased runoff from the watershed. Birch Lake flows into Tamarack Lake, and the modeling indicates the unaccounted phosphorus is likely not originating from the Birch Lake watershed but from Tamarack Lake's direct watershed. Deer Lake and an unnamed lake to the west of Tamarack Lake both flow into Tamarack Lake; however, no phosphorus data are available from these waterbodies. Tamarack Lake's direct watershed contains minimal human development with only two residential structures along its shoreline, indicating human activities are likely not the source of the unaccounted phosphorus. It is believed that the phosphorus export from Tamarack Lake's direct watershed is higher than predicted by the model due to naturally-higher background levels of phosphorus within its direct watershed. While phosphorus concentrations are higher in Tamarack Lake, it is not a concern as phytoplankton production remains low.

The potential impact of septic systems on phosphorus loading to these lakes was also estimated using data collected from the stakeholder surveys. These data indicate that phosphorus originating from septic systems around the Winchester project lakes is negligible. Please see the individual lake report sections to see estimated phosphorus loading from shoreline septic systems for each lake. Overall, the watersheds for the Winchester project lakes are in excellent shape being primarily comprised of intact, natural land cover types. These natural land cover types decrease soil erosion and nutrient runoff into these lakes and maintain their good water quality. While phosphorus concentrations in Tamarack Lake were higher than predicted, this is believed to be the result of naturally-higher phosphorus inputs from its direct watershed.

3.3 Shoreland Condition Assessment

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 swimmer's itch. Developments such as rip rap, masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails. This is not desirable for lakes that experience problems with swimmer's itch, because the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

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

Shoreland Zone Regulations

Wisconsin has numerous regulations in place at the state level which aim to enhance and protect shorelands. At the state level, the following shoreland regulations exist.

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted more restrictive shoreland ordinances. Passed in February of 2010, a revised NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances of their own. The revised NR 115 was once again examined in 2012 after some Wisconsin counties identified some provisions that were unclear or challenging to implement. The revisions proposed through Board Order WT-06-12 went into effect in December of 2013.

In July of 2015 with the passing of the state budget, the State of Wisconsin passed Wisconsin Act 55 which modified shoreland zoning provisions. Specifically, Act 55 removed authority from counties to enforce shoreland zoning ordinances that are more restrictive than the state's minimum standards contained in NR 115. Counties that had shoreland zoning ordinances that were more restrictive than state standards are no longer able to enforce those more restrictive standards. While county governments, countywide lake and river associations, individual lake associations, and lake districts across Wisconsin have moved to challenge Act 55, the Wisconsin Legislature has not yet taken any action on shoreland zoning. These policy regulations require that each county address ordinances for vegetation removal on shorelands, impervious surface standards, nonconforming structures and establishing mitigation requirements for development. Minimum requirements for each of these categories are as follows:

- <u>Vegetation Removal</u>: Land which extends 35 inland from the ordinary high-water mark is designated as the vegetative buffer zone. The removal of vegetation within the vegetative buffer zone is prohibited with the following exceptions: routine maintenance, creation of access and viewing corridors, exotic species removal, removal of damaged or diseased vegetation, removal of vegetation creating an imminent safety hazard, and removal of vegetation which is consistent with generally accepted forestry management practices as described in the WDNR publication <u>Wisconsin Forest Management Guidelines</u> (Publication FR – 226).

  Routine maintenance of vegetation is defined as "normally accepted horticultural practices that do not result in the loss of any layer of existing vegetation and do not require earth disturbance" (Wis. Admin. Code NR § 115.03(7m)). The removal of vegetation within the vegetative buffer zone to create access and viewing corridors may not exceed a combined width greater than 30% of the shoreline length or 200 feet. Removal of exotic species, diseased or damaged vegetation, or vegetation creating an imminent safety hazard must be replaced by replanting native species in the same area.

- <u>Impervious surface standards</u>: The amount of impervious surface is restricted to 15% of the total lot size on lots that are entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- <u>Nonconforming structures</u>: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows expansion laterally or vertically of a nonconforming structure within the 75-foot setback to occur if the following requirements are met:

- The structure has not been unused for a period of 12 months or more
- The existing structure is at least 35 feet from the ordinary high-water mark
- Vertical expansion is limited to a height of 35 feet
- Lateral expansion is limited to 200 square feet over the life of the structure
- No portion of the expansion may be closer to the ordinary high-water mark than the closest point of the existing structure
- Property owner receives permit from the county which requires a mitigation plant offset impacts of permitted expansion

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Photo 3.3-1. Coarse woody habitat (tree falls) provide valuable aquatic habitat.

Coarse woody habitat has shown to be advantageous for fisheries in terms of providing refuge, foraging areas as well as spawning habitat (Hanchin et al 2003). In one study, researchers observed 16 different species occupying coarse woody habitat areas in a Wisconsin lake (Newbrey et al. 2005). Bluegill and bass species in particular are attracted to this habitat type; largemouth bass stalk bluegill in these areas while the bluegill hide amongst the debris and often feed upon 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.

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). With development of a lake’s shoreland zone, much of the coarse woody debris that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800’s), and due to logging practices, the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions. 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). However, with continued education and lake stewardship in-lake habitat can be restored to Wisconsin lakes.

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 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, resulting in the first statistical analysis of the nation's lakes and reservoirs.

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

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people who move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003). The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake.

The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003, Radomski and Goeman 2001, and Elias & Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photo 3.3-2. Shoreland restoration.

In recent years, many lakefront property owners have achieved increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state (Photo 3.3-2). An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function. Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines.

Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted areas from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowners themselves. To decrease costs further, bare-root forms of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring-planting time frame.

- 100’ of shoreline.
- An upland buffer zone depth of 35’.
- An access and viewing corridor 30’ x 35’ free of planting (recreation area).
- Planting area of upland buffer zones: two 35’ x 35’ areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq. ft; and 2 shrubs/100 sq. ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (riprap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

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

Town of Winchester Lakes Shoreland Condition

Shoreland Development

The lakes within the Town of Winchester management planning project were surveyed to determine the extent of their development. These surveys were completed on each lake during that lake's respective project phase, generally in the late-summer and early-fall. In general, more developed shorelands are more stressful on a lake ecosystem, while benefits such as wildlife habitat and improved water quality arise from maintaining shoreland areas in a natural state. The shorelands of the project lakes within the Town of Winchester were categorized into one of five categories ranging from *urbanized*, or a shoreland that is completely developed and no natural vegetation remains, to *natural/undeveloped*, or a shoreland that has been completely left in an unaltered, natural state. A description of each of these five development categories can be found in Figure 3.3-1.

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

The Phase I, II, and III lakes which have been surveyed to date have portions of their shorelands that fall under all five of the shoreland condition assessment categories (Figure 3.3-2). The percentage of lake shoreline categorized as natural/undeveloped or developed-natural ranges from 93% in Tamarack Lake to 62% in South Turtle Lake, while the percentage of shoreline categorized as developed-unnatural or urbanized ranged from 3% in Hiawatha and Tamarack lakes to 16% in Birch Lake. The percentage of the shoreline that contained masonry, metal, wood, or rip-rap sea walls ranged from 0.4% in Tamarack and North Turtle lakes to 14% in Hiawatha Lake (Figure 3.3-3). Overall, the shoreland conditions assessment of the Phase I, II, and III lakes indicates the majority of the shorelines around these lakes contain minimal development. However, highly developed areas are present in some lakes and could be focus areas for restoration efforts.

While producing a completely natural shoreland is ideal for a lake ecosystem, it is not always practical from a riparian property owner'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 areas with minimal slope 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.

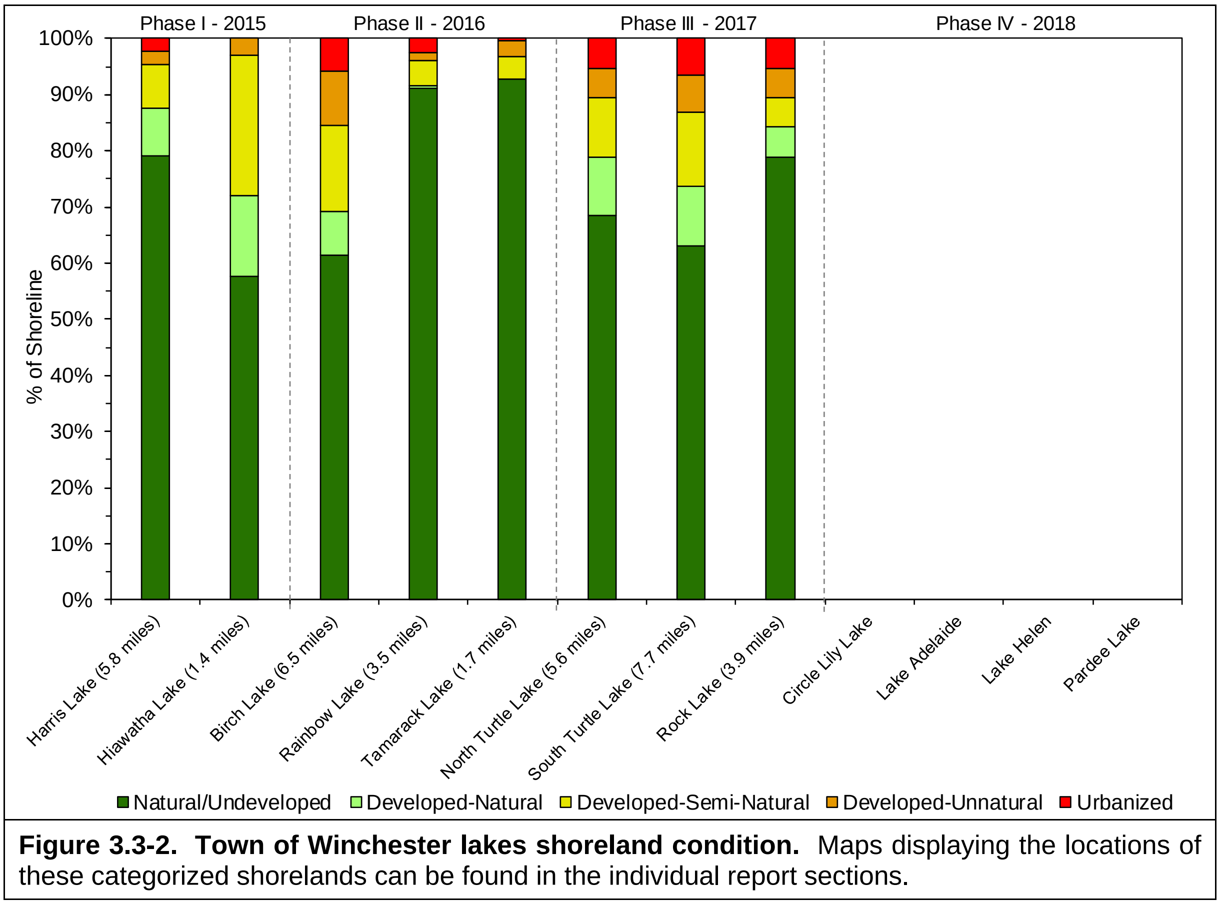

Figure 3.3-2. Town of Winchester lakes shoreland condition. Maps displaying the locations of these categorized shorelands can be found in the individual report sections.

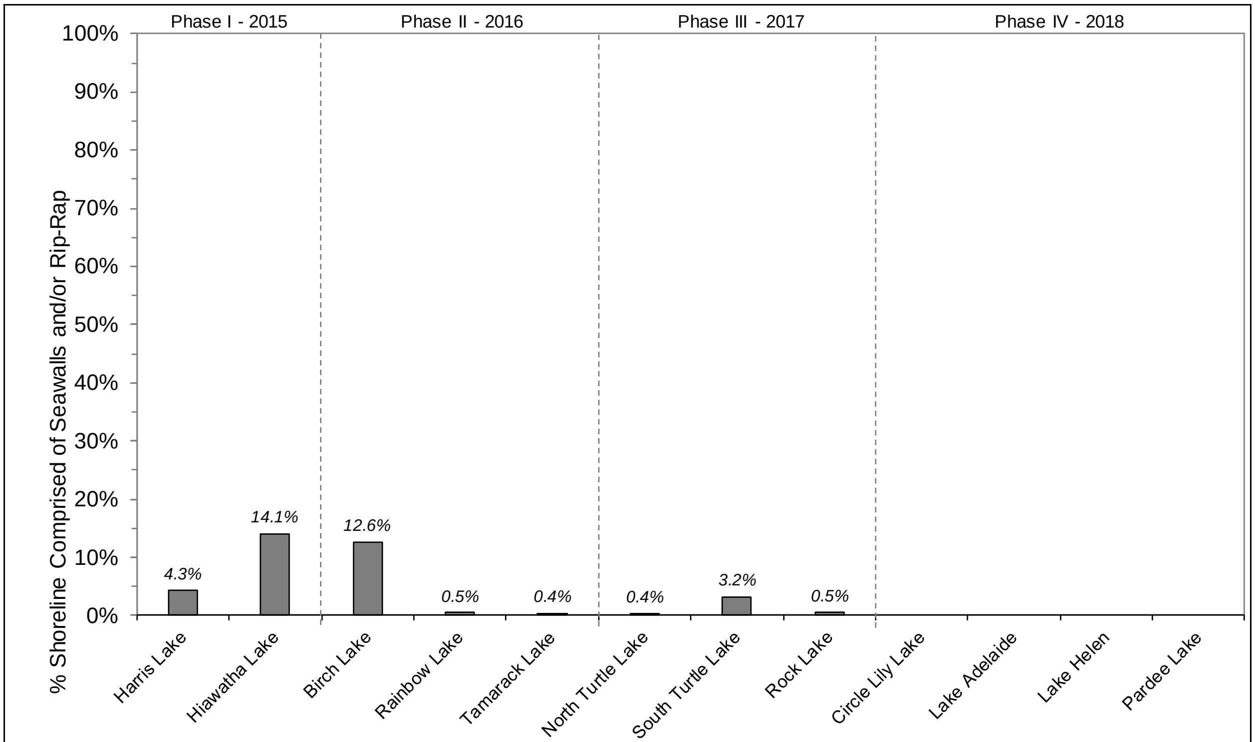

Figure 3.3-3. Town of Winchester lakes proportion of shoreline comprised of seawalls. Maps displaying the locations of these seawalls can be found in the individual report sections.

Coarse Woody Habitat

As part of the shoreland condition assessment, each Town of Winchester project lake was also surveyed to determine the extent of its coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (2-8 inches in diameter, >8 inches in diameter, 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 (Newbrey et al. 2005).

To date, Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012. Figure 3.3-4 displays the number of coarse woody habitat pieces per shoreline mile from the Winchester project lakes and how they compare with data from the 98 lakes surveyed. The number of coarse woody habitat pieces per mile ranged from 108 in Harris Lake to 11 in Tamarack Lake. Harris, Hiawatha, Birch, Rock, and South Turtle lakes have coarse woody habitat per shoreline mile values that fall at or above the 75th percentile for these 98 lakes. In fact, Harris and Hiawatha lakes had the highest coarse woody habitat pieces per shoreline mile recorded since these surveys began in 2012. The number of coarse woody habitat pieces per shoreline mile in North Turtle Lake fell above the median value, while values in Rainbow and Tamarack lakes fell below the median value. The lower numbers in Tamarack and Rainbow lakes are due to the fact that both of these lakes have a large portion of their shorelines comprised of wetlands with little tree growth, while the shorelines of the lakes with higher values are largely forested.

The individual lake reports discuss the composition of the coarse woody habitat in terms of the size and branching compositions. Refraining from removing woody habitat from the shoreland area will ensure this high-quality habitat remains in these lakes. Maps displaying the locations of the coarse woody habitat pieces located during the surveys on each lake can be found within the individual lake report sections.

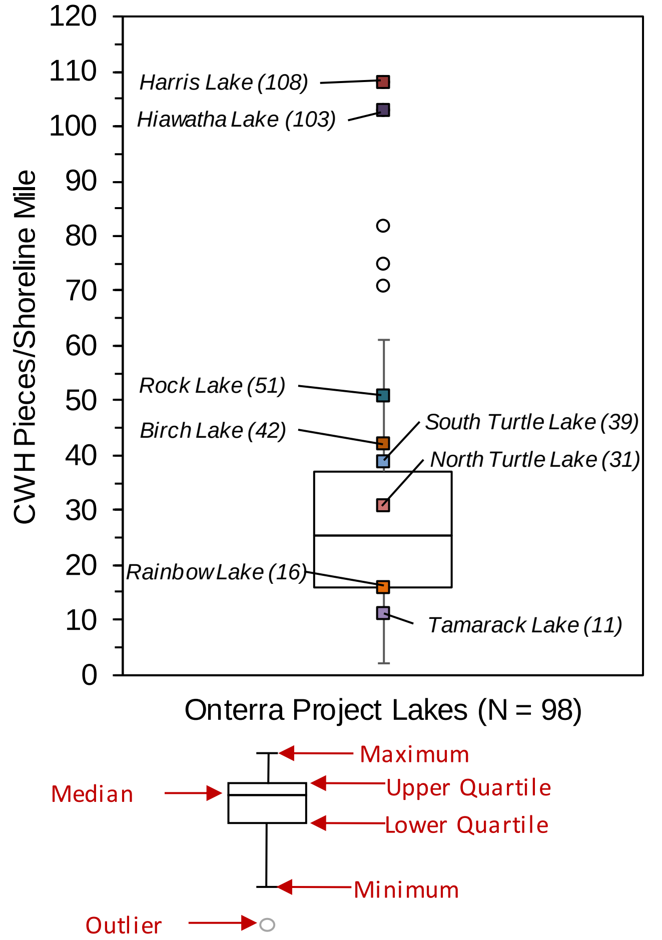

Figure 3.3-4. Town of Winchester lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. State-wide comparative data available from 98 lakes surveyed by Onterra since 2012. Maps displaying the locations of these coarse woody habitat pieces can be found in the individual report sections.

3.4 Aquatic Plants

Introduction

Although the occasional lake user considers aquatic plants (macrophytes) to be weeds and are often considered as a nuisance to the recreational use of the lake, these plants are an essential element in a healthy and functioning lake ecosystem (Photo 3.4-1). It is very important that lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative effects on it.

Photo 3.4-1. Native aquatic plant community. Fern pondweed (*Potamogeton robbinsii*). Photo credit Onterra.

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 sago pondweed (*Stuckenia pectinata*) 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.

Aquatic 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 bottom 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 nutrient levels that may lead to phytoplankton blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance phytoplankton blooms.

Because most aquatic plants are rooted in place and are unable to relocate in the wake of environmental change, they are often the first aquatic community to indicate that changes may be occurring within the system. For this reason, aquatic plants are used as indicators of environmental health. Aquatic plant communities can respond in variety of ways; there may be increases or reductions in the occurrence of sensitive species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from certain areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions.

Under certain conditions, a few species may grow to levels which can interfere with the use of the lake. 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 and curly-leaf pondweed can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

Many times, an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community.

> **Important Note:**
> Even though most of these techniques are not applicable to the Town of Winchester lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake**.** The techniques applicable to the Town of Winchester Lakes are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no silver bullets that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

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

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

Manual Removal

Native aquatic plants are an essential component of aquatic environments as they provide valuable habitat, improve water quality, and prevent the establishment of non-native species. Because of this, maintaining a healthy native aquatic plant community should be the priority of every lake riparian property owner. While the control of native aquatic plants is generally not recommended for the reasons previously discussed, riparian property owners can manually remove native aquatic plants in areas around their dock and/or swim area without a permit with certain restrictions (see below). If a riparian property owner feels the need to manually remove aquatic plants around their dock or within a swim area, it is strongly recommended that they first get in touch with Emily Heald at the North Lakeland Discovery Center or local WDNR staff. These professionals will be able to help identify if the plants are native or non-native, determine if any native plants present are Natural Heritage Inventory-listed species (e.g. endangered or threatened), and determine the most environmentally-sound manual removal methods that could be employed.

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

Manual methods for aquatic plant removal 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. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants. Wisconsin law states that all plants and plant fragments removed via manual techniques must be removed from the water (Photo 3.4-2).

Manual removal of aquatic plants can only occur within a 30-foot wide area that extends directly out from a use area which contains a dock or swim area. However, non-native species can manually removed from any area outside of the 30-foot wide zone as long as the manual technique does not remove native species. Wild rice has special protections and may not be manually removed without a permit, even if it occurs within the 30-foot wide manual removal zone.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150.

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • 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 removal may be needed as plants recolonize and/or continue to grow. • Uprooting of plants stirs bottom sediments making it difficult to conduct action. • May disturb benthic organisms and fish-spawning areas. • Risk of spreading invasive species if fragments are not removed.

Bottom Screens

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

Cost

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

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

	• Not practical in large-scale situations.

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn (Photo 3.4-3). 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.

Photo 3.4-3. Aquatic plant mechanical harvester.

Cost

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

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

Herbicide Treatment

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers (Photo 3.4-4). Traditionally, herbicides were used to control nuisance levels of aquatic plants and algae that interfere with navigation and recreation. While this practice still takes place in many parts of Wisconsin, the use of herbicides to control aquatic invasive species is becoming more prevalent.

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

Photo 3.4-4. Granular herbicide application.

While there are approximately 300 herbicides registered for terrestrial use in the United States, only 13 active ingredients can be applied into or near aquatic systems. All aquatic herbicides must be applied in accordance with the product's US Environmental Protection Agency (EPA) approved label. There are numerous formulations and brands of aquatic herbicides and an extensive list can be found in Appendix F of Gettys et al. (2009). Applying herbicides in the aquatic environment requires special considerations compared with terrestrial applications. WDNR administrative code states that a permit is required if "you are standing in socks and they get wet." In these situations, the herbicide application needs to be completed by an applicator licensed with the Wisconsin Department of Agriculture, Trade and Consumer Protection. All herbicide applications conducted under the ordinary high water mark require herbicides specifically labeled by the United States Environmental Protection Agency

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

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

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

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

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

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

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

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

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian 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.

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

Primer on Data Analysis & Data Interpretation

Four aquatic plant surveys were completed by Onterra on each of the project lakes during their respective phase. 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 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 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. The final survey included an acoustic survey where aquatic plants were mapped using sophisticated sonar techniques. The acoustic survey allows for a determination of where aquatic plants are growing and at what density.

A specimen representing each aquatic plant species located from 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 point-intercept survey method as described 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 Town of Winchester project lakes. The sampling location spacing (resolution) and resulting total number of locations varied by lake and were created based upon guidance from the WDNR (Table 3.4-1).

Table 3.4-1. Resolution and number of point-intercept sampling locations used on the Town of Winchester project lakes.

Project Phase	Lake	Sample Location Resolution (m)	Number of Sampling Locations
Phase I	Harris Lake	49	892
	Hiawatha Lake	30	176
Phase II	Birch Lake	57	624
	Rainbow Lake	40	372
	Tamarack Lake	37	188
Phase III	North Turtle Lake	45	730
	South Turtle Lake	56	627
	Rock Lake	39	332
Phase IV	Circle Lily Lake	*Not yet available*	
	Lake Adelaide		
	Lake Helen		
	Pardee Lake		

At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediments, sand, or rock/gravel), and the plant species sampled along with their relative abundance (Figure 3.4-1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 14 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 14 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 14 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

The **Littoral Zone** is the area of the lake where sunlight is able to penetrate to the sediment providing aquatic plants with sufficient light to carry out photosynthesis.

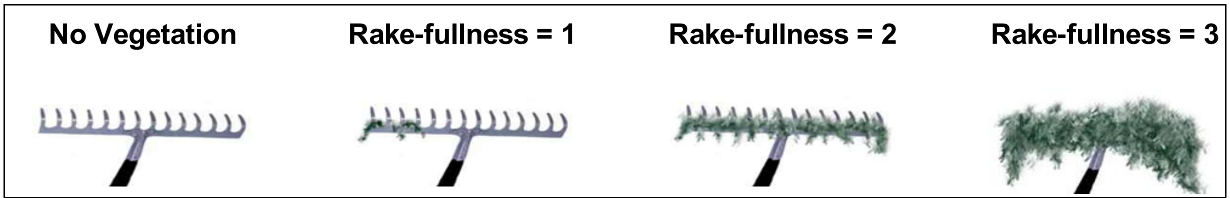

Figure 3.4-1. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

Species List

The species list is simply a list of all of the species, both native and non-native, that were located during the surveys completed on the Town of Winchester project lakes. 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 surveys completed on the Town of Winchester project lakes, plant samples were collected from plots laid out on a grid that covered the lake (point-intercept survey). 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 each lake to be compared to other lakes within the region and state.

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

Species Diversity

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species.

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

The Simpson's Diversity Index values from the Town of Winchester Project lakes are 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. Comparisons are displayed in the individual lake report sections using *boxplots* that display median values and upper/lower quartiles of lakes in the same ecoregion and in the state.

Emergent and Floating-leaf Community Mapping

A key component of the aquatic plant surveys 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 and watershield. Submersed aquatic plants species are often mixed throughout large areas of the lake and are often not visible from the surface, and therefore do not lend themselves well to mapping. However, the point-intercept survey allows for a general understanding of the distribution of submersed species within each lake.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian watermilfoil are the primary targets of this extra attention. Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). 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 cool and the majority of native plants are still dormant, and 2) in some instances once its stems reach the water surface, it does not stop growing like most native plants and instead continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

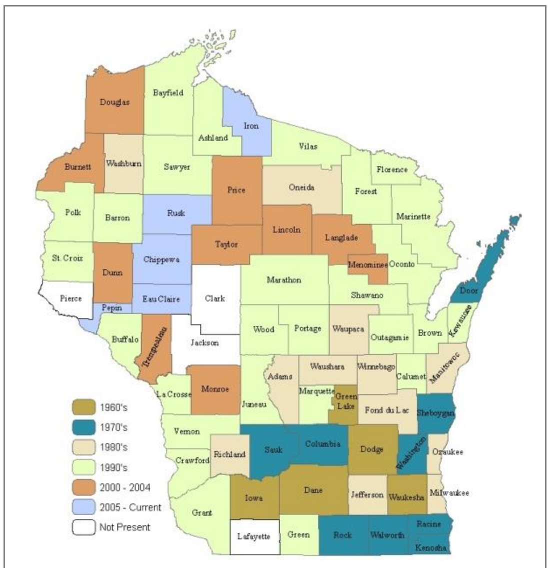

Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data mapped by Onterra (2011).

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 phytoplankton blooms spurred from the nutrients released during the plant's decomposition.

Aquatic Plant Survey Results

Within the eight Phase I, II, and III lakes that have been studied to date, a total of 91 aquatic plant species representing 27 families have been documented and collected by Onterra and verified by the UW-Stevens Point Herbarium (Table 3.3-2 and Table 3.3-3). Thirty-nine of these plant species (41%) belong to two families, the *Potamogetonaceae* (the pondweeds) and *Cyperaceae* (the sedges). Eight plant species were located in all eight lakes and include: creeping spikerush, three-way sedge, spatterdock, floating-leaf bur-reed, muskgrasses, quillworts, slender naiad, and variable-leaf pondweed.

Growth forms include 44 submersed species, 31 emergent species, six floating-leaf species, four submersed/emergent species, two floating-leaf/emergent species, and two free-floating species. The number of native aquatic plant species ranged from 56 in Harris Lake to 26 in Hiawatha. Of the 91 species located to date, two are considered to be non-native, invasive species: curly-leaf pondweed and pale-yellow iris. Curly-leaf pondweed has been found in Harris Lake while pale-yellow iris was located along the shorelines of Rock, North Turtle, and South Turtle lakes. Because of their importance, these non-native plants are discussed in detail in the subsequent Non-Native Aquatic Plants Subsection.

Two native aquatic plant species located during these studies, northeastern bladderwort and Vasey's pondweed, are listed as special concern by the WDNR Natural Heritage Inventory Program due to "a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors" (Wisconsin Natural Heritage Program 2016). Northeastern bladderwort was located in Harris Lake (Photo 3.4-5a) and Vasey's pondweed was located in Rainbow, Rock, North Turtle, and South Turtle lakes (Photo 3.4-5b). Both of these plants require high-quality conditions to survive, and their presence in these lakes is indicative of environments with minimal disturbance.

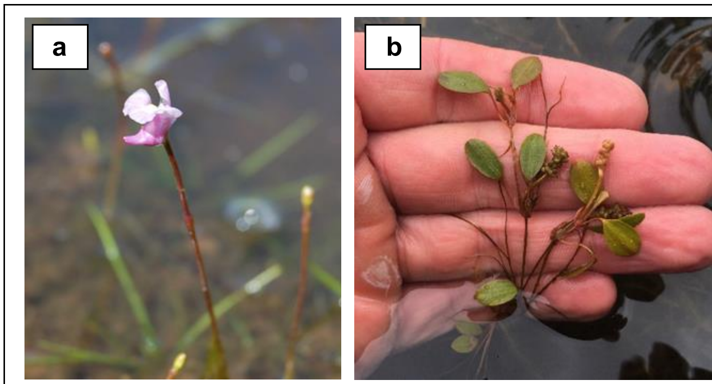

Photo 3.4-5. Native plant species listed as special concern in Wisconsin. a. Flower of northeastern bladderwort. b. Flowers and floating-leaves of Vasey's pondweed. Photo credit Onterra.

Table 3.4-2. List of emergent, floating-leaf, and free-floating aquatic plant species located in the Town of Winchester lakes.

				2015		2016			2017			2018			
Growth Form	Scientific Name	Common Name	Coefficient of Conservatism	Harris Lake	Hiawatha Lake	Birch Lake	Tamarack Lake	Rainbow Lake	North Turtle Lake	South Turtle Lake	Rock Lake	Pardee Lake	Lake Adelaide	Lake Helen	Circle Lily Lake
Emergent	*Acorus americanus*	Sweetflag	7			I		I		I	I				
	Calamagrostis canadensis	Bluejoint grass	5			I									
	Calla palustris	Water arum	9	I											
	Carex aquatilis	Long-bracted tussock sedge	7		I										
	Carex comosa	Bristly sedge	5			I				I					
	Carex lacustris	Lake sedge	6					I							
	Carex lasiocarpa	Narrow-leaved woolly sedge	9	I	I	I		I							
	Carex pseudocyperus	Cypress-like sedge	8	I											
	Carex retrorsa	Retrorse sedge	6							I					
	Carex stricta	Common tussock sedge	7					I							
	Carex utriculata	Common yellow lake sedge	7	I	I	I		I	I		I				
	Cladium mariscoides	Smooth sawgrass	10	I		I									
	Decodon verticillatus	Water-willow	7						I	I	I				
	Dulichium arundinaceum	Three-way sedge	9	X	I	I	I	I	I	I	I				
	Eleocharis palustris	Creeping spikerush	6	X	X	I	I	X	I	I	I				
	Equisetum fluviatile	Water horsetail	7	X	X	I			I	I	I				
	Glyceria canadensis	Rattlesnake grass	7		I				I						
	Iris pseudacorus	Pale yellow iris	Exotic						I	I	I				
	Iris versicolor	Northern blue flag	5			I		I	I	I					
	Juncus effusus	Soft rush	4	I	I										
	Phragmites australis subsp. americanus	Common reed	5	I		I		I							
	Pontederia cordata	Pickerelweed	9	X		X	X	X	I	I	I				
	Sagittaria latifolia	Common arrowhead	3	I		I			I	I	I				
	Sagittaria rigida	Stiff arrowhead	8	I											
	Schoenoplectus acutus	Hardstem bulrush	5	X		X	I	X	X	X	X				
	Schoenoplectus pungens	Three-square rush	5	X											
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I										
	Scirpus cyperinus	Wool grass	4	I	I										
	Sparganium americanum	American bur-reed	8			I	I		X		I				
	Sparganium eurycarpum	Common bur-reed	5						I		I				
	Typha latifolia	Broad-leaved cattail	1	I	I	I	I	I							
FL/E	*Sparganium emersum var. acaule*	Short-stemmed bur-reed	8	I	I	I									
	Sparganium sp. (sterile)	Sterile bur-reed sp.	N/A					I	I	I					
FL	*Brasenia schreberi*	Watershield	7	X			X	X	I	X	I				
	Nuphar variegata	Spatterdock	6	X	X	X	X	X	X	X	X				
	Nymphaea odorata	White water lily	6	X		X	X	X	I	X	X				
	Persicaria amphibia	Water smartweed	5	X		I									
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I											
	Sparganium fluctuans	Floating-leaf bur-reed	10	I	I	X	X	X	I	X	X				
FF	*Lemna minor*	Lesser duckweed	5				I								
	Lemna trisulca	Forked duckweed	6				X								

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

Table 3.4-3. List of submersed aquatic plant species located in the Town of Winchester project lakes.

				2015		2016			2017			2018			
Growth Form	Scientific Name	Common Name	Coefficient of Conservatism	Harris Lake	Hiawatha Lake	Birch Lake	Tamarack Lake	Rainbow Lake	North Turtle Lake	South Turtle Lake	Rock Lake	Pardee Lake	Lake Adelaide	Lake Helen	Circle Lily Lake
Submersed	*Bidens beckii*	Water marigold	8	X		X	X	X	X	X	X				
	Callitriche palustris	Common water starwort	8		I						I				
	Ceratophyllum demersum	Coontail	3				X		X	X	X				
	Ceratophyllum echinatum	Spiny hornwort	10			X		X		X	X				
	Chara spp.	Muskgrasses	7	X	X	X	X	X	X	X	X				
	Elodea canadensis	Common waterweed	3	X		X	I	X		X	X				
	Elodea nuttallii	Slender waterweed	7					X		X	X				
	Eriocaulon aquaticum	Pipewort	9	X	X		X								
	Fontinalis sphagnifolia	Rolled water moss	N/A		X					X					
	Heteranthera dubia	Water stargrass	6	X				X		X	X				
	Isoetes spp.	Quillwort spp.	8	X	X	X	X	X	X	I	X				
	Lobelia dortmanna	Water lobelia	10	X							X				
	Myriophyllum alterniflorum	Alternate-flowered watermilfoil	10	X											
	Myriophyllum farwellii	Farwell's watermilfoil	9								I				
	Myriophyllum sibiricum	Northern watermilfoil	7	X		X	X	X	X	X	X				
	Myriophyllum tenellum	Dwarf watermilfoil	10	X		X			X						
	Najas flexilis	Slender naiad	6	X	X	X	X	X	X	X	X				
	Nitella spp.	Stoneworts	7		X	X		X	X	X	X				
	Potamogeton amplifolius	Large-leaf pondweed	7	X		X	X	X	X	X	X				
	Potamogeton berchtoldii	Slender pondweed	7		X		X	X			X				
	Potamogeton crispus	Curly-leaf pondweed	Exotic	I											
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X		X	I	I		I				
	Potamogeton foliosus	Leafy pondweed	6								I				
	Potamogeton friesii	Fries' pondweed	8	X											
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X	X	X	X	X	X	X				
	Potamogeton illinoensis	Illinois pondweed	6	X											
	Potamogeton natans	Floating-leaf pondweed	5		I			X		I					
	Potamogeton obtusifolius	Blunt-leaved pondweed	9					I							
	Potamogeton praelongus	White-stem pondweed	8	X			I	X		X					
	Potamogeton pusillus	Small pondweed	7	X						X					
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X		X	I	X	X	X	X				
	Potamogeton robbinsii	Fern-leaf pondweed	8	X		X	X	X	X	X	X				
	Potamogeton spirillus	Spiral-fruited pondweed	8		X	I	X	X	I	I	X				
	Potamogeton strictifolius	Stiff pondweed	8	X											
	*Potamogeton vaseyi**	Vasey's pondweed	10					X	I	I	X				
	Potamogeton zosteriformis	Flat-stem pondweed	6	X			X	X		X	X				
	Ranunculus flammula	Creeping spearwort	9	X											
	Stuckenia pectinata	Sago pondweed	3	X											
	Utricularia gibba	Creeping bladderwort	9					I							
	Utricularia intermedia	Flat-leaf bladderwort	9	X				X							
	Utricularia minor	Small bladderwort	10				X	X							
	*Utricularia resupinata**	Northeastern bladderwort	9	X											
	Utricularia vulgaris	Common bladderwort	7	I		X	X	X	I	X	X				
	Vallisneria americana	Wild celery	6	X		X		X	X	X	X				
S/E	*Eleocharis acicularis*	Needle spikerush	5	X			I			X	X				
	Juncus pelocarpus	Brown-fruited rush	8	X											
	Sagittaria cristata	Crested arrowhead	9	I											
	Schoenoplectus subterminalis	Water bulrush	9					X							

S/E = Submersed and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern by WI Natural Heritage Inventory*

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. During the whole-lake point-intercept surveys completed on the Winchester project lakes, substrate data were also recorded at each sampling location in one of three general categories: soft sediments, sand, or rock/gravel. In addition, substrate hardness was also measured through an acoustic survey conducted on each lake, the details of which are discussed in the individual lake report sections.

The project study lakes varied greatly in terms of their substrate composition. Figure 3.4-4 illustrates the proportion of substrate types (soft sediments, sand, and rock) as determined from the whole-lake aquatic plant point-intercept surveys. Substrate composition within littoral areas ranged from being primarily comprised of sand and rock in Harris, Hiawatha, and Birch lakes to littoral areas primarily comprised of soft sediments in Tamarack and Rainbow lakes. 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.

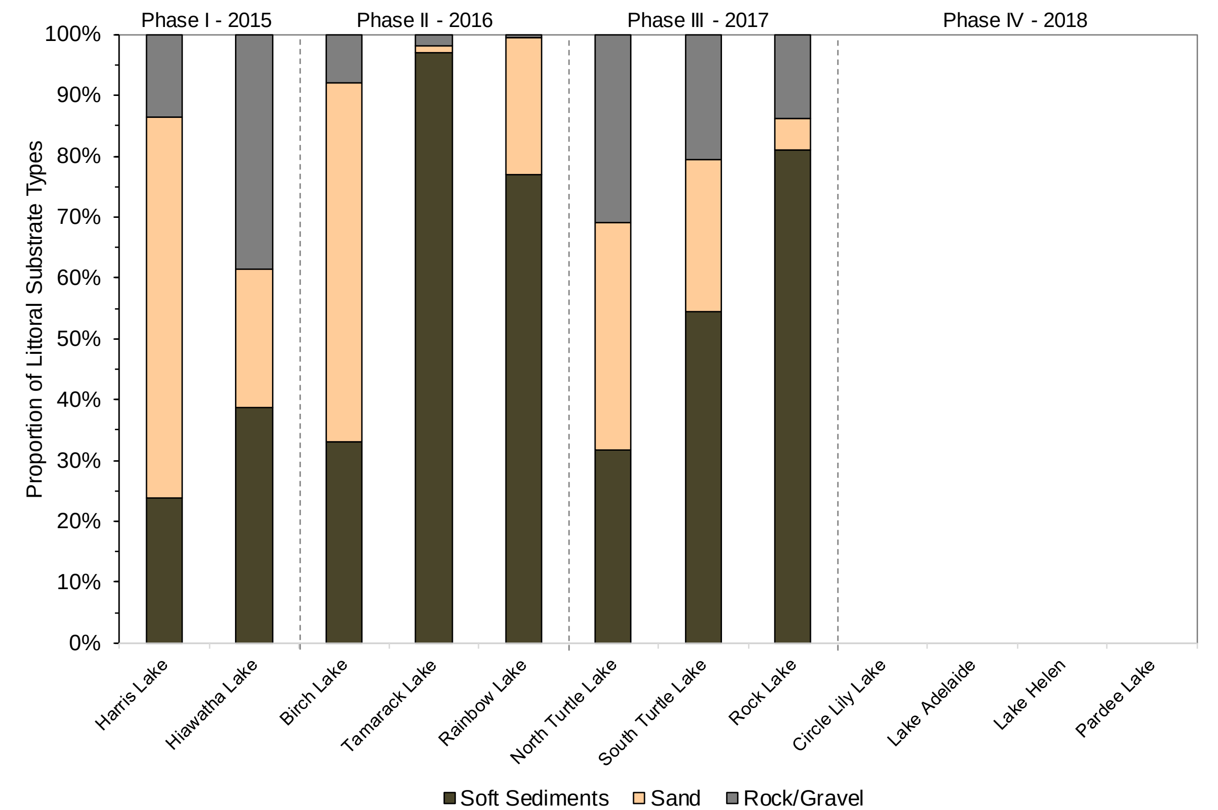

Figure 3.4-3. Town of Winchester project lakes proportion of substrate types. Created using data collected during the whole-lake point-intercept survey.

The maximum depth of aquatic plant growth within the Winchester project lakes ranged from 28 feet in Harris Lake to 7 feet in Hiawatha Lake. The maximum depth of aquatic plant growth was highly correlated with average summer Secchi disk depth (Figure 3.4-4). Higher water clarity allows light to penetrate deeper into the water column allowing plants to grow at deeper depths. Harris Lake has exceptional water clarity, and because of this, aquatic plants grow to deeper depths. In contrast, Hiawatha Lake has low water clarity and aquatic plants are restricted to shallower areas where they can receive adequate light.

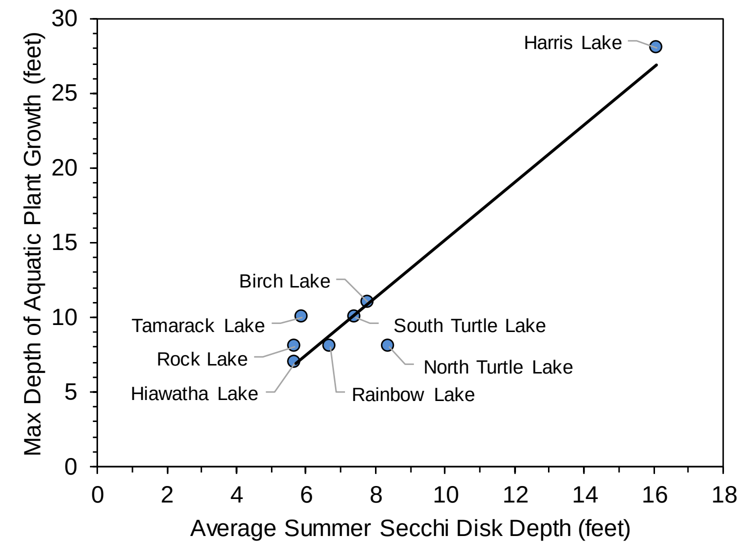

Figure 3.4-4. Town of Winchester project lakes maximum depth of aquatic plant growth plotted against average summer Secchi disk depth.

The littoral frequency of occurrence of aquatic vegetation in the Winchester project lakes ranged from 79% in Tamarack Lake to 24% in North Turtle Lake (Figure 3.4-5). The proportion of aquatic plant total rake fullness (TRF) ratings varied among the five lakes, indicating lower biomass of aquatic plants in lakes like Hiawatha, Birch, and North Turtle lakes, and higher biomass in lakes like Tamarack, Rainbow, and South Turtle lakes.

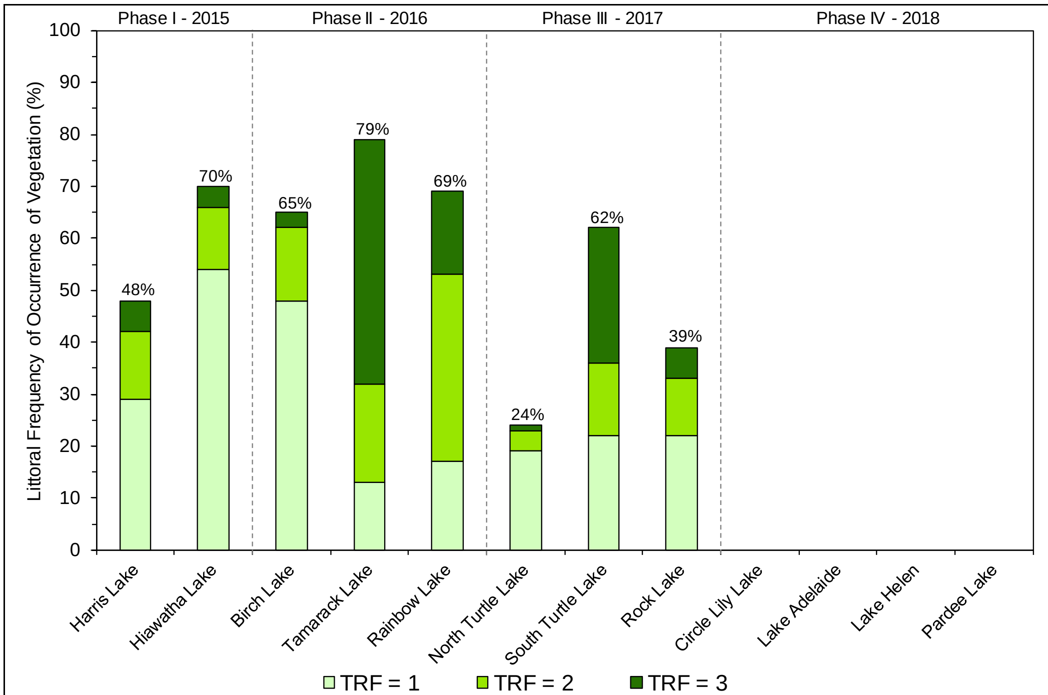

Figure 3.4-5. Town of Winchester lakes littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings. Created using data collected during the whole-lake point-intercept surveys.

The number of native aquatic plant species (species richness) per lake ranged from 56 in Harris Lake to 26 in Hiawatha Lake (Figure 3.4-6). When comparing a lake's aquatic plant community to other lakes within the ecoregion and the state, only the native plant species that were directly encountered on the rake during the whole-lake point-intercept survey are used in the analysis. For example, while a total of 56 native aquatic plant species were located in Harris Lake in 2015, 40 were directly encountered on the rake during the point-intercept survey while 16 were 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.

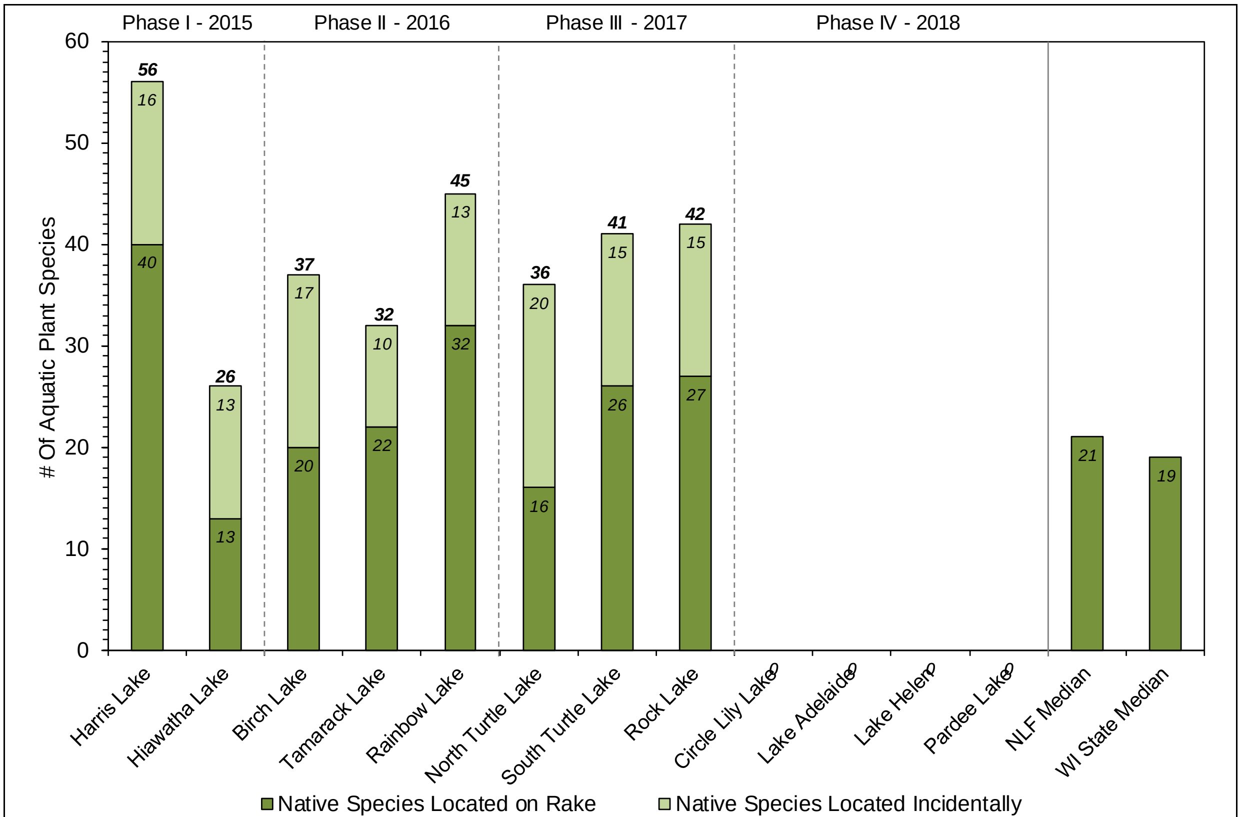

Figure 3.4-6. Town of Winchester lakes native aquatic plant species richness and median species richness for Northern Lakes and Forests (NLF) ecoregion lakes and Wisconsin lakes. Includes species located on rake during point-intercept surveys and incidentally-located species.

The native aquatic plant species richness in Harris, Tamarack, Rainbow, South Turtle, and Rock lakes exceeded median species richness values for lakes within the NLF ecoregion and for lakes throughout Wisconsin (Figure 3.4-6). Native aquatic plant species richness in Birch Lake fell just below the median value for lakes within the NLF ecoregion and just above the median value for lakes in Wisconsin, while native species richness in Hiawatha and North Turtle fell below both median values.

Pearson correlation indicated that native plant species richness among the Winchester project lakes was strongly correlated with water clarity and littoral area. Studies have shown that the number of species present tends to increase with the area of suitable habitat (Lacoul and Freedman 2006). The lake's morphometry in combination with water clarity are going to determine the size of the littoral zone. Lakes with lower water clarity have been shown to support fewer species, those which can tolerate lower-light conditions.

In addition, studies have also shown that aquatic plant species richness also tends to increase with increasing *shoreline complexity* (Vestergaard and Sand-Jensen 2000). Shoreline complexity is an index that relates the area of the lake to the perimeter of its shoreline. If a lake were a perfect circle, its shoreline complexity value would be 1.0. The farther a lake deviates from a perfect circle, the higher its shoreline complexity value is. Lakes with greater shoreline complexity harbor more areas that are sheltered from wind and wave action creating additional habitat types for aquatic plants. There is not a wide range in shoreline complexity among the Winchester project lakes, with values ranging from 2.1 in Tamarack Lake to 6.1 in South Turtle lake. There was no significant relationship between shoreline complexity and native aquatic plant species richness in these lakes, indicating that littoral area and water clarity among other factors are likely primary parameters driving the differences in species richness among these lakes.

Studies have also shown that alkalinity as it relates to the amount of bicarbonate within the water is one of the primary factors in determining the composition of a lake's aquatic plant community (Vestergaard and Sand-Jensen 2000). Most aquatic plants cannot meet their carbon demand for photosynthesis solely from the availability of dissolved carbon dioxide within the water and require supplemental carbon from dissolved bicarbonate. While still considered softwater lakes, the Winchester project lakes with the exception of Hiawatha Lake have moderate alkalinity levels and there are sufficient concentrations of dissolved bicarbonate to support the photosynthesis of a higher number of aquatic plant species. Alkalinity in Hiawatha Lake is approximately half when compared to the other lakes, and dissolved bicarbonate concentrations are low. Only those plants which are adapted to live in this carbon-limited environment in combination with lower light levels are able to persist. While Hiawatha Lake contains a lower number of aquatic plants species, this is to be expected given the lake's carbon-limited environment, small littoral area, and low water clarity.

Figure 3.4-7 compares the average conservatism values of the native aquatic plant species located on the rake during each of the point-intercept surveys conducted on the Town of Winchester lakes. The average conservatism values range from 6.6 in South Turtle Lake to 7.3 in Tamarack Lake, with an average of 7.0. The average conservatism values for these lakes fall near or exceed the median value for lakes within the NLF ecoregion and lakes throughout Wisconsin. This indicates that the Winchester project lakes harbor a higher number of aquatic plant species that are considered sensitive to environmental disturbance (higher C-values) and indicate high-quality environmental conditions.

As discussed in the primer section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The number of native species encountered on the rake during the whole-lake point-intercept surveys and their conservatism values were used to calculate the FQI of the Town of Winchester lakes. Figure 3.4-8 displays the FQI values for the Town of Winchester project lakes and compares them to median values of lakes within the NLF ecoregion and lakes throughout Wisconsin. While average conservatism values were relatively similar among all five lakes, the FQI values are more variable and range from 25.8 in Hiawatha Lake to 44.3 in Harris Lake with an average of 34.0.

The differences in FQI values among these five lakes is largely the result of differences in native aquatic plant species richness. The FQI values for Harris, Birch, Tamarack, Rainbow, South Turtle, and Rock lakes exceed the median values for lakes within the NLF ecoregion and lakes throughout Wisconsin. The FQI value for Hiawatha and North Turtle lakes fall below the median values for lakes within the ecoregion; however, this is not an indication of a degraded aquatic plant community but the result of the natural conditions present in these lakes. These natural conditions are discussed in more detail in the respective individual lake sections.

Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. If a lake has a high number of aquatic plant species, it does not necessarily mean that the lake will also have high species diversity as diversity is also influenced by how evenly the aquatic plant species are distributed within the community.

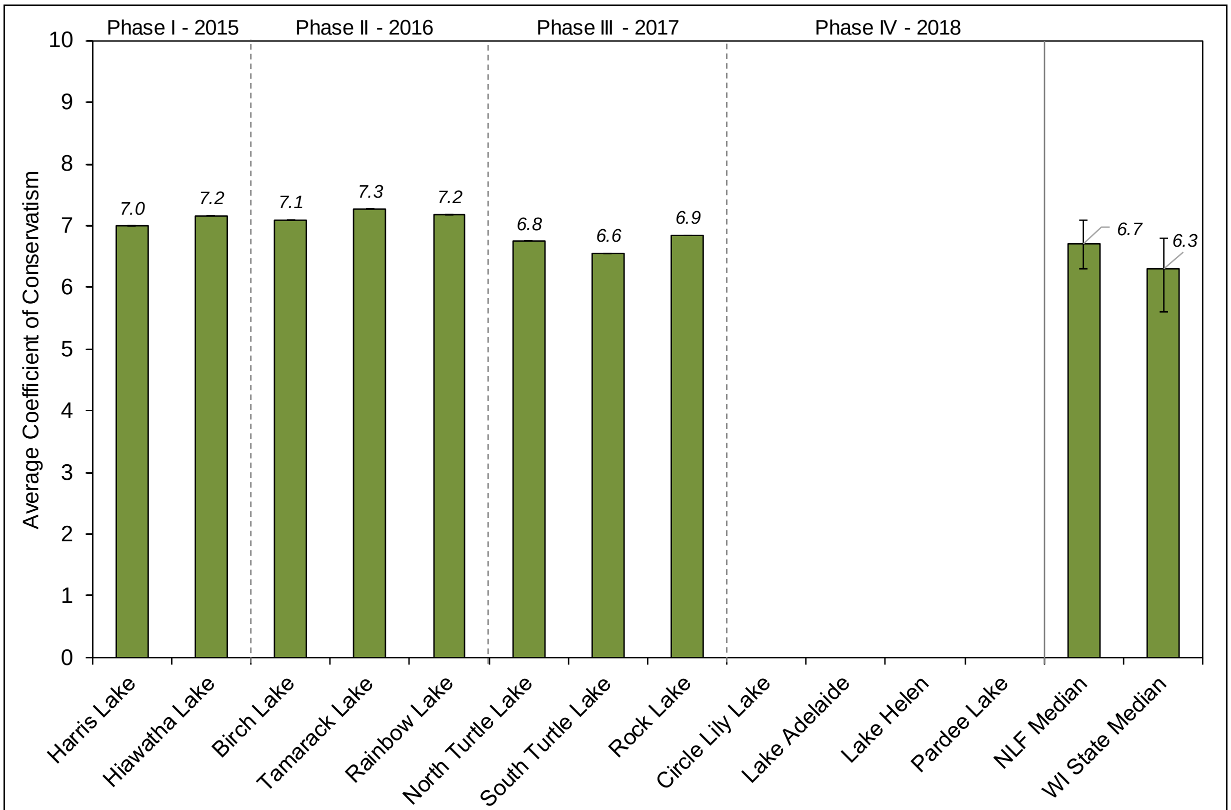

Figure 3.4-7. Town of Winchester lakes native aquatic plant average coefficients of conservatism. Error bars represent interquartile range. Created using conservatism values of native aquatic plant species located on the rake during the whole-lake point-intercept surveys. Analysis follows Nichols (1999).

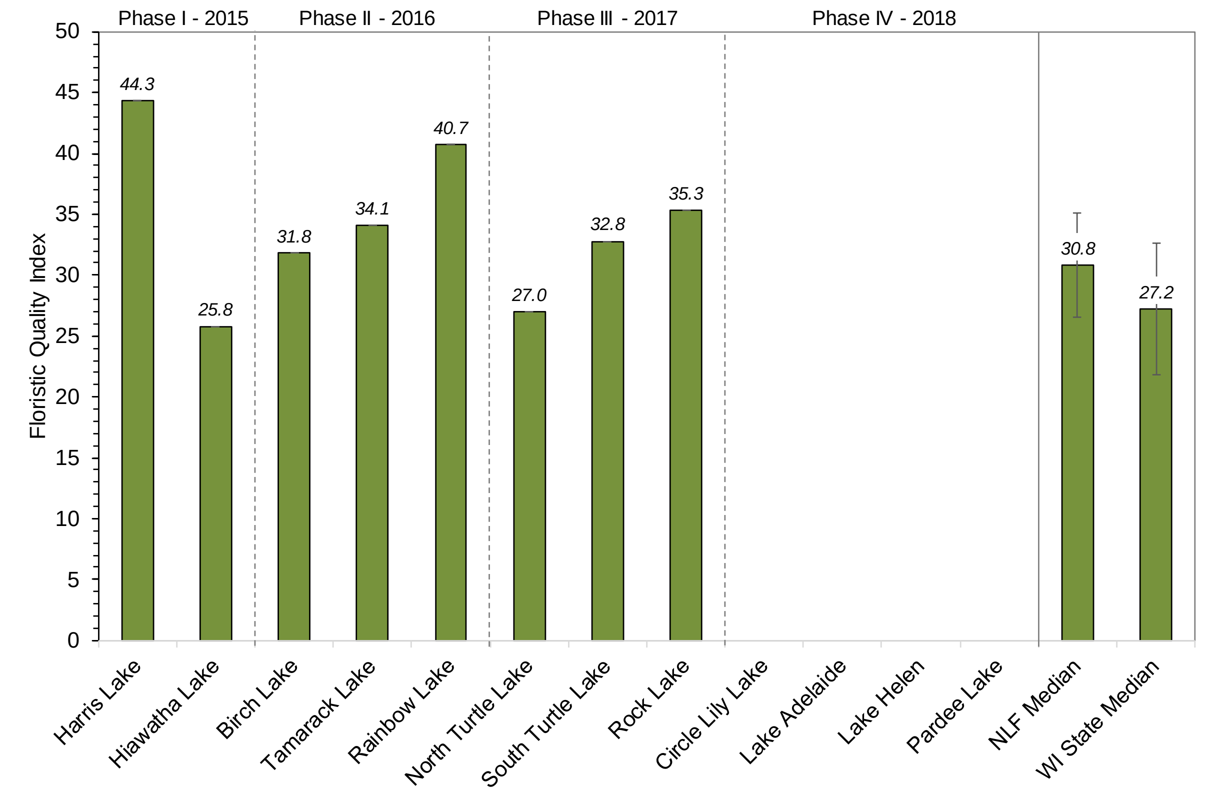

Figure 3.4-8. Town of Winchester lakes Floristic Quality Index values. Created using conservatism values and number of native aquatic plant species located on the rake during the whole-lake point-intercept surveys. Analysis follows Nichols (1999).

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Town of Winchester lakes' diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF Ecoregion (Figure 3.4-9). Simpson's Diversity Index values were calculated using data collected from the whole-lake aquatic plant point-intercept surveys. Simpson's Diversity Index values range from 0.80 in Birch Lake to 0.93 in Rainbow Lake (Figure 3.4-9).

In other words, if aquatic plants were to be randomly sampled from two locations in Rainbow Lake, there would be a 93% probability that they would be of different species. The diversity values for Harris, Rainbow, South Turtle, and Rock lakes exceed the median value for lakes within the NLF ecoregion. The diversity values for Hiawatha and North Turtle lake fall near the median value for lakes within the NLF ecoregion, while diversity values in Birch and Tamarack lakes fall below the median value. Like species richness, the differences in species diversity among the Town of Winchester lakes are primarily due to differences in lake morphometry, water clarity, water chemistry, and substrate composition.

The previous analyses indicate that native the plant communities of the Winchester project lakes are healthy and of high quality. The aquatic plant communities within these lakes provide essential habitat and aid in maintaining the high water quality of these lakes. An important component of a lake's aquatic plant community are the emergent and floating-leaf communities which provide valuable structural habitat and stabilize bottom and shoreland sediments. These communities are even more important during periods of lower water levels when coarse woody habitat becomes exposed above the lower water line. The mapping of emergent and floating-leaf aquatic plant communities in the Winchester project lakes found that the acreage of these communities ranged from 0.8 acres in Hiawatha Lake to 91.9 acres in Harris Lake, with the percentage of lake area inhabited by these communities ranging from 2% in Hiawatha Lake to 31% in both Tamarack and Rainbow lakes (Table 3.4-4). A total of 39 emergent and floating-leaf aquatic plant species were located within Winchester project lakes (Table 3.4-2).

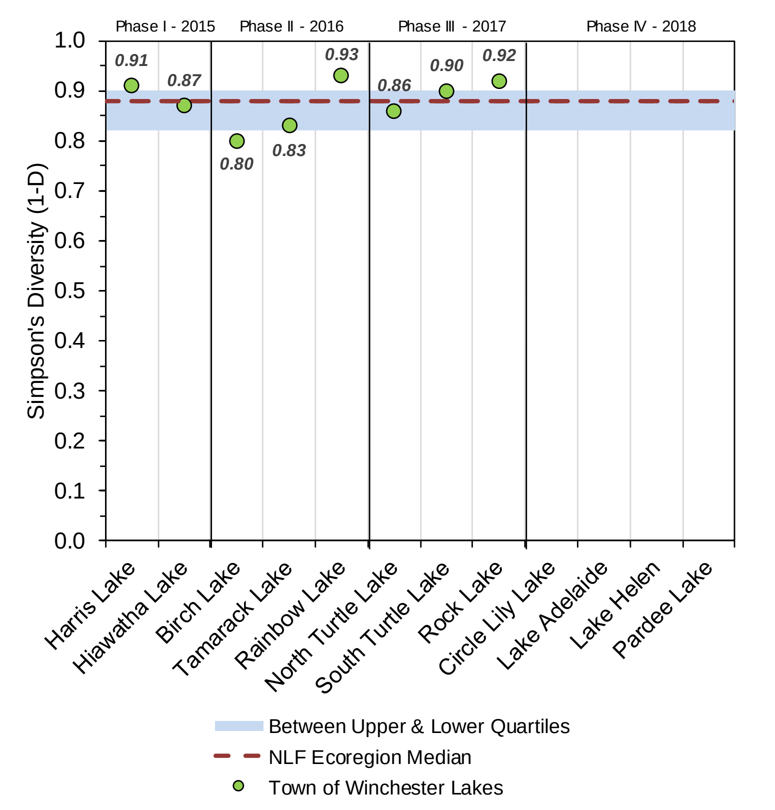

Figure 3.4-9. Town of Winchester lakes Simpson's Diversity Index. Created using data collected from whole-lake point-intercept surveys. Ecoregion data calculated using Onterra and WDNR science services point-intercept survey data.

Figure 3.4-10 illustrates the composition of emergent and floating-leaf aquatic plant communities in the Town of Winchester Lakes. As illustrated, the composition of emergent versus floating-leaf communities varied among the lakes. For example, Harris Lake contains communities primarily comprised of emergent species while Tamarack supports large communities of floating-leaf species. Other lakes supported a more even mix of both emergent and floating-leaf species.

Continuing the analogy that 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 Town of Winchester project lakes. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

Table 3.4-4. Acreage of emergent and floating-leaf aquatic plant communities in the Town of Winchester lakes.

	Phase I -2016		Phase II - 2016			Phase III - 2017			Phase IV - 2018			
Plant Community	**Harris Lake**	**Hiawatha Lake**	**Birch Lake**	**Tamarack Lake**	**Rainbow Lake**	**North Turtle Lake**	**South Turtle Lake**	**Rock Lake**	**Circle Lily Lake**	**Lake Adelaide**	**Lake Helen**	**Pardee Lake**
Emergent Acres	88.8	0.2	24.6	7.8	3.0	5.4	6.7	3.8				
Floating-leaf Acres	0.1	0.2	3.7	12.3	22.5	0.8	13.0	4.7				
Mixed Emergent & Floating-leaf Acres	2.9	0.4	40.8	0.0	21.6	4.5	3.7	2.4				
Total Acres	**91.9**	**0.8**	**69.1**	**20.0**	**47.1**	**10.8**	**23.3**	**11.0**				

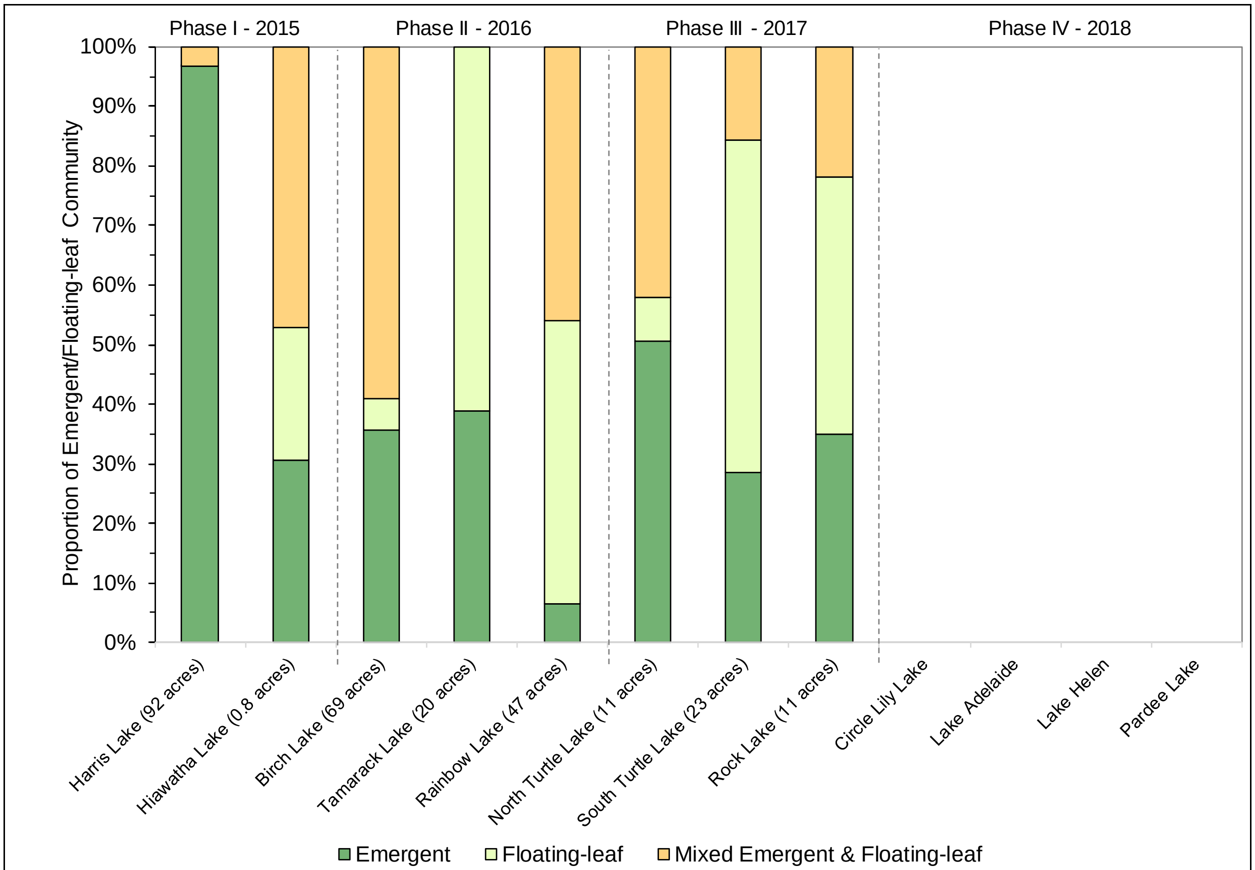

Figure 3.4-10. Town of Winchester lakes emergent and floating-leaf aquatic plant community composition. Locations of these aquatic plant communities are displayed on maps within the individual lake report sections.

Non-native Aquatic Plants in the Town of Winchester Lakes

Curly-leaf pondweed

Curly-leaf pondweed (*Potamogeton crispus*; CLP; Photo 3.4-6) is a non-native aquatic plant that has invaded over 530 waterbodies in Wisconsin. The plant may outcompete other native aquatic vegetation with its dominating, aggressive growth and reach the point where its populations form dense mats on the surface of a lake's littoral zone. These dense mats impact recreation as well as the ecology of the lake. Further, a natural, mid-summer senescence (die-back) of large populations of CLP may contribute to an increase of water column phosphorus with larger populations resulting in mid-summer algal blooms.

Photo 3.4-6. The non-native, invasive aquatic plant curly-leaf pondweed.

Curly-leaf pondweed was first discovered in Harris Lake in 2008 by members of the Harris Lake Association, Inc. (HLA), and was later verified by the WDNR. Following its discovery, the HLA was advised to seek professional assistance to survey the lake for additional occurrences of CLP and develop an appropriate management strategy for controlling and monitoring the population. Of the eight lakes studied to date within Phase I, II, and III, CLP has only been found in Harris Lake.

In the fall of 2008, the HLA contracted with Onterra aid in the development of a CLP management strategy. With Onterra's assistance, the HLA was awarded a WDNR Aquatic Invasive Species (AIS)-Early Detection and Response (EDR) Grant to aid in the funding of the CLP surveys in 2009 and 2010 and associated treatment development and monitoring. Onterra ecologists completed the first whole-lake meander-based mapping of CLP in Harris Lake in June of 2009. This survey revealed a number of isolated colonies of CLP comprised mainly of single plants spread around the lake (Figure 3.4-11). The first herbicide application of approximately 10.4 acres using endothall to control CLP occurred in the spring of 2011.

Traditionally, CLP control strategies involve the annual application of herbicide in May/June with a goal of causing plant mortality before they are able to produce asexual reproductive structures called turions. Studies have indicated that viable CLP turions can remain dormant within the sediment for at least seven years, and is the reason a number of consecutive annual treatments are needed to prevent the formation of new turions and to kill plants that sprout from dormant turions deposited in years past. After multiple years of treatment (generally three to five), the turion bank within the sediment is exhausted and the CLP population declines.

Post-treatment assessments of the 2011 treatment were deemed successful as little to no CLP could be observed within the herbicide application areas. Subsequent endothall applications occurred during the springs of 2012 (4.1 acres) and 2013 (2.0 acres). These treatments were followed-up by volunteer monitoring and hand-removal by HLA volunteers. The HLA volunteers also implemented monitoring and hand-removal of CLP in smaller areas that were no applied with herbicide. All of these treatments were deemed successful, and following the mapping of CLP in

2013, it was determined that the CLP had declined to a level that did not warrant herbicide treatment in 2014 and that manual hand-removal by HLA volunteers would be the most appropriate method for control.

In the early summer of 2014, Onterra ecologists completed a mapping survey aimed at locating occurrences of CLP. These locations would then be provided to the HLA volunteers for their use in hand-removal. However, Onterra ecologists were unable to locate any of the CLP that had been mapped in 2013 nor was any CLP observed in any of areas previously applied with herbicide. While volunteer hand-removal of CLP did not occur in 2014, the HLA volunteers monitored the lake for potential occurrences of CLP; however, no additional CLP was located.

On June 30, 2015, Onterra ecologists completed the Early-Season AIS Survey on Harris Lake as part of the Town of Winchester Lake Management Planning Project – Phase I. During this survey, Onterra ecologists were unable to locate any occurrences of CLP. Onterra ecologists returned to Harris Lake on June 29, 2016 to complete another Early-Season AIS Survey as part of the Town of Winchester Lake Management Planning Project – Phase II. During this survey, three plants were located in close proximity to one another in the northwestern portion of the lake (Figure 3.4-12). These plants were hand-removed with a rake during this survey.

On June 1, 2017, NLDC staff located a clump of CLP in Harris Lake in the same locations where the plants were observed in 2016. The NLDC informed the HLA of their observation, and both NLDC staff and HLA volunteers conducted hand-removal of CLP within this area. On June 27, 2017, Onterra ecologists visited Harris Lake to complete the Early-Season AIS Survey. During this survey, a remaining small clump of CLP was observed in the area where the NLDC had reported plants and where hand-removal had taken place (Figure 3.4-12). The NLDC will be completing AIS surveys on Harris Lake again in 2018 and Onterra ecologists are also scheduled to complete an AIS survey in 2018 if the Phase IV grant is successfully awarded. Based on the findings in 2017, it is likely that any CLP located in Harris Lake in 2018 will likely lend itself well to hand-removal. The continued monitoring and management of CLP in Harris Lake beyond 2018 is discussed within the Harris Lake Implementation Plan (Ind. Lake Report Section Harris Lake 8.1).

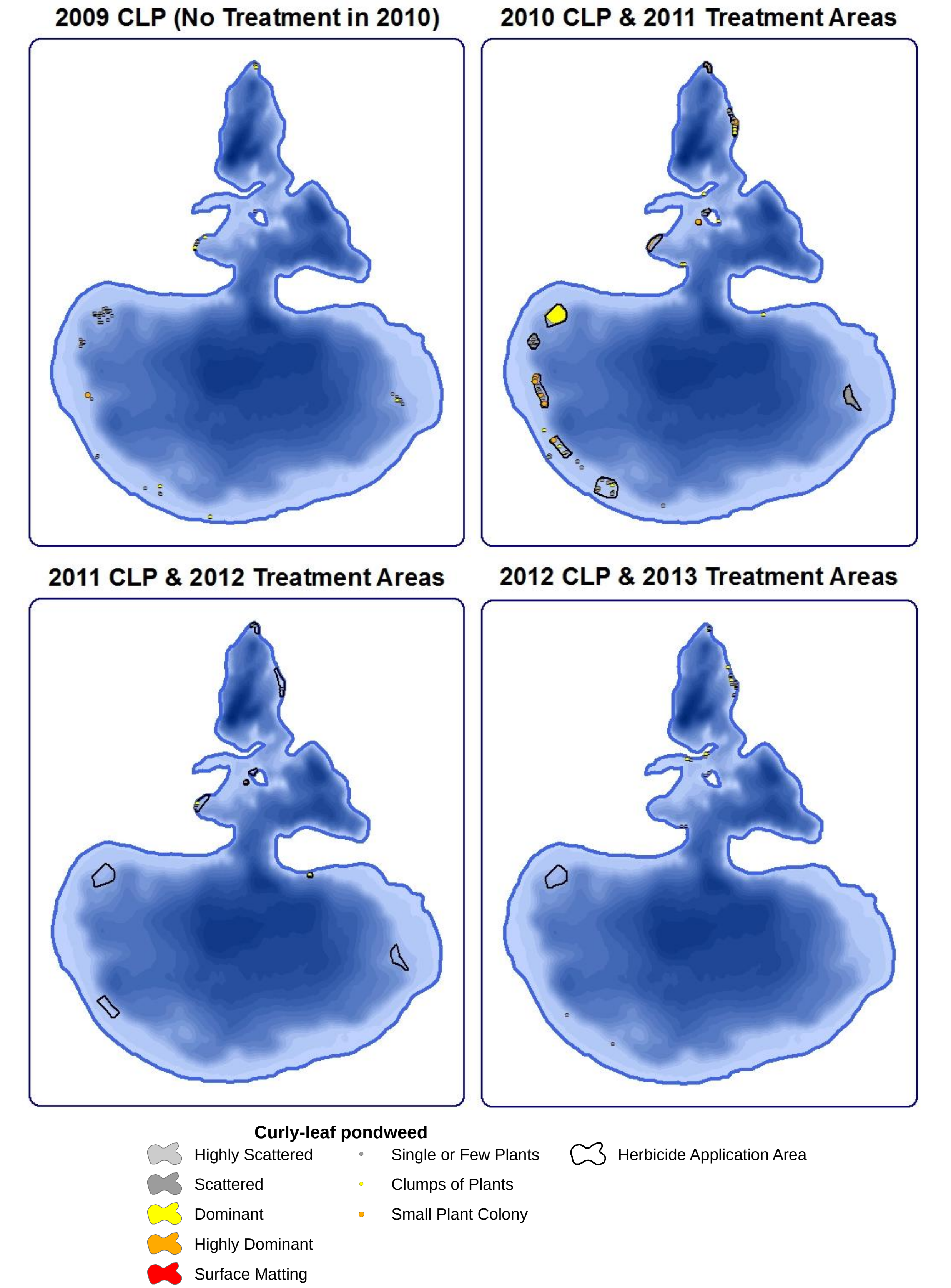

Figure 3.4-11. Locations of CLP and herbicide application areas in Harris Lake from 2009-2012.

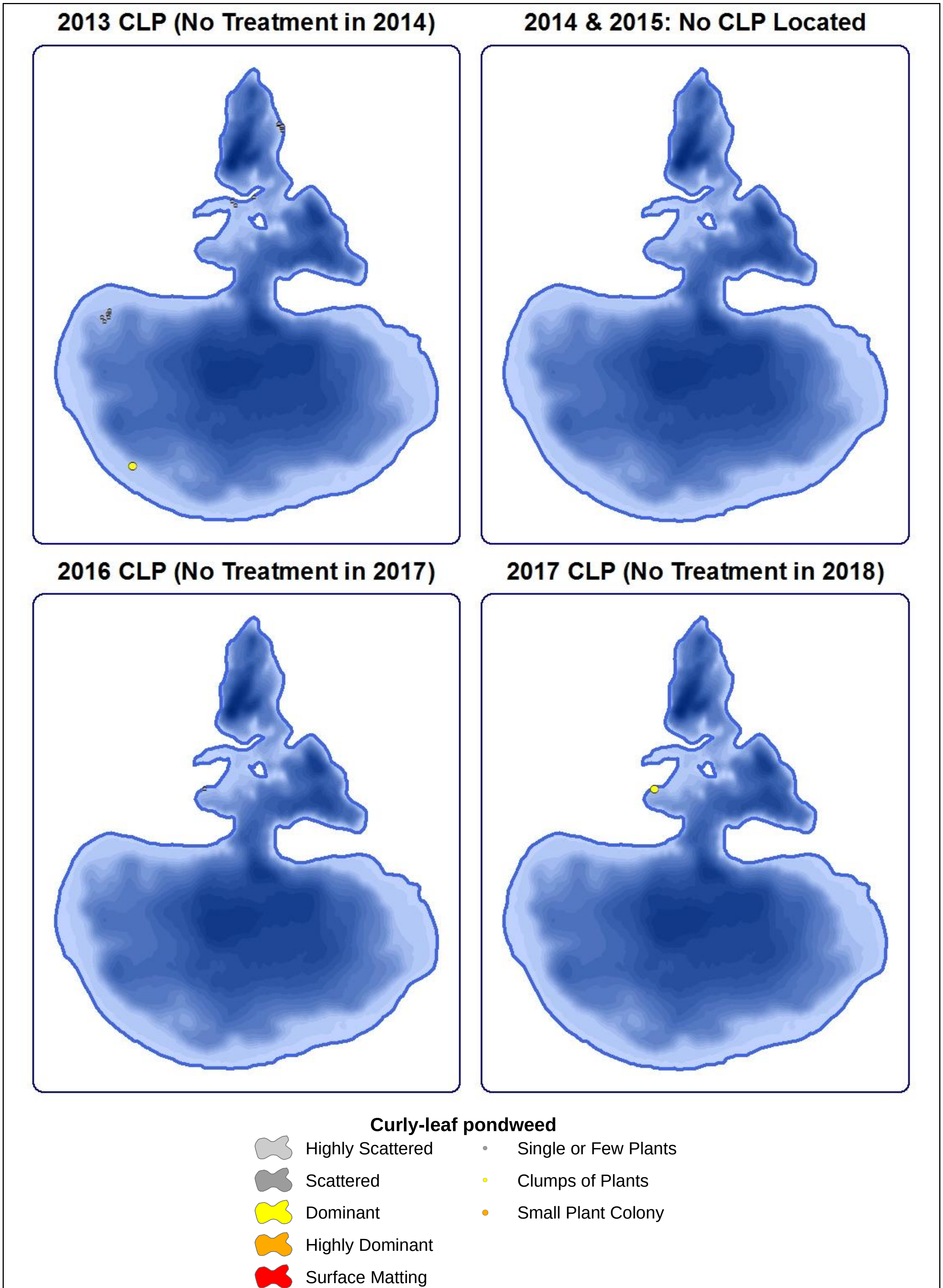

Figure 3.4-12. Locations of CLP in Harris Lake from 2013-2016.

Pale-yellow Iris

Pale yellow iris (*Iris pseudacorus*; Figure 3.4-13) 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 was located growing along the shorelines of Rock, North Turtle, and South Turtle lakes by NLDC and Onterra staff in 2017 (Figure 3.4-13). There are a number of control strategies that can be used to control pale-yellow iris. A strategy for managing pale-yellow iris on the Turtle Chain is discussed within the Turtle Chain Implementation Plan.

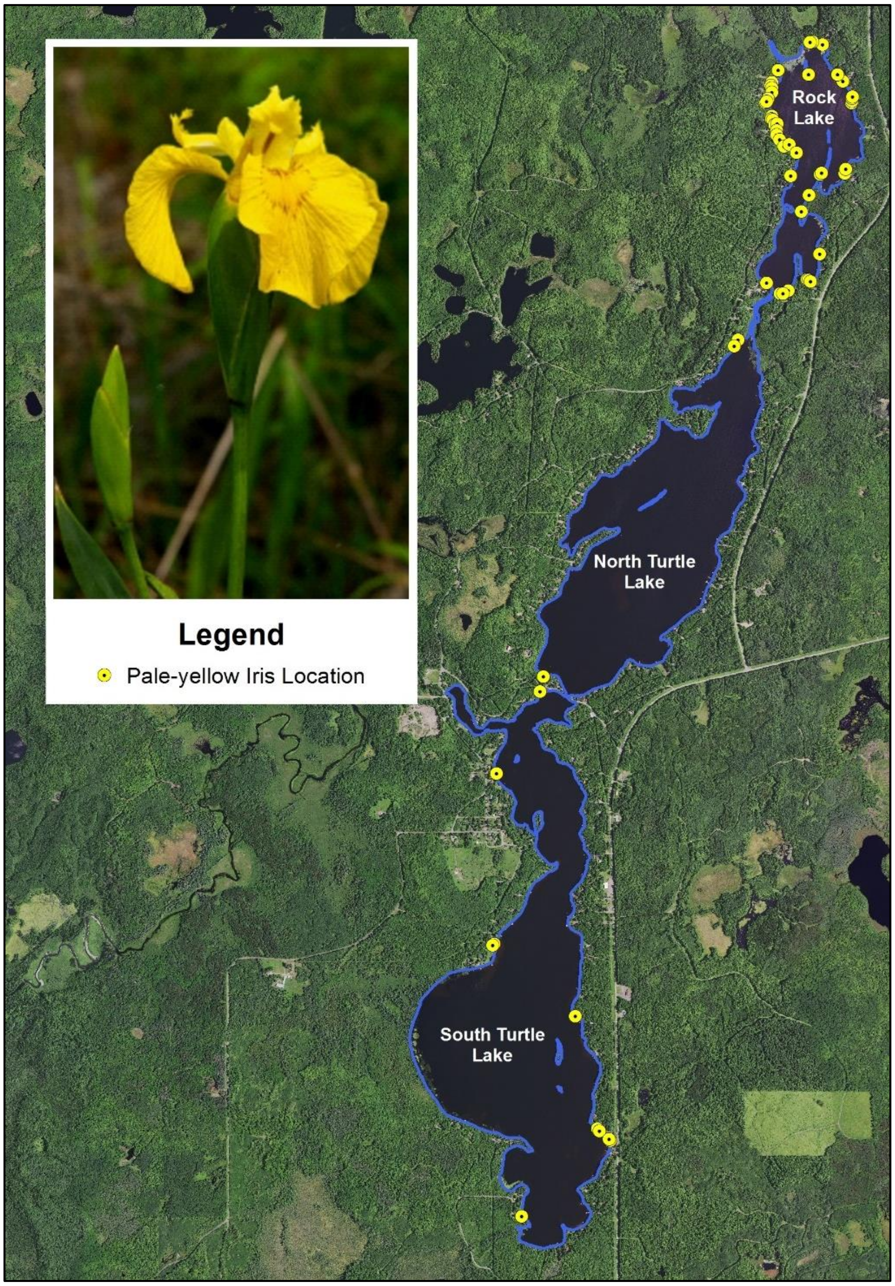

Figure 3.4-13. Rock, North Turtle, and South Turtle lakes 2017 pale-yellow iris locations.

3.5 Other Aquatic Invasive Species in the Town of Winchester Lakes

While non-native, aquatic invasive plants (e.g. curly-leaf pondweed) were discussed in the Aquatic Plant Section, a number of aquatic invasive invertebrates have been documented within the Town of Winchester project lakes (Table 3.5-1). These include the banded mystery snail (*Viviparus georgianus*), Chinese mystery snail (*Cipanogopaludina chinensis*), rusty crayfish (*Orconectes rusticus*), and the freshwater jellyfish (*Craspedacusta sowerbyi*). To date, plankton tows were completed by Onterra ecologists on the Phase I lakes in an effort to detect potential occurrences of zebra mussel (*Dreissena polymorpha*) veligers and the spiny waterflea (*Bythrotrephes cederstroemi*), and the samples were negative for the presence of both species.

Table 3.5-1. Aquatic invasive species in the Town of Winchester project lakes. Species presence documented by the WDNR. Updated in 2016.

			Phase I		Phase II			Phase III			Phase IV			
Type	Scientific Name	Common Name	Harris Lake	Hiawatha Lake	Birch Lake	Rainbow Lake	Tamarack Lake	North Turtle Lake	South Turtle Lake	Rock Lake	Circle Lily Lake	Lake Adelaide	Lake Helen	Pardee Lake
Plant	*Lythrum salicaria*	Purple loosestrife										X		
	Myosotis scorpioides	Aquatic forget-me-not			X									
	Potamogeton crispus	Curly-leaf pondweed	X											
Snail	*Cipanogopaludina chinensis*	Chinese mystery snail			X									
	Viviparus georgianus	Banded mystery snail			X									X
Crayfish	*Orconectes rusticus*	Rusty crayfish			X			X			X		X	
Jellyfish	*Craspedacusta sowerbyi*	Freshwater jellyfish												X

X = AIS species presence documented by WDNR as of 2016

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

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). The ecological impacts from freshwater jellyfish, which are believed to have been introduced from China, are not known. However, it is theorized that these jellyfish may have some impacts to zooplankton communities.

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 within each lake's individual report section. The fishery data integration sections are not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing the Town of Winchester Lakes. The goal of these sections is to provide an overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc.) that were brought forth by the stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected as a part of this project, the fisheries information was compiled based upon some of the data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2016 & GLIFWC 2016A and 2016B).

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three primary objectives:

1) Collect baseline data to increase the general understanding of the Town of Winchester project lakes' ecosystems.
2) Collect detailed information on non-native aquatic plant species, if present, within each lake.
3) Collect sociological information from lake stakeholders regarding their use of their lake and their thoughts pertaining to the past and current condition of the lake and its management.

Completing a town-wide comprehensive management plan for a large group of lakes which differ in their morphometry, water quality, and aquatic plant communities is an ambitious undertaking. By dividing the project into four phases, the Town of Winchester, NLDC, WDNR, and Onterra ecologists were able to provide individualized attention to two to four lakes at a time and address specific issues that arose for each lake during the planning project. This is important because while these lakes are in close proximity to one another, differences in their morphometry and position within the landscape drive differences in their water quality and aquatic plant communities. This process allowed individual lake challenges, such as the population of curly-leaf pondweed in Harris Lake, to be addressed.

The studies completed to date on the Phase I, II, and III lakes indicate that these lakes are overall very healthy. Historical water quality data and data collected as a part of this project indicate that the water quality parameters assessed fall within the *excellent* to *good* category for all eight lakes. The watersheds for these five lakes contain minimal human development, and watershed modeling indicates that the majority of the phosphorus within these lakes originates from natural sources. Conservation of the natural land cover within these watersheds will ensure that the water quality and habitat in these lakes is maintained into the future.

The aquatic plant surveys found that these five lakes harbor high quality native aquatic plant communities, two of which are listed as species of special concern in Wisconsin: northeastern bladderwort and Vasey's pondweed. However, the species composition of these communities differs between the lakes, largely a result of differences in lake morphometry, water chemistry, and light availability. While Harris Lake contains a population of the non-native curly-leaf pondweed, the most recent survey in 2017 indicates that efforts to reduce the occurrence of this plant have been successful and the population is currently comprised of a few single plant-occurrences. Continued monitoring of the curly-leaf pondweed in Harris Lake will ensure that actions can be taken quickly if larger colonies do develop.

The Town of Winchester harbors high-quality lakes that are sought after by recreationalists for varying uses. These exceptional water resources are utilized for relaxation, wildlife viewing, fishing, swimming, and more. With the knowledge that that continues to be gained through this lake management project, the Town of Winchester will have a strategic plan in place to maximize the positive attributes of each lake, minimize negative attributes, and effectively and efficiently manage the town's lakes as ecosystems. The Town-Wide Implementation Plan that follows is a result of the hard work for many Town of Winchester lakes' stakeholders, NLDC staff, and WDNR staff, and can be applied to each lake within the town. Lake-specific issues are addressed within the individual lake implementation plans found within the individual lake sections.

5.0 IMPLEMENTATION PLAN

The Town-Wide Implementation Plan will begin to be developed as a part of the Phase IV project.

6.0 METHODS

Lake Water Quality

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

Parameter	Spring		June		July		August		Fall		Winter	
	S	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**	**S**	**B**
Dissolved Phosphorus	●	●			●	●					●	●
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Chlorophyll-*a*	●		●		●		●		●			
True Color	●				●							
Hardness	●				●							
Total Suspended Solids	●	●			●	●			●	●		
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Calcium	●				●							

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on each lake in mid to late June in order to correspond with the anticipated peak growth of the plant. Please refer to each individual lake section for the exact date in which each survey was conducted. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on each lake in July or August of the corresponding phase to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the WDNR document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (Hauxwell 2010) was used to complete the studies. Based upon advice from the WDNR, the resolution of sampling points found in Table 3.4-1 were used.

During the species inventory work, the aquatic vegetation community types within each lake (emergent and floating-leaved vegetation) were mapped using a Trimble GeoXT Global Positioning System (GPS) with sub-meter accuracy. These surveys were conducted on each lake during their respective years. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were collected, pressed, and sent to the University of Wisconsin-Stevens Point herbarium for verification of correct identification.

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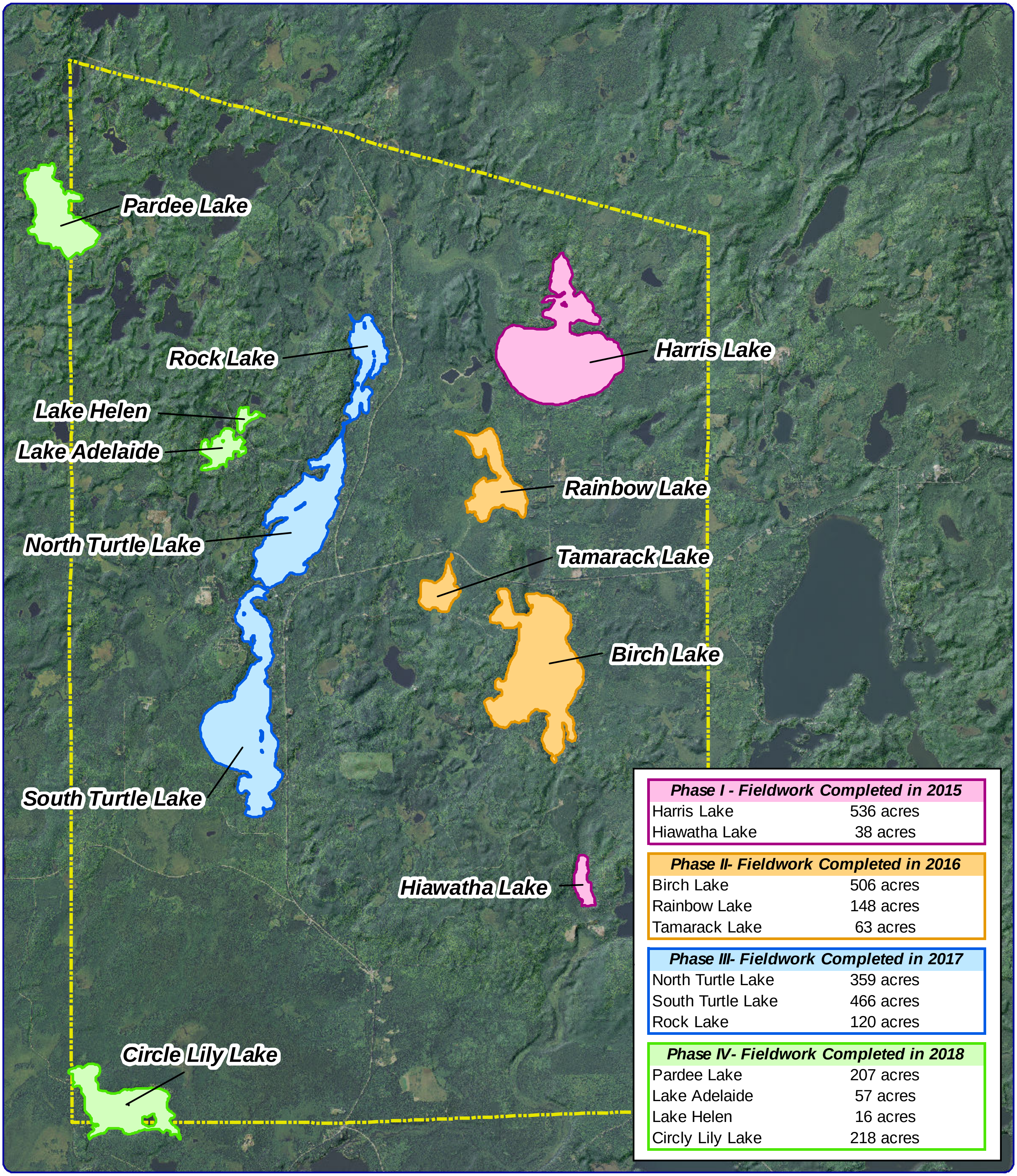

Phase I - Fieldwork Completed in 2015	
Harris Lake	536 acres
Hiawatha Lake	38 acres
Phase II- Fieldwork Completed in 2016	
Birch Lake	506 acres
Rainbow Lake	148 acres
Tamarack Lake	63 acres
Phase III- Fieldwork Completed in 2017	
North Turtle Lake	359 acres
South Turtle Lake	466 acres
Rock Lake	120 acres
Phase IV- Fieldwork Completed in 2018	
Pardee Lake	207 acres
Lake Adelaide	57 acres
Lake Helen	16 acres
Circly Lily Lake	218 acres

N W E S

1
Miles

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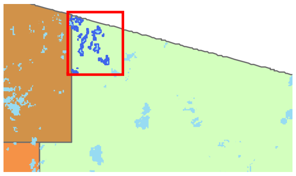
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads & Hydro: WDNR
Orthophotgraphy: NAIP, 2013
Map date: June 2, 2016
Filename: Map1_Winchester_Location.mxd


Extent of large map shown in red.

Legend

Winchester Township

Map 1
Town of Winchester Lakes
Vilas County, Wisconsin

Project Location & Lake Boundaries

Please note that study methods and explanations of analyses for Harris Lake can be found within the Town of Winchester Town-wide Management Plan document.

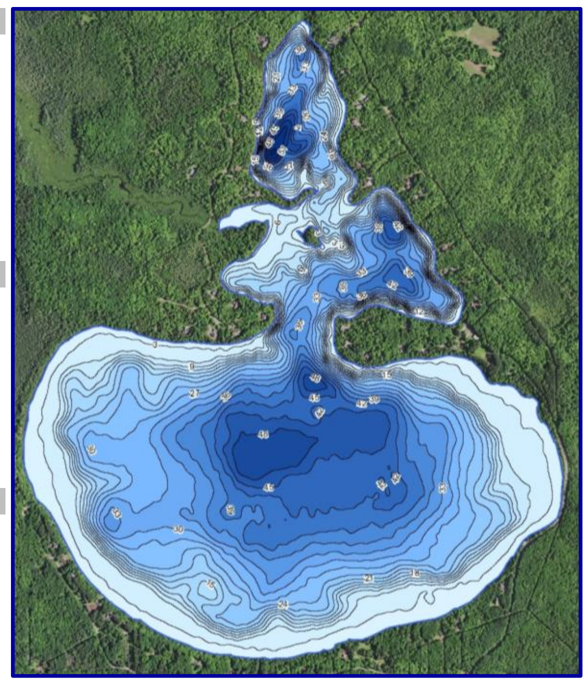
8.1 Harris Lake

An Introduction to Harris Lake

Harris Lake, Vilas County, is a deep, headwater oligo-mesotrophic drainage lake with a maximum depth of 57 feet, a mean depth of 24 feet, and a surface area of approximately 536 acres (Harris Lake – Map 1). Its surficial watershed encompasses approximately 2,348 acres comprised mainly of intact forests and wetlands. Water from Harris Lake flows out through Harris Creek to the Presque Isle River and ultimately Lake Superior. In 2015, 55 native aquatic plant species were located within the lake, of which muskgrasses (*Chara* spp.) were the most common. A small population of the non-native aquatic plant curly-leaf pondweed (*Potamogeton crispus*) was discovered in the lake in 2008; however, control strategies including herbicide applications and manual hand-removal have significantly reduced this population.

Lake at a Glance - Harris Lake

Morphology	
LakeType	Deep, Headwater Drainage
Surface Area (Acres)	536
Max Depth (feet)	57
Mean Depth (feet)	24
Perimeter (Miles)	5.8
Shoreline Complexity	3.2
Watershed Area (Acres)	2,348
Watershed to Lake Area Ratio	3:1
Water Quality	
Trophic State	Oligo-mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	12.2
Avg Summer Chl-α (µg/L)	2.4
Avg Summer Secchi Depth (ft)	16.1
Summer pH	8.1
Alkalinity (mg/L as $CaCO_3$)	38.7
Vegetation	
Number of Native Species	56
NHI-Listed Species	Northeastern bladderwort (*Utricularia resupinata*)
Exotic Species	Curly-leaf pondweed (*Potamogeton crispus*)
Average Conservatism	7.0
Floristic Quality	44.3
Simpson's Diversity (1-D)	0.91



Descriptions of these parameters can be found within the town-wide portion of themanagement plan

8.1.1 Harris Lake Water Quality

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

In 2015, a stakeholder survey was sent to 79 Harris Lake riparian property owners. Approximately 43%, or 34 surveys were completed. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Harris Lake, but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B. When asked about Harris Lake's current water quality, the majority of respondents (91%) described the current water quality of Harris Lake as *excellent* or *good*, 3% described it as *poor*, and 2% were *unsure* (Figure 8.1.1-1). When asked how water quality has changed in Harris Lake since they first visited the lake, approximately 61% of respondents indicated water quality has *remained the same*, 3% indicated it has *somewhat improved*, 24% indicated it has *somewhat* or *severely degraded*, and 12% were *unsure* (Figure 8.1.1-1).

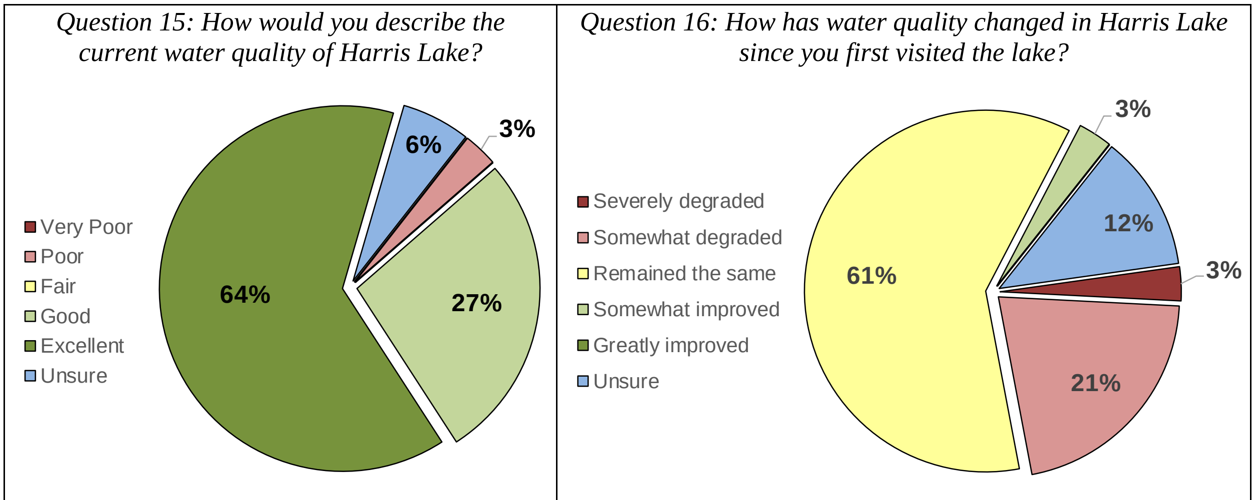


Figure 8.1.1-1. Harris Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 33 (43%) respondents of 79 surveys distributed.

Near-surface total phosphorus data for Harris Lake are available from 1979, 1992-1996, 1999, 2000, and 2002-2015 (Figure 8.1.1-2). All historical near-surface total phosphorus concentrations and the data collected as part of the lake management planning project in 2015 fall within the *excellent* category for deep, headwater drainage lakes in Wisconsin. The weighted average of summer near-surface total phosphorus concentrations using all data that are available is 12.2 µg/L, and falls below the median concentration for other deep, headwater drainage lakes in Wisconsin (17.0 µg/L) and the median concentration for all lake types within the Northern Lakes and Forests (NLF) ecoregion (21.0 µg/L).

Trends analysis indicates that near-surface total phosphorus concentrations have remained stable over the time period for which data are available, and no trends (positive or negative) are occurring over time. As is discussed further in Harris Lake Watershed Section, measured near-surface total phosphorus concentrations align with predicted concentrations based on watershed modeling. The mid-summer total nitrogen to total phosphorus ratio measured from Harris Lake in 2015 was 27:1, indicating that phosphorus is the limiting nutrient, or the nutrient controlling phytoplankton growth in Harris Lake.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Harris Lake from 1979, 1993-1996, 1999-2000, and 2002-2015 (Figure 8.1.1-3). With the exception of 1979, all historical data and the data collected in 2015 fall into the *excellent* category for deep, headwater drainage lakes. The average weighted summer chlorophyll-*a* concentration for Harris Lake is 2.4 µg/L, significantly lower than the median chlorophyll-*a* concentration for other deep, headwater drainage lakes in Wisconsin (5.0 µg/L) and the median concentration for all lake types within the NLF ecoregion (5.6 µg/L). The low level of phytoplankton production in Harris Lake is a result of the low concentrations of phosphorus, the nutrient regulating phytoplankton production. Trends analysis indicates that like total phosphorus, chlorophyll-*a* concentrations have remained stable over the time period for which data are available, and no trends (positive or negative) are occurring over time.

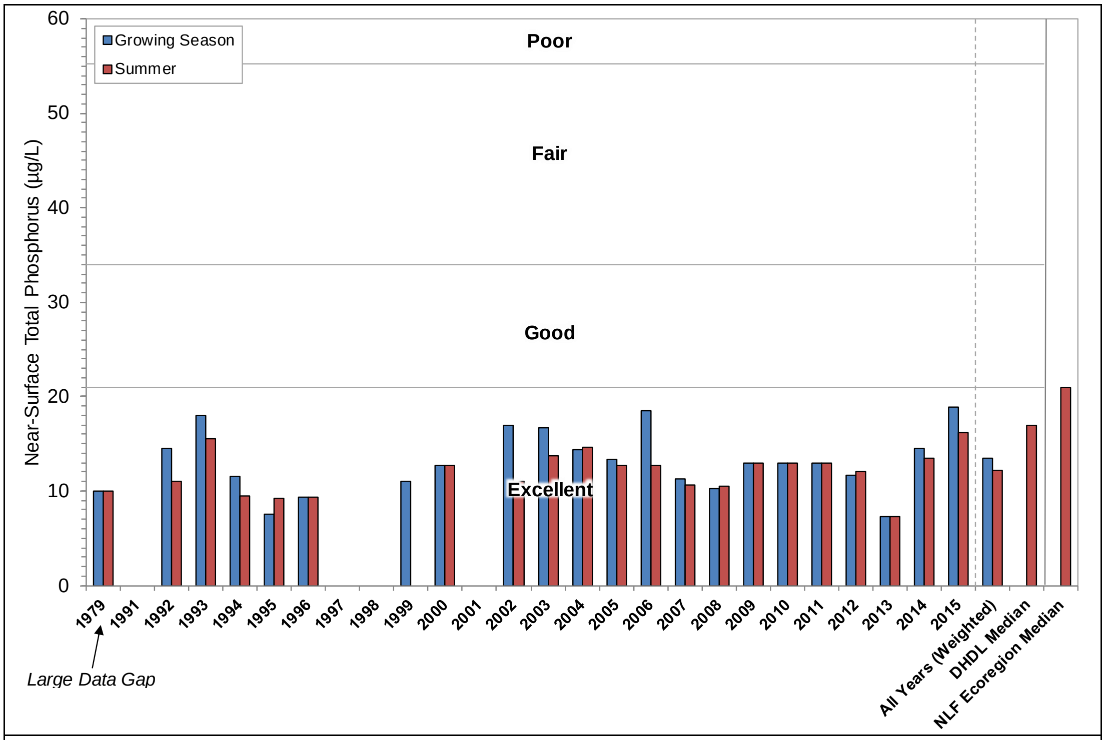


Figure 8.1.1-2. Harris Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data from Harris Lake are available from 1979, 1991-1996, 1999-2000, 2002-2004, and 2006-2015 (Figure 8.1.1-4). Average annual growing season and summer Secchi disk transparency data fall within the *excellent* category for deep, headwater drainage lakes for all years that have available data. The weighted average summer Secchi disk transparency in Harris Lake is 16.1 feet, exceeding the median value for other deep, headwater drainage lakes in Wisconsin (10.8 feet) and the median value for all lake types within the NLF ecoregion (8.9 feet).

Unlike total phosphorus and chlorophyll-*a* which have remained relatively stable in Harris Lake, Secchi disk transparency data indicate that water clarity is more variable from year to year. Trends analysis indicates that Secchi disk transparency in Harris Lake has been approximately 4.0 feet lower in 2013, 2014, and 2015 when compared to averages prior to 2013 (Figure 8.1.1-4). Given that water clarity in most Wisconsin lakes is governed by phytoplankton abundance, when water clarity begins to decline in a lake, ecologists look to see if there is a corresponding increase in chlorophyll-*a* concentrations. However, in Harris Lake, chlorophyll-*a* concentrations in 2013, 2014, and 2015 are not statistically different from those measured prior to 2013 indicating that another factor is driving the reductions in water clarity observed in these years.

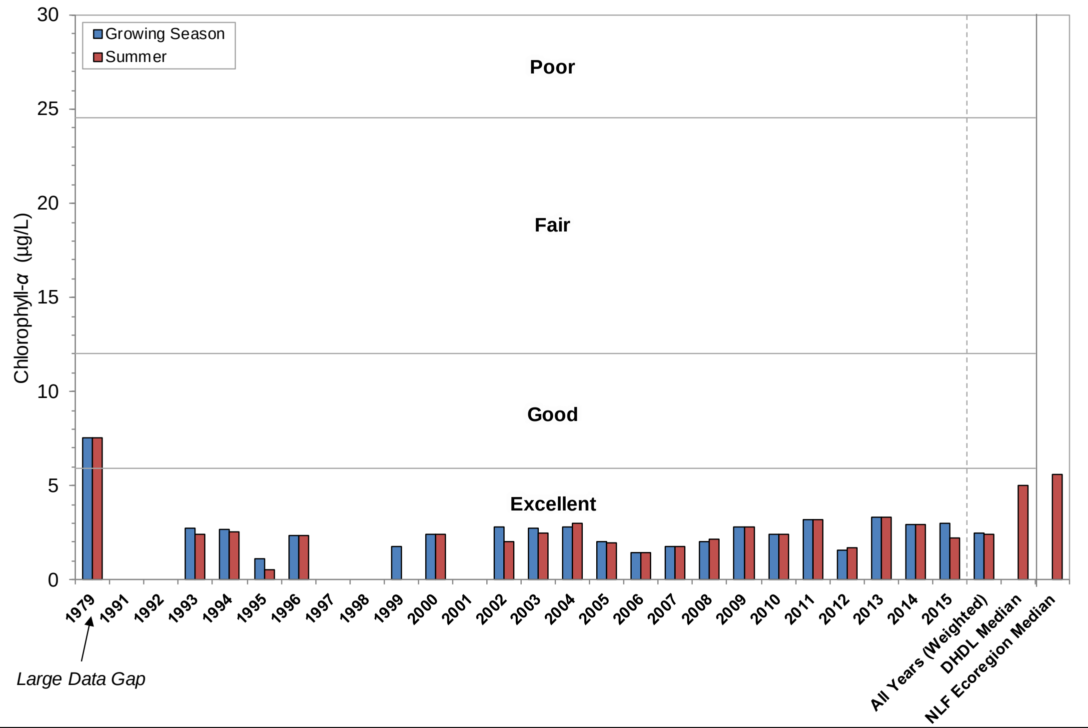


Figure 8.1.1-3. Harris Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep, headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Increases in abiotic suspended particulates, such as sediment, can cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were below the limit of detection in Harris Lake in 2015 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Harris Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and indicates the level of dissolved material within the water. True color values measured from Harris Lake in 2015 averaged 30 SU (standard units), indicating the lake's water is *lightly tea-colored*. The true color of Harris Lake's water was also measured in 2003 with a value of 15 SU, indicating *clear* water. It is believed that the concentration of dissolved organic compounds in Harris Lake increased in 2013 (and likely 2014 and 2015) as the result of increases in annual precipitation.

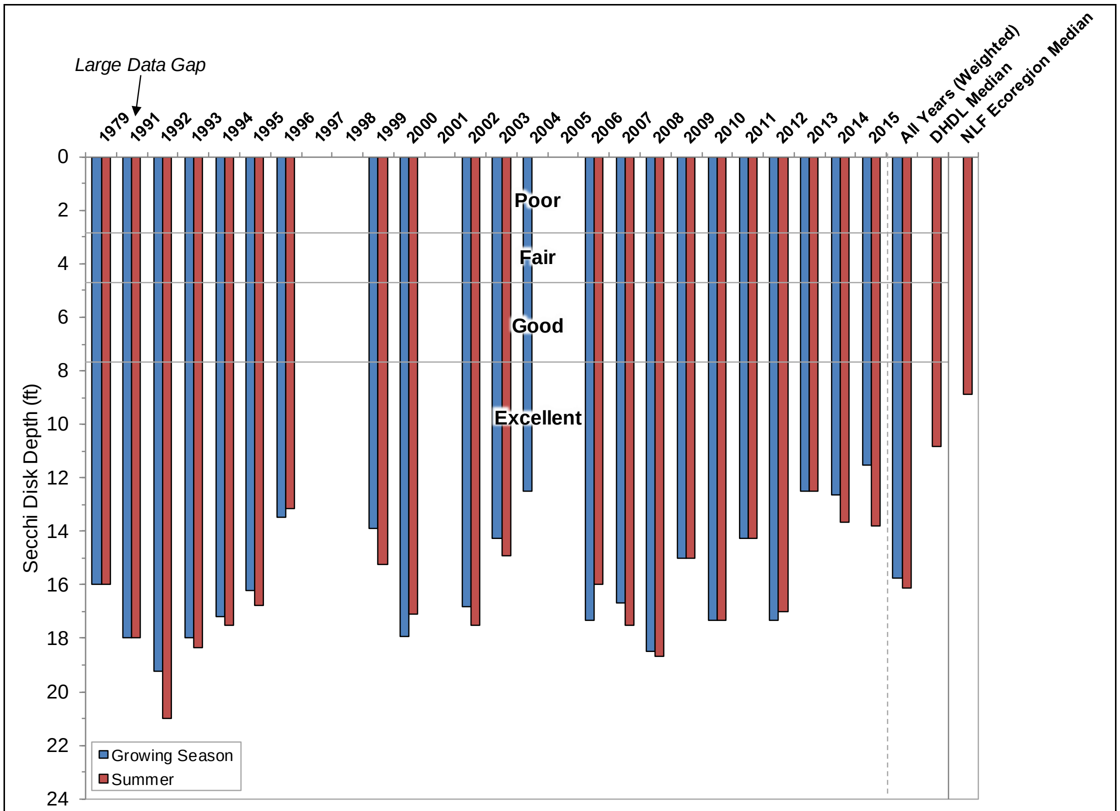


Figure 8.1.1-4. Harris Lake average annual Secchi disk depths and median Secchi disk depths for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Precipitation data obtained from nearby Hurley, WI indicate that precipitation in 2013 and 2014 was approximately 21 and 6 inches above average, respectively (Figure 8.1.1-5). This increase in precipitation likely flushed a greater amount of these dissolved organic compounds from coniferous wetlands in Harris Lake's watershed into the lake, resulting in reduced water clarity. While precipitation in 2015 was average, the dissolved compounds delivered to the lake in 2013 and 2014 likely persisted given the lake's water residence time of over five years. While these compounds contributed to a reduction in Harris Lake's water clarity, it is important to note that these compounds are natural and do not indicate degraded water quality. Given the large areas of coniferous wetlands in Harris Lake's watershed, it is to be expected that larger amounts of these dissolved compounds will be delivered to the lake during years with higher precipitation. Because chlorophyll-*a* concentrations have not increased over this same time period, the decline in water clarity in Harris Lake since 2013 is not of concern.

To determine if internal nutrient loading (discussed in town-wide section of management plan) occurs in Harris Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on three occasions from Harris Lake in 2015 and once in 2016, and historical near-bottom total phosphorus concentrations are available from 1979 and 1992-1996 (Figure 8.1.1-6). As illustrated, on some occasions near-bottom total phosphorus concentrations are similar to those measured near the surface, while on other occasions near-bottom concentrations are significantly higher than near-surface concentrations. The higher concentrations of phosphorus near the bottom occurred when Harris Lake was stratified and the cold, bottom layer of water (hypolimnion) was anoxic. These higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia, or that internal nutrient loading is occurring.

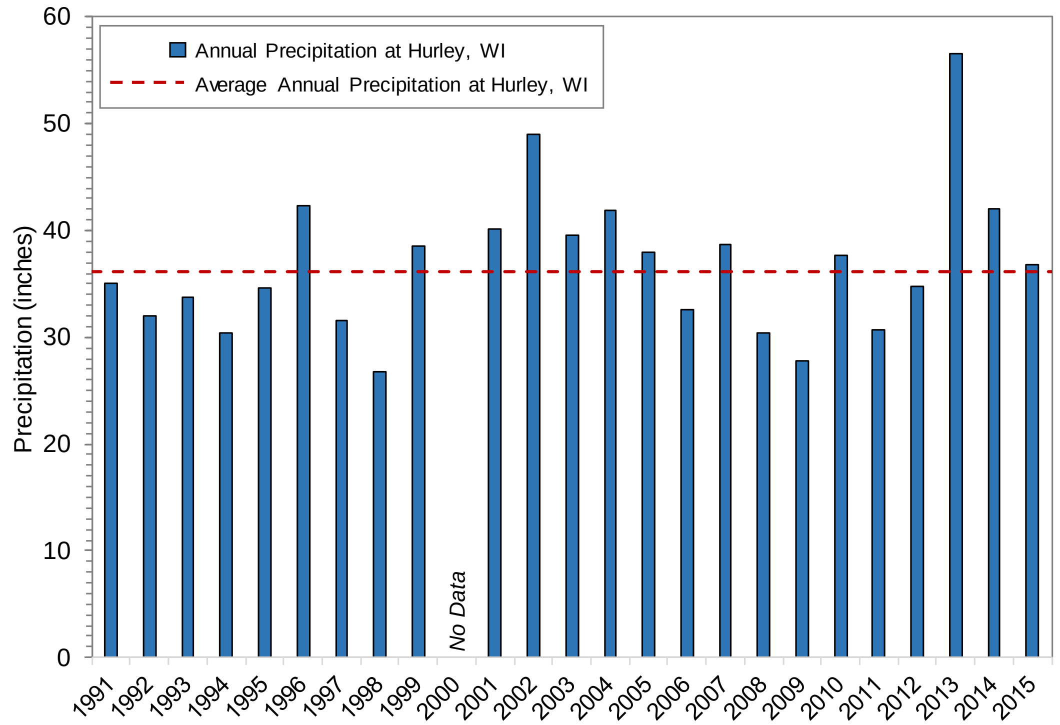


Figure 8.1.1-5. Total annual precipitation measured in Hurley, WI. Data obtained from National Oceanic and Atmospheric Administration website (https://www.ncdc.noaa.gov/cdo-web/).

While phosphorus is likely being released from bottom sediments into the hypolimnion during periods of stratification and anoxia in the summer, near-surface concentrations indicate that this sediment-released phosphorus is not being mixed into surface waters. Harris Lake is *dimictic*, meaning the lake completely mixes or turns over two times per year; once in spring and again in fall. While phosphorus is released from bottom sediments into the hypolimnion during periods of anoxia in the summer, this phosphorus remains 'trapped' near the bottom as the hypolimnion is unable to mix with the warmer epilimnion above due to large differences in density. In fall when the epilimnion cools and its density becomes similar to the hypolimnion below, the lake turns over and the phosphorus released into the hypolimnion is mixed throughout the water column.

Figure 8.1.1-7 displays the average monthly near-surface total phosphorus concentrations, chlorophyll-*a* concentrations, and Secchi disk transparency in Harris Lake calculated from all available growing season data. Near-surface total phosphorus concentrations are higher in the spring, likely a result of higher runoff from snowmelt and increased precipitation. As the summer progresses, near-surface total phosphorus concentrations decline as precipitation declines and phytoplankton incorporate the phosphorus into their tissues, die, and sink to the bottom. In fall, phosphorus concentrations quickly increase as the phosphorus that was released from bottom sediments into the hypolimnion is mixed throughout the water column during fall turnover. However, because this delivery of phosphorus from the near-bottom to the surface occurs in fall when water temperatures are cooler, an increase in phytoplankton growth is not observed. While internal nutrient loading occurs to some extent in Harris Lake, this phosphorus remains unavailable to phytoplankton at the surface in summer and does not appear to have a detectable impact to the lake's water quality.

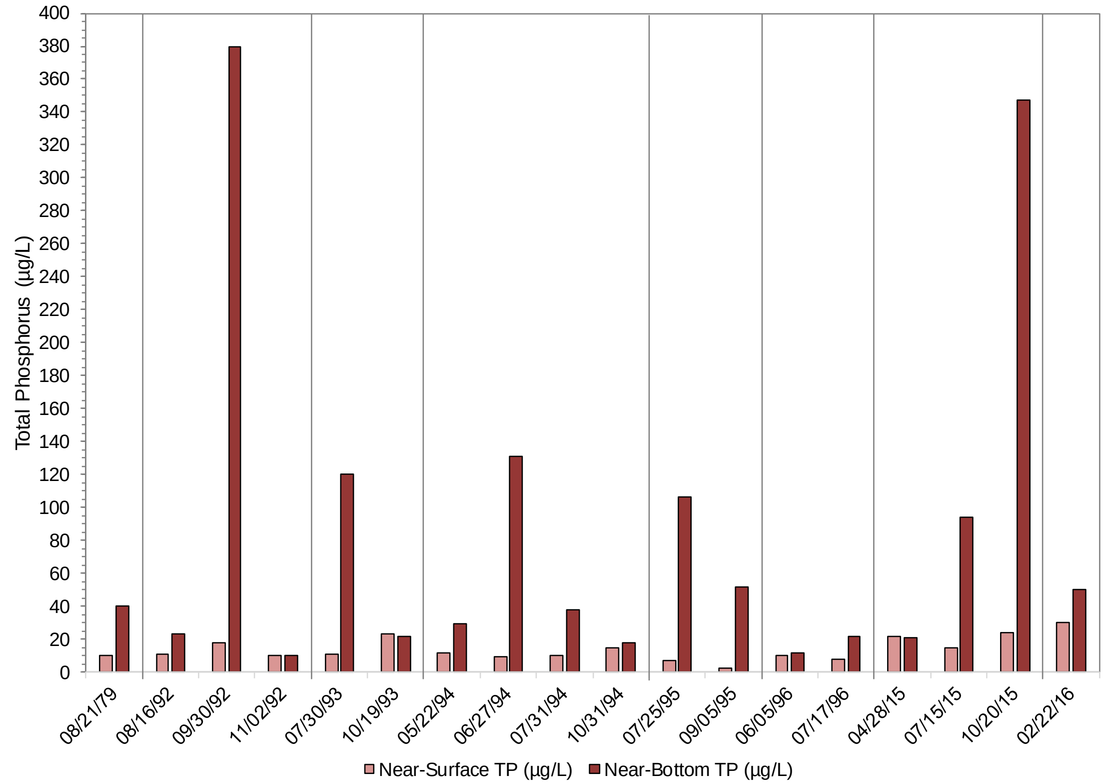


Figure 8.1.1-6. Harris Lake available near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations.

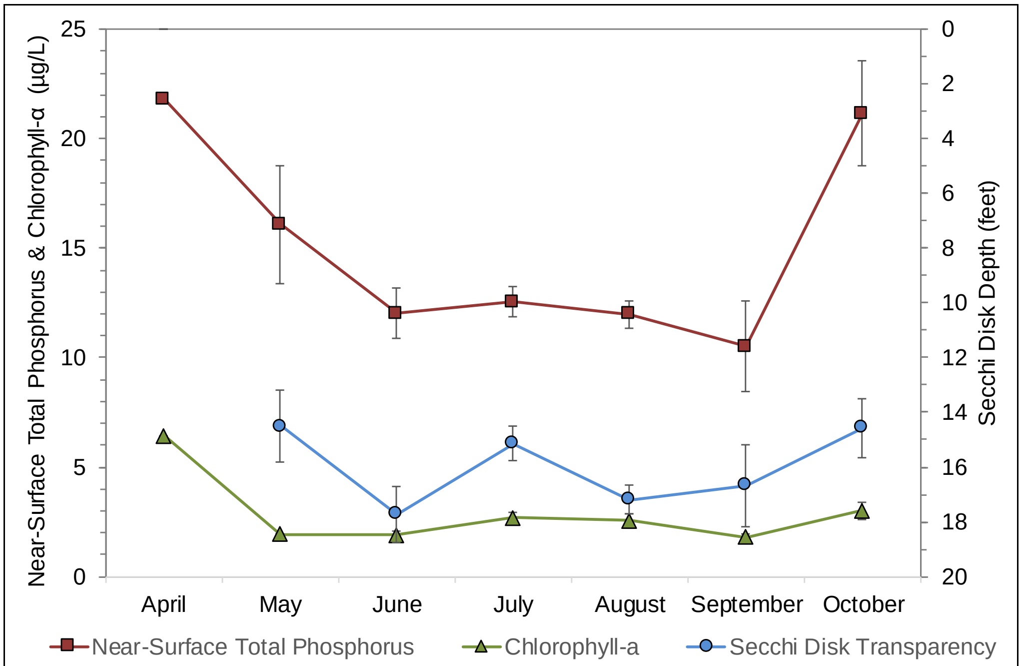


Figure 8.1.1-7. Harris Lake average monthly near-surface total phosphorus, chlorophyll-α, and Secchi disk transparency.

Harris Lake Trophic State

Figure 8.1.1-8 contains the weighted average Trophic State Index (TSI) values for Harris 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 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 Harris Lake straddle the threshold between oligotrophic and mesotrophic, and the lake can be classified as currently being in a oligo-mesotrophic state. Harris Lake's TSI values are all relatively similar, indicating phosphorus regulates phytoplankton growth and phytoplankton growth regulates water clarity. Harris Lake is in a lower productivity state than the majority of other deep, headwater drainage lakes in Wisconsin and the majority of lakes within the NLF ecoregion.

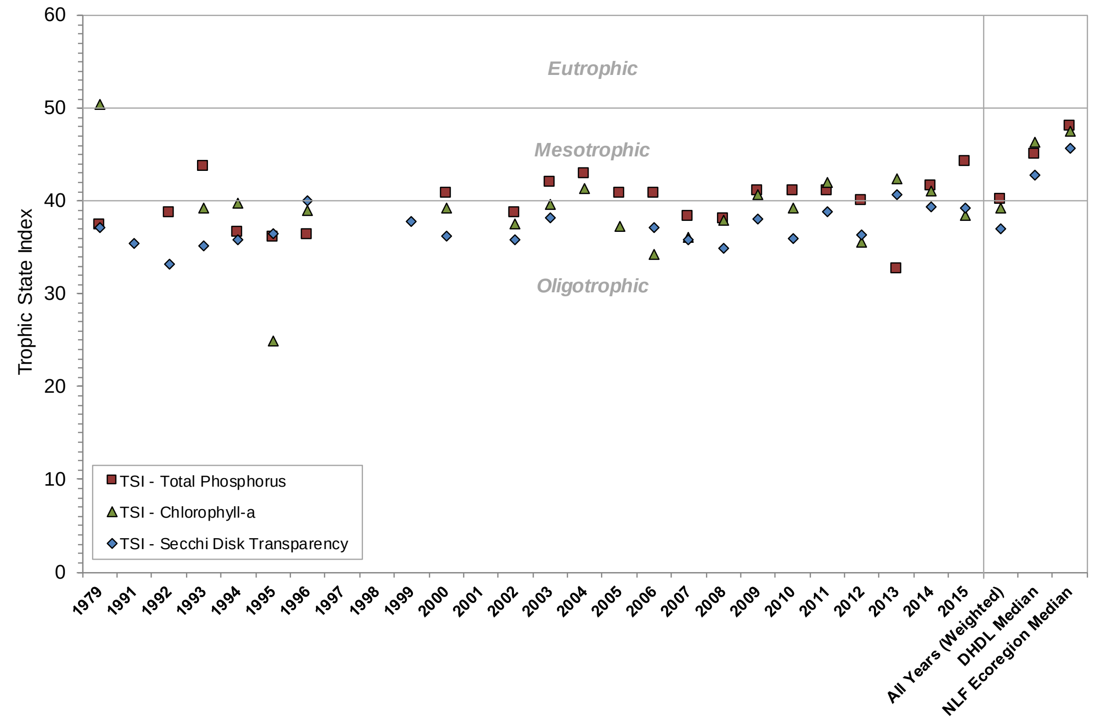


Figure 8.1.1-8. Harris Lake, statewide deep, headwater drainage lakes (DHDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Harris Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling event conducted by Onterra ecologists. These data are displayed in Figure 8.1.1-9. As mentioned previously, Harris Lake is dimictic, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Harris Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer, upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen, and decomposition of organic matter within this layer depletes available oxygen. Once anoxia sets in, phosphorus (and other nutrients) are released from bottom sediments into the overlying hypolimnion.

In fall as surface temperatures cool, the entire water column is again able to mix which re-oxygenates the hypolimnion and delivers sediment-released nutrients to the surface. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. In February of 2016, oxygen concentrations remained above 2.0 mg/L throughout the majority of the water column, indicating that fishkills as a result of winter anoxia are likely not a concern in Harris Lake.

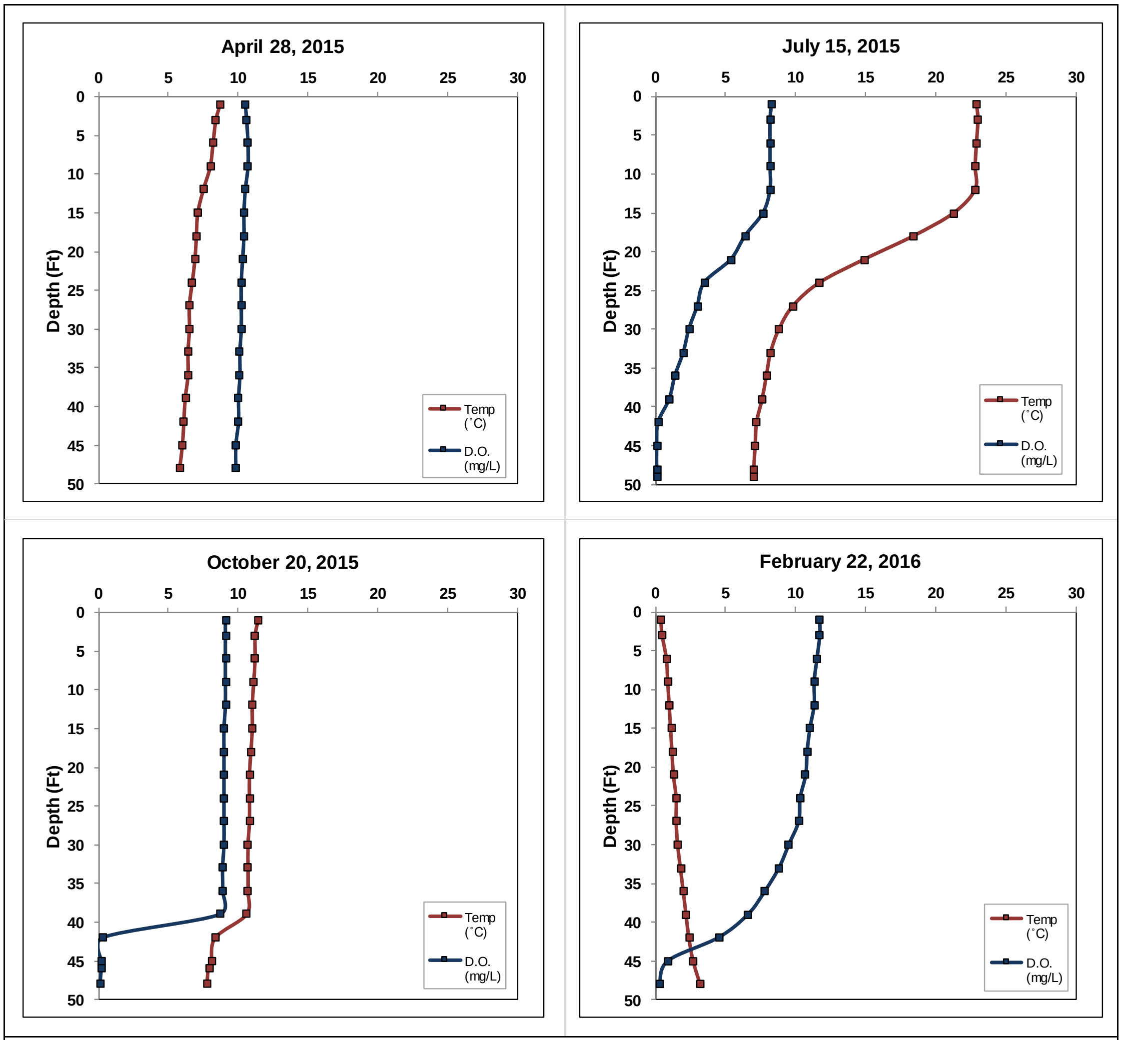


Figure 8.1.1-9. Harris Lake 2015/16 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Harris Lake

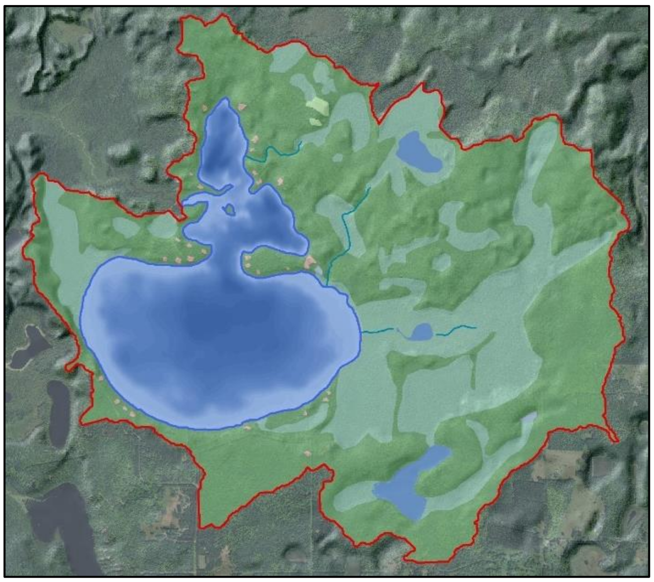
The previous section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Harris Lake's water quality and are recommended as a part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

As the Town-wide 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. Harris Lake's mid-summer surface water pH was measured at roughly 8.1 in 2015. This value indicates Harris Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Harris Lake's average alkalinity measured in 2015 was 38.7 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that Harris Lake is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from Harris Lake in 2015 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Harris Lake's pH falls within this range. Harris Lake's calcium concentration in 2015 was 12.2 mg/L, indicating the lake has *low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Harris Lake in 2015 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veliger and for the invasive spiny water flea.

8.1.2 Harris Lake Watershed Assessment

Harris Lake's surficial watershed encompasses approximately 2,348 acres (Figure 8.1.2-1 and Harris Lake – Map 2). The watershed is comprised mainly of natural land cover types including forests (51%), wetlands (26%), and the lake surface itself (23%) (Figure 8.1.2-1). Less than 1% is comprised of rural residential areas and pasture/grass. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Harris Lake's residence time is approximately 5.2 years, or the water within the lake is completely replaced once every 5.2 years.



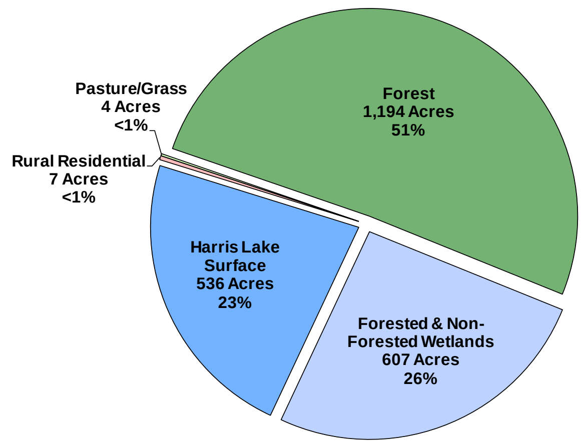


Figure 8.1.2-1. Harris Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types and their acreages within Harris Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Harris Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Harris Lake riparian property owners in 2015 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a total of approximately 299 pounds of phosphorus are delivered to Harris Lake from its watershed on an annual basis (Figure 8.1.2-2).

Of the estimated 299 pounds of phosphorus being delivered to Harris Lake on an annual basis, the majority (143 pounds - 8%) originates from atmospheric deposition directly onto the lake's surface (Figure 8.1.2-2). Forests account for approximately 95 pounds (32%), wetlands account for 55 pounds (18%), and riparian septic systems were estimated to account for approximately 5 pounds (2%). The phosphorus delivered from rural residential areas and pasture/grass were negligible. Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 14 µg/L, which is essentially identical to the measured growing season average total phosphorus concentration of 13.5 µg/L. The similarity between the predicted and measured total phosphorus concentrations in Harris Lake is an indication that this is an accurate model of the lake's watershed and that there are no significant, unaccounted sources of phosphorus entering the lake.

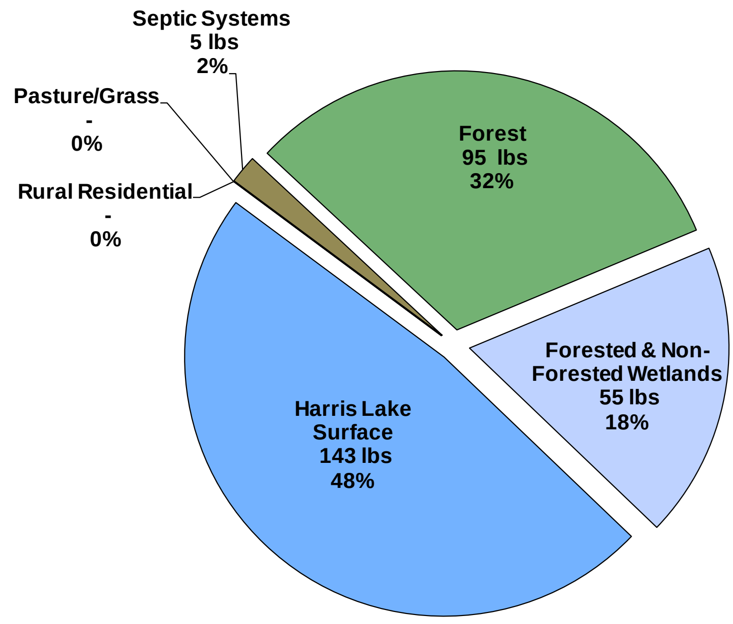


Figure 8.1.2-2. Harris Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the WiLMS model for Harris Lake's watershed, scenarios can be run to determine how Harris Lake's water quality would change given alterations to its watershed. For example, if 25% of the forests within Harris Lake's watershed were converted to pasture/grass, phosphorus concentrations are predicted to increase from the current growing season concentration of 13.5 µg/L to 16.0 µg/L. This increase in total phosphorus would result in chlorophyll-*a* concentrations increasing from the current growing season average of 2.5 µg/L to 4.8 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 15.8 feet to 10.4 feet. In another scenario, if 25% of the forests in Harris Lake's watershed were converted to row crop agriculture, phosphorus concentrations are predicted to increase to 21 µg/L, chlorophyll-*a* concentrations would increase to 7.2 µg/L, and Secchi disk transparency would decline to 8.0 feet. This modeling illustrates the importance of the natural land cover types within Harris Lake's watershed in maintaining the lake's excellent water quality.

8.1.3 Harris Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the late-summer of 2015, the immediate shoreland of Harris Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

The 2015 survey revealed that Harris Lake has stretches of shoreland that fit all of the five shoreland assessment categories (Figure 8.1.3-1). In total, 5.0 miles (88%) of the 5.8-mile shoreland zone were categorized as natural/undeveloped or developed-natural, or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.2 miles (4%) of the shoreland was categorized as developed-unnatural or urbanized, shorelands which provide little benefit to and may actually adversely impact the lake. If restoration of Harris Lake's shoreland is to occur, primary focus should be placed on these shoreland areas. Harris Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

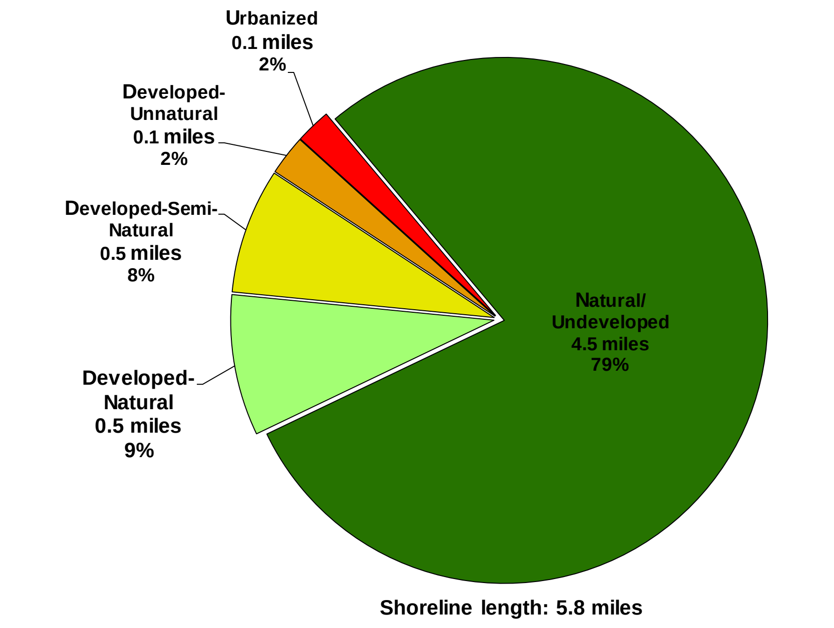


Figure 8.1.3-1. Harris Lake shoreland categories and total lengths. Based upon a late-summer 2015 survey. Locations of these categorized shorelands can be found on Harris Lake - Map 3.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Harris Lake in 2015. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on Harris Lake, a total of 624 pieces were observed along 5.8 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 108:1 (Figure 8.1.3-2). Onterra ecologists have been completing these surveys on Wisconsin's lakes for five years, and Harris Lake has one the highest coarse woody habitat pieces per shoreline recorded on any Onterra project to date. Refraining from removing these woody habitats from the

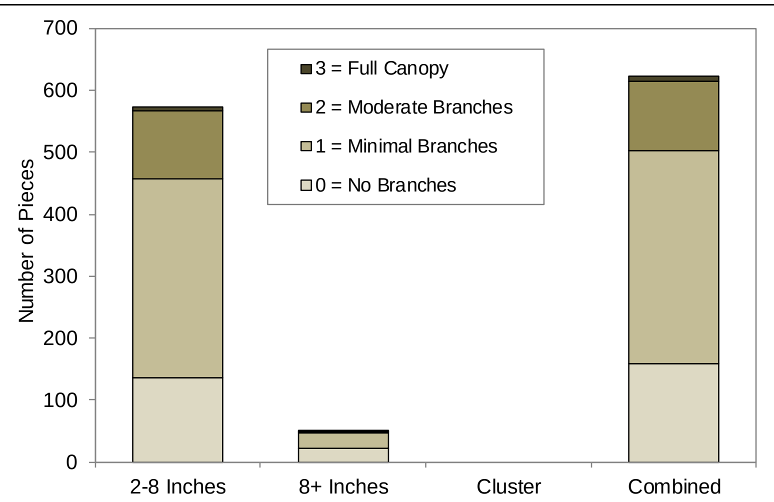


Figure 8.1.3-2. Harris Lake coarse woody habitat survey results. Based upon a late-summer 2015 survey. Locations of Harris Lake coarse woody habitat can be found on Harris Lake – Map 4.

shoreland area will ensure this high-quality habitat remains in these lakes. The locations of these coarse woody habitat pieces are displayed on Harris Lake – Map 4.

8.1.4 Harris Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Harris Lake on June 30, 2015. 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. Curly-leaf pondweed was discovered by Harris Lake Association members in 2008, and efforts to manage the population of this invasive plant are discussed in the subsequent Harris Lake Non-Native Plants section. However, no curly-leaf pondweed could be located in Harris Lake during the 2015 meander-based ESAIS survey.

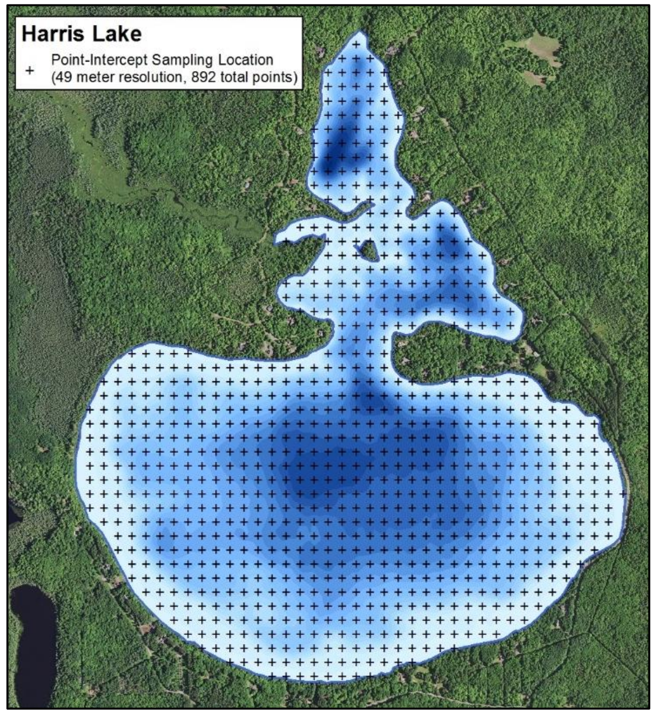


Figure 8.1.4-1. Harris Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Harris Lake by Onterra ecologists on August 4, 2015 (Figure 8.1.4-1). During these surveys, a total of 57 aquatic plant species were located, one of which is considered to be a non-native, invasive species: curly-leaf pondweed (Table 8.1.4-1). As mentioned previously, curly-leaf pondweed was not observed in 2015 following a number of years of control efforts; however, because it has been documented in previous surveys it is included here. One native aquatic plant species present in Harris Lake, northeastern bladderwort, is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state. The WDNR completed a whole-lake point-intercept survey on Harris Lake in 2009 following the discovery of curly-leaf pondweed, and the species located during that survey are also included in Table 8.1.4-1.

Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In early August of 2015, Onterra ecologists completed an acoustic survey on Harris Lake (bathymetric results shown in introduction). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Harris Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Table 8.1.4-1. List of aquatic plant species located in Harris Lake during Onterra 2015 and WDNR 2009 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2009 (WDNR)	2015 (Onterra)
Emergent	*Calla palustris*	Water arum	9		I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9		I
	Carex pseudocyperus	Cypress-like sedge	8		I
	Carex utriculata	Common yellow lake sedge	7		I
	Cladium mariscoides	Smooth sawgrass	10		I
	Dulichium arundinaceum	Three-way sedge	9	X	X
	Eleocharis palustris	Creeping spikerush	6	X	X
	Equisetum fluviatile	Water horsetail	7	X	X
	Juncus effusus	Soft rush	4		I
	Phragmites australis subsp. *americanus*	Common reed	5		I
	Pontederia cordata	Pickerelweed	9		X
	Sagittaria latifolia	Common arrowhead	3		I
	Sagittaria rigida	Stiff arrowhead	8		I
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Schoenoplectus pungens	Three-square rush	5	X	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		X
	Scirpus cyperinus	Wool grass	4		I
	Typha latifolia	Broad-leaf cattail	1		I
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8		I
FL	*Brasenia schreberi*	Watershield	7		X
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
	Persicaria amphibia	Water smartweed	5	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	9		I
	Sparganium fluctuans	Floating-leaf bur-reed	10		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Eriocaulon aquaticum	Pipewort	9	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes spp.	Quillwort spp.	8	X	X
	Littorella uniflora	American shoreweed	10	X	
	Lobelia dortmanna	Water lobelia	10	X	X
	Myriophyllum alterniflorum	Alternate-flowered water milfoil	10		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum tenellum	Dwarf water milfoil	10	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	8	X	
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton crispus °	Curly-leaf pondweed	Exotic	X	I
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6	X	
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X
	Potamogeton illinoensis	Illinois pondweed	6		X
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	8		X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus flammula	Creeping spearwort	9	X	X
	Stuckenia pectinata	Sago pondweed	3	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X	X
	*Utricularia resupinata**	Northeastern bladderwort	9	X	X
	Utricularia vulgaris	Common bladderwort	7		I
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X
	Juncus pelocarpus	Brown-fruited rush	8	X	X
	Sagittaria cristata	Crested arrowhead	9	X	I

FL/E = Floating Leaf and Emergent; FL = Floating Leaf; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern by WI Natural Heritage Inventory*
° = CLP documented in past surveys, but not observed in 2015

Data regarding substrate hardness collected during the 2015 acoustic survey reveals that Harris Lake's average substrate hardness ranges from hard to moderately hard with deeper areas containing softer, more flocculent sediments (Figure 8.1.4-2 and Harris Lak – Map 5). Substrate hardness is highest within the shallowest areas of Harris Lake, and between one and ten feet, hardness declines relatively rapidly with depth. From ten and deeper, substrate hardness remains relatively constant. Figure 8.1.4-3 illustrates the spatial distribution of substrate hardness in Harris Lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

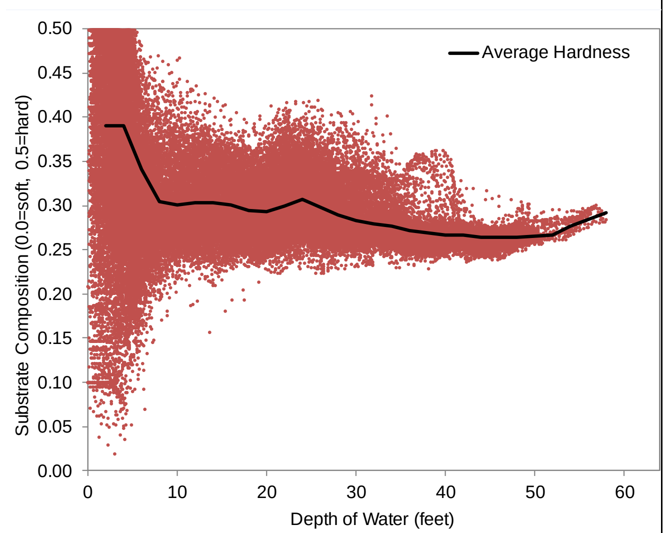


Figure 8.1.4-2. Harris Lake substrate hardness across water depth. Individual data points are displayed in red. Creating using data from August 2015 acoustic survey.

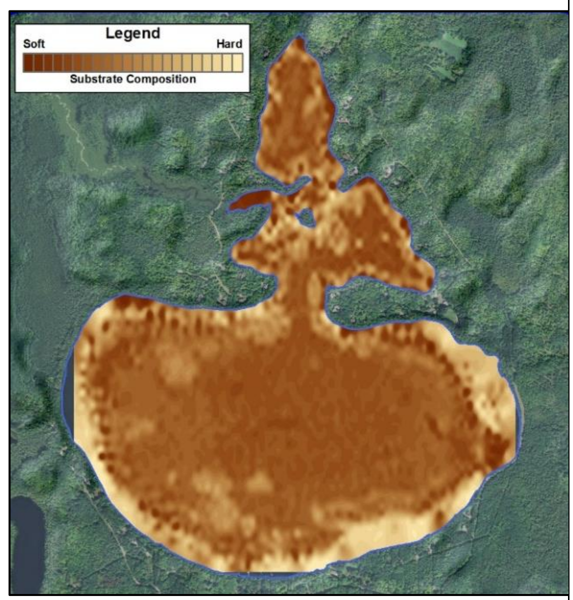


Figure 8.1.4-3. Harris Lake substrate hardness. Created using data from August 2015 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2015 aquatic plant bio-volume data are displayed in Figure 8.1.4-4 and Harris Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2015 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 28 feet, and the acoustic data indicate some growth at around 30 feet within the northern portion of the lake. However, the majority of aquatic plant growth occurs within the first 14 feet of water, and the presence of aquatic plants quickly diminished beyond 14 feet. Overall, the 2015 acoustic survey indicates that approximately 22% of Harris Lake contains aquatic vegetation (Figure 8.1.4-4). The remaining area of the lake is too deep to support aquatic plant growth.

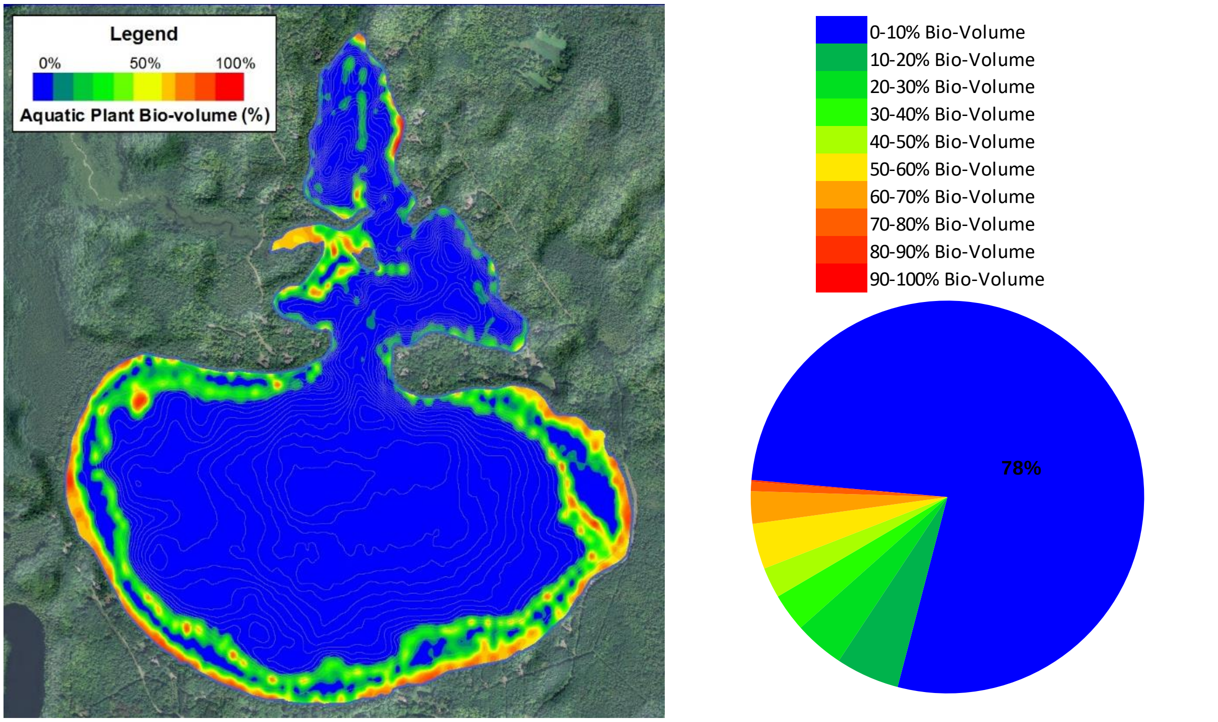


Figure 8.1.4-4. Harris Lake 2015 aquatic plant bio-volume. Created using data from August 2015 acoustic survey data. Contour lines represent three-foot increments.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. During the 2015 aquatic plant point-intercept survey, the maximum depth recorded with aquatic plants was 28 feet; however, this represented just one sampling location, and the majority of the plant growth was found in 14 feet of water or less. Of the 456 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone), approximately 49% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2015 indicates that 30% of the 456 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 13% had a TRF rating of 2, and 6% had a TRF rating of 3 (Figure 8.1.4-5).

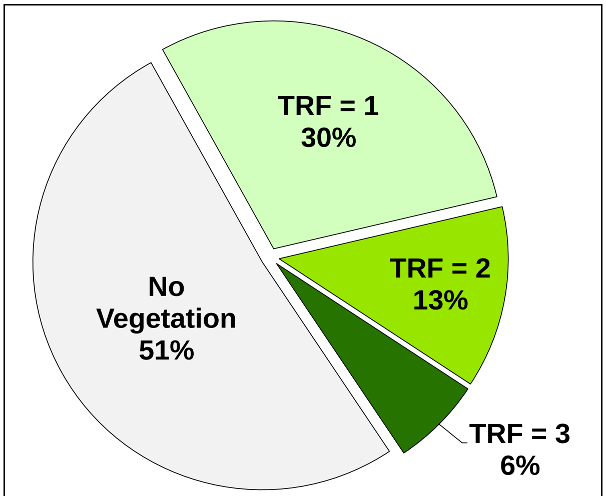


Figure 8.1.4-5. Harris Lake 2015 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2015 whole-lake point-intercept survey (N = 456).

Of the 57 aquatic plant species located in Harris Lake in 2015, 40 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.1.4-6). The remaining 17 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 40 species directly sampled with the rake during the point-intercept survey, muskgrasses, hardstem bulrush, slender naiad, variable-leaf pondweed, and wild celery were the five-most frequently encountered plants, respectively (Figure 8.1.4-6).

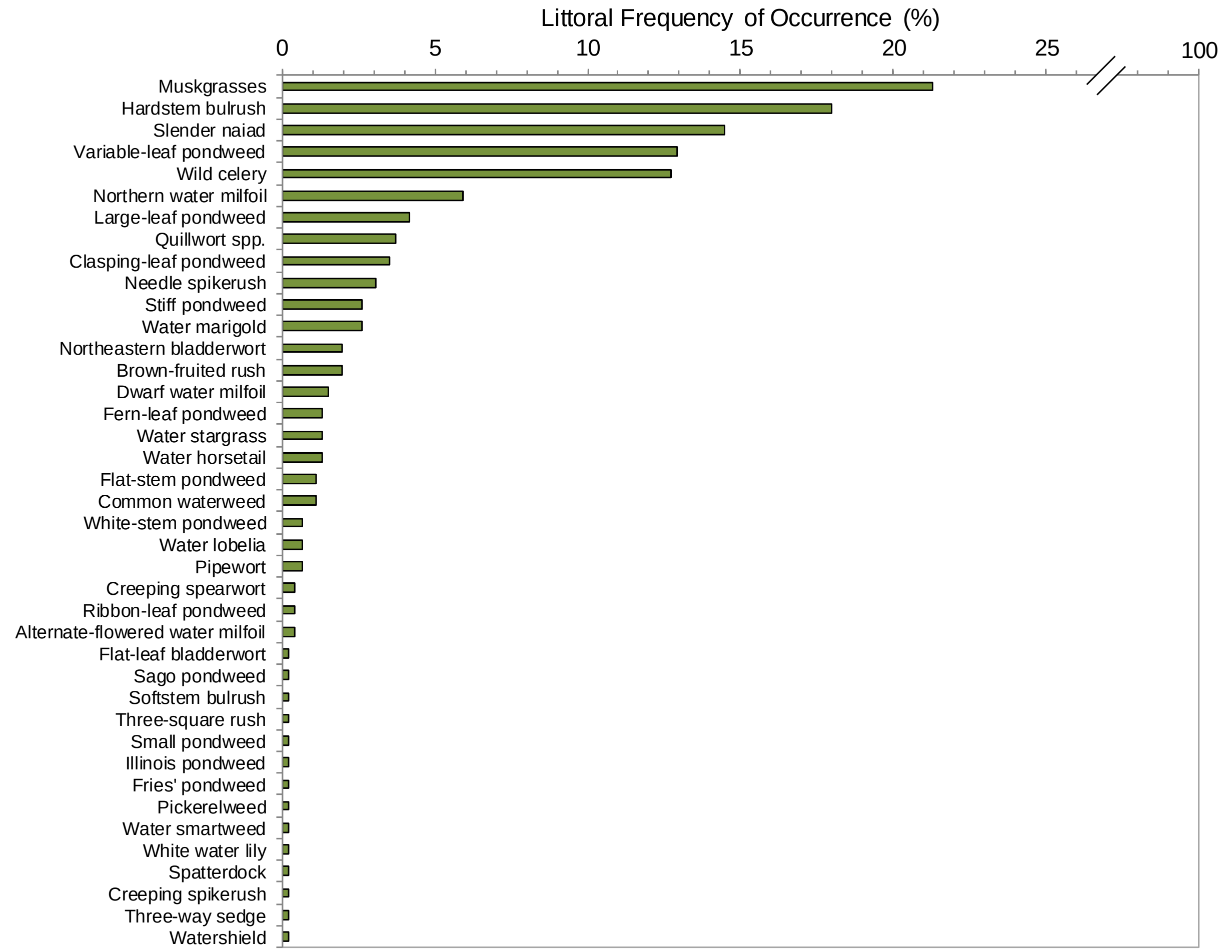


Figure 8.1.4-6. Harris Lake 2015 littoral frequency of occurrence of aquatic plant species. Created using data from 2015 whole-lake point-intercept survey.

Muskgrasses, the most abundant aquatic plants in Harris Lake with a littoral frequency of occurrence of approximately 21%, are a group of macroalgae of which there are several species in Wisconsin. While they are not vascular plants, muskgrasses still grow to a considerable size and form large, dense beds along the lake bottom where the supply oxygen to deeper waters and provide structural habitat for aquatic invertebrates and fish. Studies have also shown that these plants stabilize bottom sediments and improve water quality by removing nutrients to the water that would otherwise be available to algae.

Hardstem bulrush was the second-most frequently encountered aquatic plant in Harris Lake in 2015 with a littoral frequency of occurrence of approximately 18%. Contrary to its name, hardstem bulrush is not a rush (family *Juncaceae*) but is actually a tall, giant sedge in the family *Cyperaceae*. Harris Lake possesses large colonies of hardstem bulrush in shallow waters around the lake, and these communities are important habitat and food sources for wildlife and the stabilization of bottom and shoreline sediments.

Photo 8.1.4-1. Flower of northeastern bladderwort (*U. resupinata*). Photo credit: Onterra.

One aquatic plant species located in 2015, northeastern bladderwort (*Utricularia resupinata* – Photo 8.1.4-1), is listed as special concern in Wisconsin by the Natural Heritage Inventory due to uncertainty regarding its population and rarity in the state (WDNR PUBL-ER-001 2014). Northeastern bladderwort is one of nine bladderwort species found in Wisconsin, and one of three species found in Harris Lake. 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. Northeastern bladderwort is often difficult to locate, as the majority of the plant is buried within the substrate. In Harris Lake, this plant was found in shallow areas of sand near shore.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.1.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.1.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) found in Harris Lake is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*), also found in Harris Lake, are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Harris Lake Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

Photo 8.1.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

In the summer of 2009, the WDNR conducted a whole-lake point-intercept survey on Harris Lake following the discovery of curly-leaf pondweed. The methodology and sampling locations were the same as the survey completed in 2015, and therefore, the data collected from these two surveys can be statistically compared to determine if any significant changes in Harris Lake's aquatic plant community have occurred over this time period. Figure 8.4.1-7 displays the littoral frequency of occurrence of aquatic plant species from the 2009 and 2015 point-intercept surveys. Only the species that had a littoral frequency of occurrence of at least 5% are applicable for analysis. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of muskgrasses and stoneworts were combined for this analysis.

Fern-leaf pondweed, small pondweed, dwarf water milfoil, and common waterweed exhibited statistically valid reductions in their occurrence between the 2009 and 2015 point-intercept surveys (Figure 8.1.4-7). Slender naiad, wild celery, and hardstem bulrush exhibited statistically valid increases in their littoral occurrence between the 2009 and 2015 point-intercept surveys. However, the apparent increase in hardstem bulrush is a result of surveyors in 2009 recording its presence at a number of sampling locations as a 'visual occurrence' and they did not record it as present on the rake. If the visual occurrences are included, there is not statistical difference in the occurrence of hardstem bulrush between these two surveys. The littoral occurrences of muskgrasses and stoneworts, variable-leaf pondweed, large-leaf pondweed, needle spikerush, and northern water milfoil were not statistically different.

Aquatic plant communities are dynamic and the abundance of certain species from year to year can fluctuate depending on climatic conditions, herbivory, competition, and disease among other factors. Native aquatic plants can also decline following the implementation of herbicide applications to control non-native aquatic plants; however, as is discussed in detail within the Non-Native Aquatic Plant Section, the reductions in occurrence of the previously-mentioned aquatic plants in Harris Lake are not believed to be a result of the herbicide applications from 2010-2013 to control curly-leaf pondweed. Rather, these observed reductions and increases in occurrence of certain species are believed to be due to varying interannual environmental conditions, including the reduction in water clarity observed since 2013 as is discussed in the Harris Lake Water Quality Section.

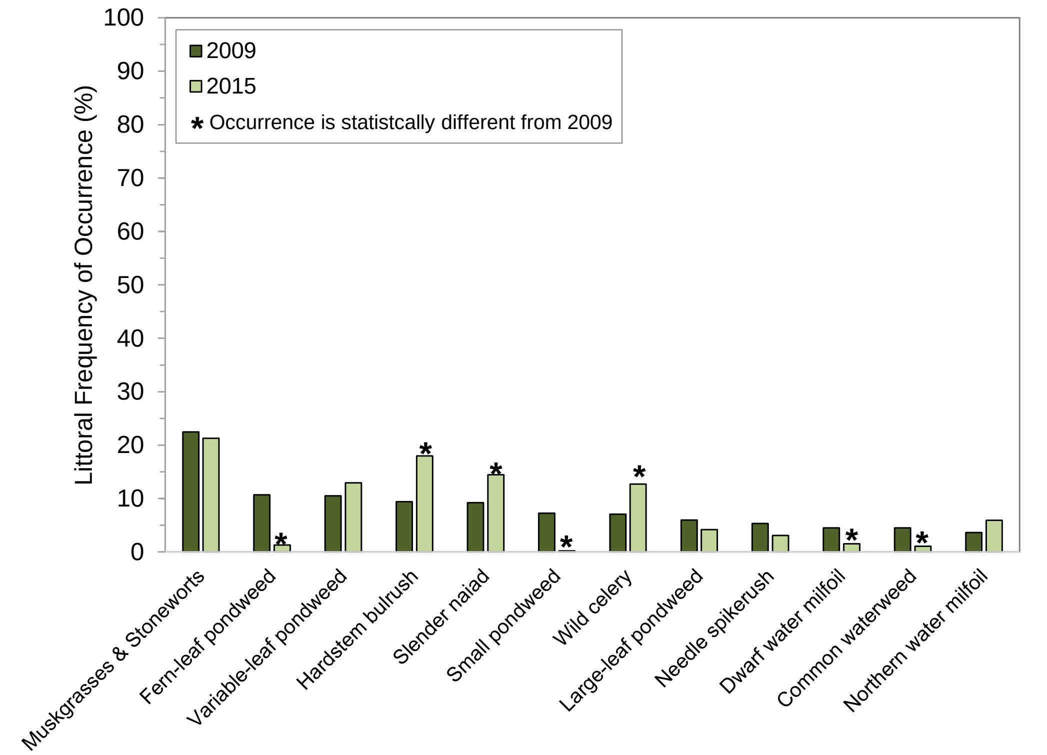


Figure 8.1.4-7. Harris Lake 2009 and 2015 aquatic plant littoral frequency of occurrence comparison. Please note that only the species with a littoral occurrence of at least 5% in one of the two surveys are displayed. Statistical significance determined using Chi-square analysis (α = 0.05). Created using data collected during WDNR 2009 and Onterra 2015 whole-lake point-intercept surveys.

As discussed in the Town-wide section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during the 2009 and 2015 point-intercept surveys and their conservatism values were used to calculate the FQI of Harris Lake's aquatic plant community (equation shown below).

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

Figure 8.1.4-8 compares the 2009 and 2015 FQI components of Harris Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. The number of native aquatic plant species encountered on the rake, or native species richness, was similar between the 2009 and 2015 surveys at 38 and 40, respectively. Harris Lake's species richness greatly exceeds the upper quartile value for lakes within the ecoregion and the state. The lake's excellent water quality and diversity of habitat types result in this high species richness.

Like native plant species richness, Harris Lake's average conservatism in 2009 and 2015 was also similar with values of 6.9 and 7.0, respectively (Figure 8.1.4-8). Harris Lake's average conservatism exceeds the median values for lakes in the ecoregion and throughout Wisconsin, and indicates Harris Lake's aquatic plant community contains a higher number of aquatic plants that are considered to be sensitive to environmental degradation and require high-quality habitats. Given Harris Lake's high native species richness and average conservatism values from 2009 and 2015, Harris Lake has high Floristic Quality Index values in both years of 42.5 and 44.3, respectively. These FQI values exceed the upper quartile values for lakes in the ecoregion and the state, and indicate that Harris Lake's aquatic plant community is of higher quality than the majority of lakes in the region and throughout Wisconsin.

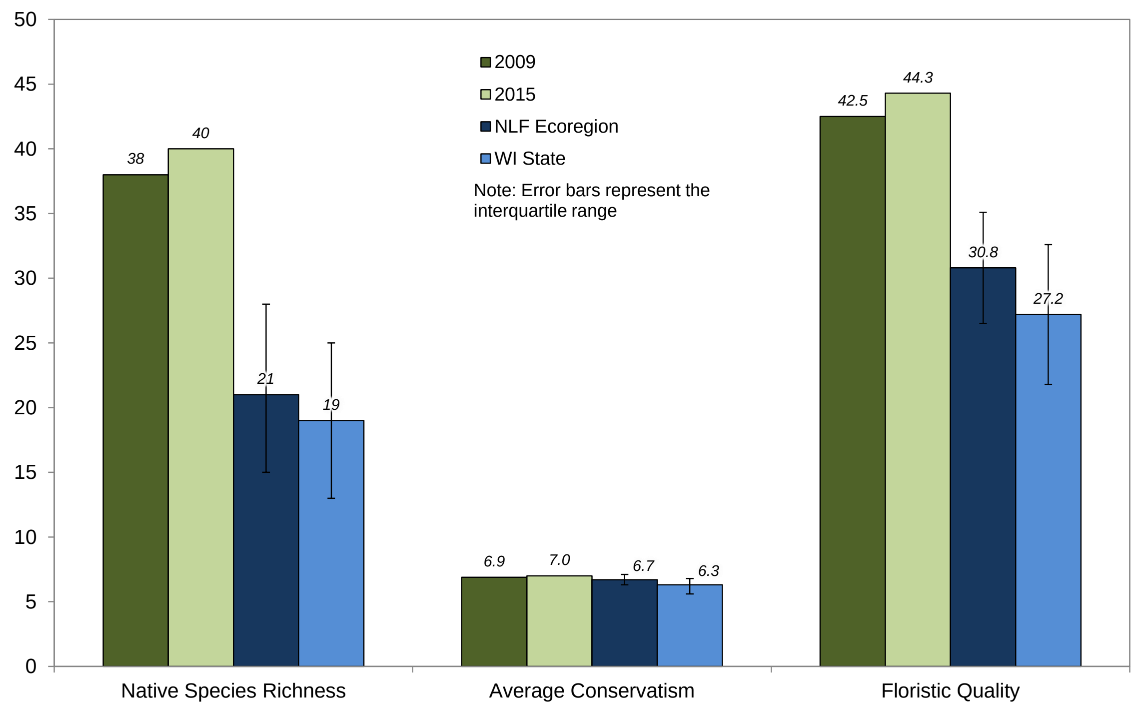


Figure 8.1.4-8. Harris Lake Floristic Quality Assessment. Created using data from WDNR 2009 and Onterra 2015 whole-lake point-intercept surveys. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Harris Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Harris Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 8.1.4-9). Using the data collected from the 2009 and 2015 point-intercept surveys, Harris Lake's aquatic plant is shown to have high species diversity with Simpson's Diversity Index values of 0.94 and 0.91, respectively. In other words, if two individual aquatic plants were randomly sampled from Harris Lake in 2015, there would be a 91% probability that they would be different species. These diversity values fall above the upper quartile value for lakes in the ecoregion and the state.

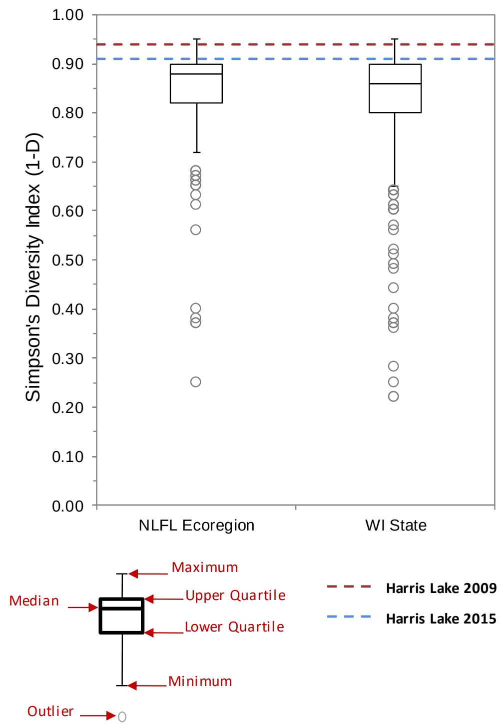


Figure 8.1.4-9. Harris Lake species diversity index. Created using data from WDNR 2009 and Onterra 2015 point-intercept surveys.

One way to visualize Harris Lake's high species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-10 displays the relative frequency of occurrence of aquatic plant species created from the 2015 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. 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 muskgrasses were found at 21% of the littoral sampling locations in Harris Lake in 2015, their relative frequency of occurrence is 17%. Explained another way, if 100 plants were randomly sampled from Harris Lake in 2015, 17 of them would be muskgrasses.

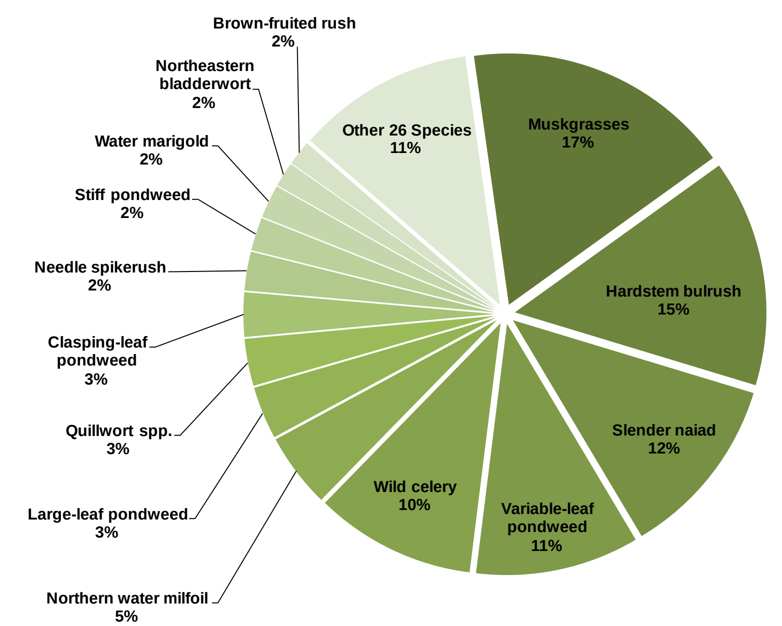


Figure 8.1.4-10. Harris Lake 2015 relative frequency of occurrence of aquatic plant species. Created using data from 2015 point-intercept survey.

In 2015, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Harris Lake. This survey revealed Harris Lake contains approximately 92 acres of these communities comprised of 24 different aquatic plant species (Harris Lake – Map 7 and Table 8.1.4-2). The majority of these communities are comprised of emergent species, primarily hardstem bulrush and three-square rush. These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

Table 8.1.4-2. Harris Lake 2015 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2015 aquatic plant community mapping survey.

Harris Lake	
Plant Community	**Acres**
Emergent	88.8
Floating-leaf	0.1
Mixed Emergent & Floating-leaf	2.9
Total	**91.9**

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Harris Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Non-native Aquatic Plants in Harris Lake

Curly-leaf pondweed (CLP)

Curly-leaf pondweed

Curly-leaf pondweed (*Potamogeton crispus*; CLP; Photo 3.4-3) is a non-native aquatic plant that has invaded over 530 waterbodies in Wisconsin. The plant may outcompete other native aquatic vegetation with its dominating, aggressive growth and reach the point where its populations form dense mats on the surface of a lake's littoral zone. These dense mats impact recreation as well as the ecology of the lake. Further, a natural, mid-summer senescence (die-back) of large populations of CLP may contribute to an increase of water column phosphorus with larger populations.

Photo 8.1.4-3. The non-native, invasive aquatic plant curly-leaf pondweed.

Of the two lakes studied to date under Phase I, CLP in Harris Lake has been the only non-native aquatic plant located thus far. Curly-leaf pondweed was first discovered in Harris Lake in 2008 by members of the Harris Lake Association, Inc. (HLA), and was later verified by the WDNR. Following its discovery, the HLA was advised to seek professional assistance to survey the lake for additional occurrences of CLP and develop an appropriate management strategy for controlling and monitoring the population.

In the fall of 2008, the HLA contracted with Onterra aid in the development of a CLP management strategy. With Onterra's assistance, the HLA was awarded a WDNR Aquatic Invasive Species (AIS)-Early Detection and Response (EDR) Grant to aid in the funding of the CLP surveys in 2009 and 2010 and associated treatment development and monitoring. Onterra ecologists completed the first whole-lake meander-based mapping of CLP in Harris Lake in June of 2009. This survey revealed a number of isolated colonies of CLP comprised mainly of single plants spread around the lake (Figure 8.1.4-11). The first herbicide application of approximately 10.4 acres using endothall to control CLP occurred in the spring of 2011.

Traditionally, CLP control strategies involve the annual application of herbicide in May/June with a goal of causing plant mortality before they are able to produce asexual reproductive structures called turions. Studies have indicated that viable CLP turions can remain dormant within the sediment for at least seven years, and is the reason a number of consecutive annual treatments are needed to prevent the formation of new turions and to kill plants that sprout from dormant turions deposited in years past. After multiple years of treatment (generally three to five), the turion bank within the sediment is exhausted and the CLP population declines.

Post-treatment assessments of the 2011 treatment were deemed successful as little to no CLP could be observed within the herbicide application areas. Subsequent endothall applications occurred during the springs of 2012 (4.1 acres) and 2013 (2.0 acres). These treatments were followed-up by volunteer monitoring and hand-removal by HLA volunteers. The HLA volunteers also implemented monitoring and hand-removal of CLP in smaller areas that were no applied with herbicide. All of these treatments were deemed successful, and following the mapping of CLP in 2013, it was determined that the CLP had declined to a level that did not warrant herbicide treatment in 2014 and that manual hand-removal by HLA volunteers would be the most appropriate method for control.

In the early summer of 2014, Onterra ecologists completed a mapping survey aimed at locating occurrences of CLP. These locations would then be provided to the HLA volunteers for their use in hand-removal. However, Onterra ecologists were unable to locate any of the CLP that had been mapped in 2013 nor was any CLP observed in any of areas previously applied with herbicide. While volunteer hand-removal of CLP did not occur in 2014, the HLA volunteers monitored the lake for potential occurrences of CLP; however, no additional CLP was located.

On June 30, 2015, Onterra ecologists completed the Early-Season AIS Survey on Harris Lake as part of the Town of Winchester Lake Management Planning Project – Phase I. During this survey, Onterra ecologists were unable to locate any occurrences of CLP. Onterra ecologists returned to Harris Lake on June 29, 2016 to complete another Early-Season AIS Survey as part of the Town of Winchester Lake Management Planning Project – Phase II. During this survey, three plants were located in close proximity to one another in the northwestern portion of the lake (Figure 8.1.4-12). These plants were hand-removed with a rake during this survey. Professional monitoring of CLP in Harris Lake is scheduled to occur in 2017 and 2018 under Phase III and IV of the lake management planning project, and monitoring of CLP beyond 2018 in Harris Lake is discussed within Harris Lake's Implementation Plan.

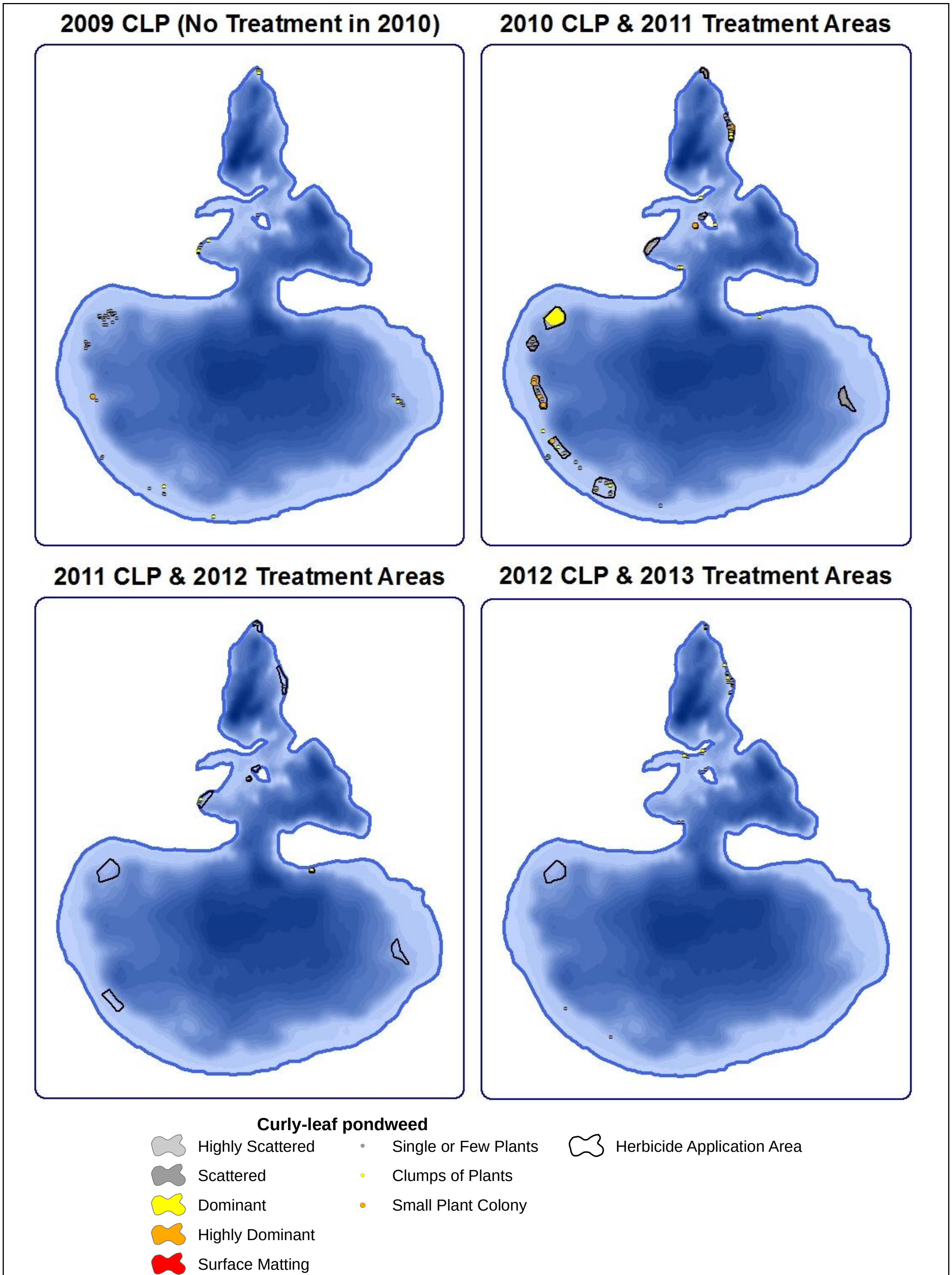


Figure 8.1.4-11. Locations of CLP and herbicide application areas in Harris Lake from 2009-2012.

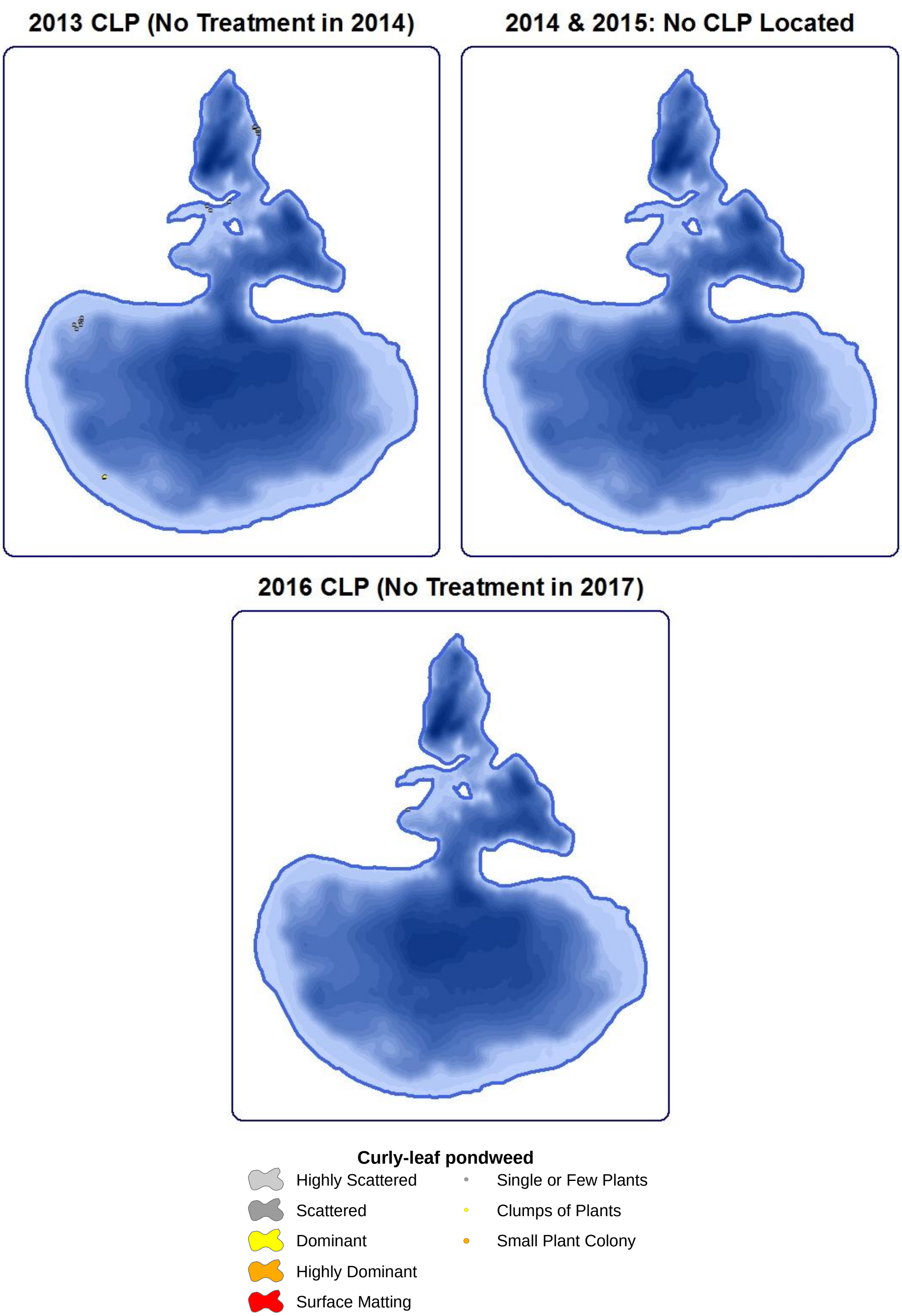


Figure 8.1.4-12. Locations of CLP in Harris Lake from 2013-2016.

8.1.5 Other Aquatic Invasive Species in Harris Lake

As of 2016, curly-leaf pondweed is the only aquatic invasive species listed as present in Harris Lake. As discussed in Harris Lake's Water Quality Section, plankton tows completed by Onterra ecologists in 2015 were negative for the presence of zebra mussel (*Dreissena polymorpha*) veligers and the spiny waterflea (*Bythrotrephes cederstroemi*). Nearby lakes within the Town of Winchester contain the non-native banded mystery snail (*Viviparus georgianus*), Chinese mystery snail (*Cipanogopaludina chinensis*), and freshwater jellyfish (*Craspedacusta sowerbyi*). Anne Lake, which flows into Harris Lake, contains the rusty crayfish (*Orconectes rusticus*). It is possible that Harris Lake contains one or more of these non-native invertebrates and that they have gone unreported.

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

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). The ecological impacts from freshwater jellyfish, which are believed to have been introduced from China, are not known. However, it is theorized that these jellyfish may have some impacts to zooplankton communities.

8.1.6 Harris Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by WDNR biologists overseeing the Town of Winchester Lakes. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2016B & GLIFWC 2016A and 2016B).

Harris Lake Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), open water fishing was the highest ranked important or enjoyable activity on Harris Lake (Question #14). 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 Harris Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscovores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.1.6-1.

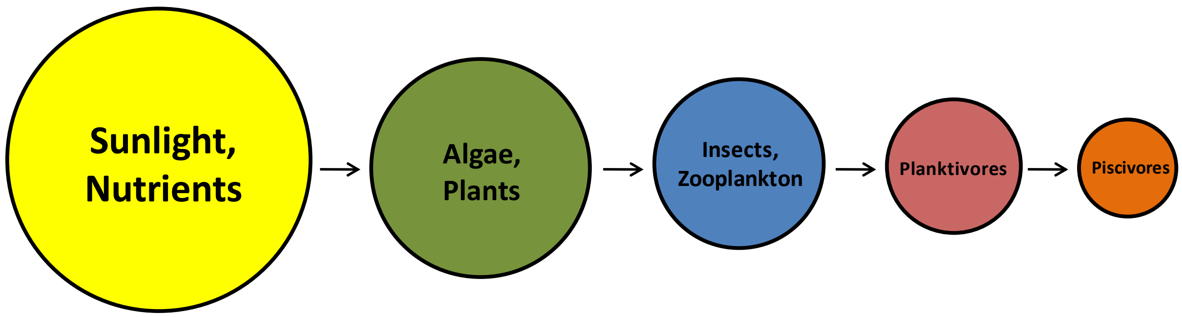


Figure 8.1.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Harris Lake is an oligo-mesotrophic lake, meaning it has fairly low nutrient content and thus relatively low primary productivity. Simply put, this means Harris Lake may be limited in supporting sizable populations of predatory fish (piscivores) because the supporting food chain is relatively modest.

Table 8.5.1-1. Gamefish present in the Harris Lake with biological information (Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May – June	Nests more common on shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
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
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
Walleye	*Sander vitreus*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish

Harris Lake Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.1.6-2). The Town of Winchester falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process.

This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a “total allowable catch” is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake’s known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the “safe harvest level”.

Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

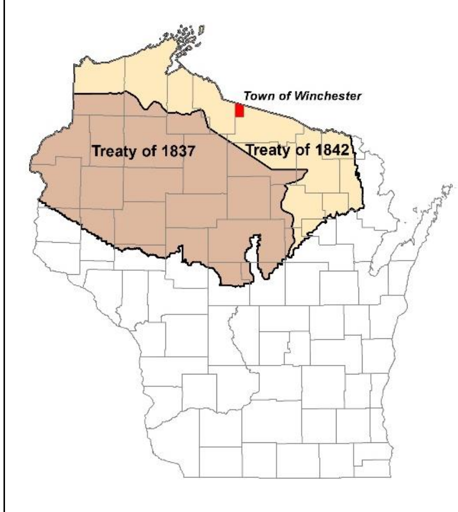


Figure 8.1.6-2. Location of the Town of Winchester within the Native American Ceded Territory (GLIFWC 2016A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spearers are able to 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 2015B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 8.1.6-3. One common misconception is that the spear harvest targets the large spawning females. Figure 8.1.6-3 shows that 7% (108 fish) of the total walleye harvest (1,550 fish) from 2000 to 2012 was comprised of female fish. 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 (GLIWC 2015B). This regulation limits the harvest of the larger, spawning female walleye. Figure 8.1.6-4 displays the Native American open water muskellunge spear harvest since 1989. Since 1989, five muskellunge have been harvested on Harris Lake during the open water spear fishery and none have been harvested since 2009.

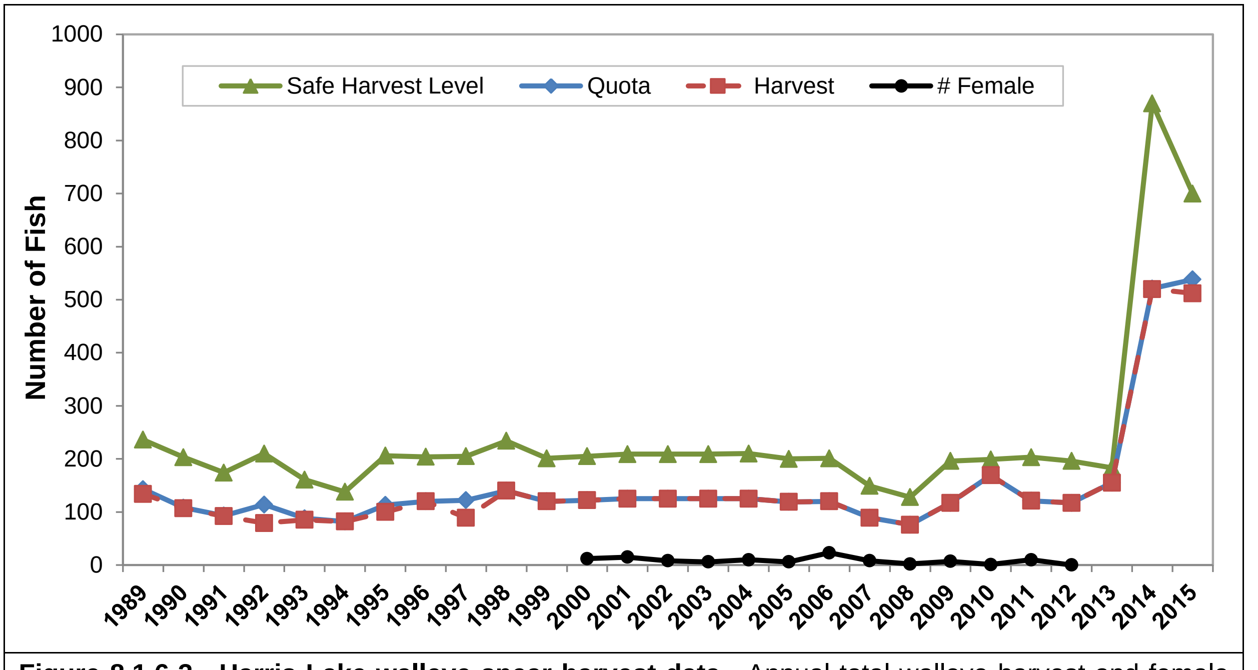


Figure 8.1.6-3. Harris Lake walleye spear harvest data. Annual total walleye harvest and female walleye harvest are displayed since 1989 from WDNR records.

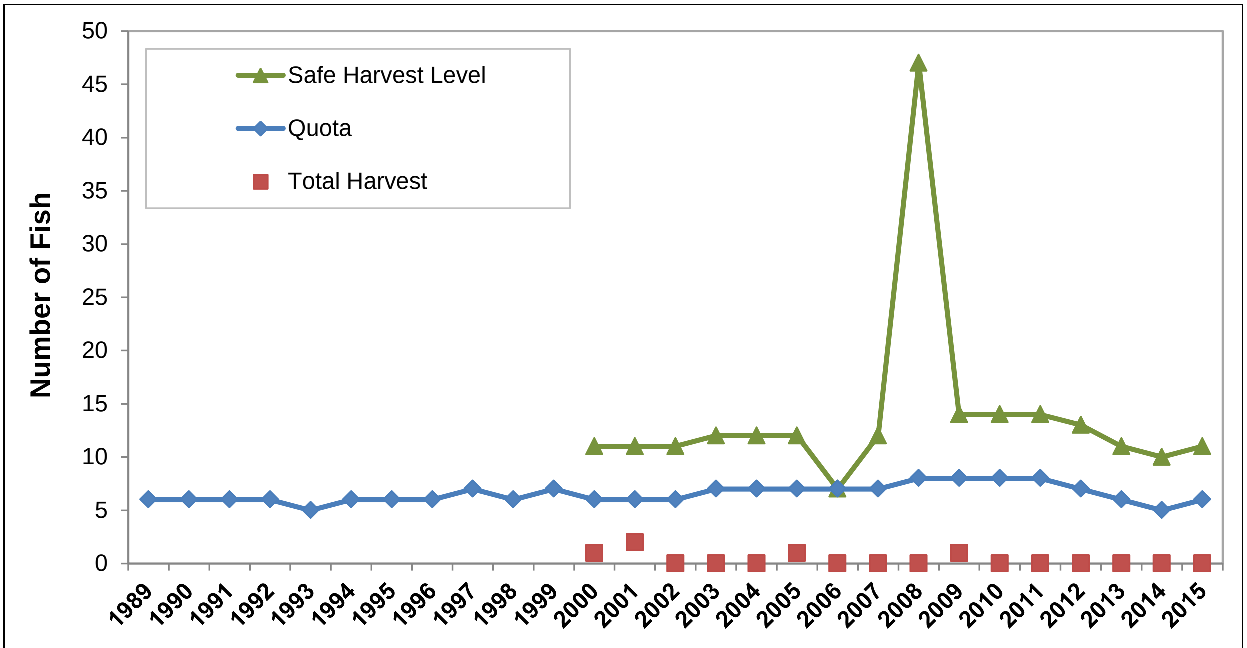


Figure 8.1.6-4. Harris Lake muskellunge spear harvest data. Annual total muskellunge harvests are displayed since 1989 from WDNR records.

Harris Lake Fishing Regulations

The Town of Winchester Lakes are within the northern bass zone in Wisconsin. From May 7 – June 17, smallmouth bass are catch and release only whereas largemouth bass have a daily bag limit of 5 fish and a minimum length of 14 inches. From June 18 to March 5, five largemouth or smallmouth bass in combination may be kept and must be at least 14 inches in length. The Town of Winchester Lakes are in the northern management zone for muskellunge and northern pike. No minimum length limit exists for northern pike and five pike may be kept in a single day. Statewide regulations apply for all other fish species. Wisconsin species regulations are provided in each annual WDNR fishing regulations publication. Anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Harris Lake Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fish in a waterbody that were raised in nearby permitted hatcheries. Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults. A stocking summary for the Harris Lake is displayed in Table 8.1.6-2. Limited stocking of gamefish has occurred on Harris Lake due to the sustaining naturally reproducing populations within the lake.

Table 8.1.6-2. Available Stocking History on Harris Lake.

Harris Lake WDNR Stocking					
Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1974	Walleye	Unspecified	Fingerling	10,000	3
1978	Muskellunge	Unspecified	Fingerling	1,020	10

Harris Lake Substrate Type

Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result.

Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well. According to the point-intercept survey conducted by Onterra in 2015, the majority (76%) of the substrate in Harris Lake is composed of either sand or gravel, whereas 24% is composed of a soft, mucky or organic substrate.

8.1.7 Harris Lake Implementation Plan

The Implementation Plan presented below was created through the collaborative efforts of the Harris Lake Association (HLA) Planning Committee, Onterra ecologists, and North Lakeland Discovery Center (NLDC) and WDNR staff. It represents the path the HLA 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 Harris Lake stakeholders as portrayed by the members of the Planning Committee and the numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

Management Action:	Continue monitoring of Harris Lake's water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	HLA Board of Directors (suggested)
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. As discussed in the Water Quality Section, Harris Lake's water quality is excellent, and early detection of potential negative trends may lead to the reason as of why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the HLA have been collecting water quality data from Harris Lake since 1991. The HLA realizes the importance of continuing this effort, which will supply them with valuable data about their lake. Tim Nickels is currently the CLMN volunteer collecting water quality data from Harris Lake, and the HLA Board of Directors will appoint a water quality monitor at the annual meeting. When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. HLA Board of Directors appoints/recruits new volunteer(s) as needed at annual meeting.
2. New volunteer(s) contact Sandy Wickman (715.365.8951) as needed.
3. Volunteer(s) reports results to WDNR and to HLA members during annual meeting.

Management Action: Preserve natural and restore highly developed shoreland areas on Harris Lake.

Timeframe: Initiate 2017

Facilitator: HLA Board of Directors (suggested)

Description: The 2015 Shoreland Condition Assessment found that approximately 88% (5.0 miles) of Harris Lake's immediate shoreland zone contains little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 4% (0.2 miles) contains a higher degree of development categorized as *developed-unnatural* or *urbanized*. It is important that the owners of properties with little development become educated on the benefits their shoreland is providing to Harris Lake in terms of maintaining the lake's water quality and habitat, and that these shorelands remain in a natural or semi-natural state. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to Harris Lake's water quality and contribution to habitat loss.

The HLA board of directors will work with appropriate entities such as the NLDC to research grant programs and other pertinent information that will aid the HLA in preserving and restoring Harris Lake's shoreland. 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.

Action Steps:

1. HLA Board of Directors gathers appropriate information from entities listed above.
2. The HLA provides Harris Lake property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Goal 2: Assure and Enhance the Communication and Outreach of the Harris Lake Association with Harris Lake Stakeholders

<u>Management Action:</u> Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Harris Lake.

Timeframe: Continuation of current effort

Facilitator: HLA Board of Directors (suggested)

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The HLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the HLA regularly publishes and distributes a monthly hardcopy and electronic newsletter that provides association-related information including current association projects and updates, meeting times, and educational topics. This is an excellent source for communication to association members. In addition, the HLA maintains an association website and Facebook page.

The majority of Harris Lake stakeholder survey respondents indicated that the HLA keeps them either fairly well informed or highly well informed regarding issues with the lake and its management. The HLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Harris Lake and its preservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter or distributed as separate educational materials. In addition, the HLA can invite professionals who work within these topics to come and speak at the association's annual meeting or hold workshops if available.

Example Educational Topics

- Shoreline restoration and protection
- Effect lawn fertilizers/herbicides have on the lake
- Importance of maintaining course woody habitat
- Fishing rules and regulations
- Catch-and-release fishing
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community

- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention
- Water quality monitoring updates from Harris Lake
- Septic system maintenance
- Littering on the ice and year-round

Action Steps:

1. See description above.

Management Goal 3: Reduce Shoreland Erosion on Harris Lake Brought About by Beaver Activity

Management Action: Investigate management strategies for beaver and beaver dam removal in Harris Creek to reduce shoreland erosion caused by high water.

Timeframe: Initiate in 2017

Facilitator: HLA Board of Directors (suggested)

Description: During the two planning meetings with the HLA Planning Committee, one of the top concerns regarding Harris Lake was shoreland erosion caused by higher water levels maintained by a series of beaver dams in Harris Creek, the outlet to Harris Lake. Respondents to the Harris Lake stakeholder survey also indicated that high water caused by beaver dams were among their top concerns for the lake and that a number of lake property owners have observed significant erosion of their shorelands.

During the second planning committee meeting, the WDNR's document *Beaver Dam Control* (http://dnr.wi.gov/topic/waterways/factsheets/beaverdamage.pdf) was presented to the committee members and beaver management options were discussed. As is discussed within this document, assistance from the WDNR relating to beavers is limited to providing the HLA with instructional materials, clarification of applicable laws, and referral to experienced trappers or wildlife control companies. The WDNR does not visit problem sites or aid in beaver removal.

The HLA would like to take an active role in managing beavers at the outlet to Harris Lake to reduce shoreland erosion. This active management strategy will likely involve the trapping and removal of beavers along with removal of the dams. Removal of the dams without removal of the beavers would likely result in the dams being rebuilt shortly thereafter. Landowners may remove beaver dams causing property damage without any permit, permission, or authorization from the WDNR. However, if a dam is to be removed via blasting, the blaster must be licensed. Blasting cannot be used to kill beaver, and may only be used on vacated lodges. And as mentioned previously, removal of the dam without the beavers will likely result in the dams being rebuilt.

The property along Harris Creek where the beaver dams occur is privately owned, and the HLA should contact these property owners before any beaver trapping and/or dam removal is conducted. The NLDC recommended the HLA consult with Zach Wilson (715.561.2234), a local trapper and conservation specialist with Iron County Land and Water Conservation Department regarding the removal of beaver from Harris Creek. The HLA needs to understand that beaver trapping and dam removal may be expensive, and may need to occur periodically as new beavers move in and construct new dams.

Action Steps:

1. HLA Board of Directors reviews WDNR's *Beaver Damage Control* (http://dnr.wi.gov/topic/waterways/factsheets/beaverdamage.pdf) to review legal beaver management options.
2. HLA Board of Directors contacts Zach Wilson (715.531.2234), a local trapper and conservation specialist with the Iron County Land and Water Conservation Department, for consultation on beaver trapping in Harris Creek.
3. HLA enacts beaver management strategy as needed.

Management Goal 4: Control Existing Aquatic Invasive Species and Prevent New Introductions to Harris Lake

Management Action: Continue curly-leaf pondweed monitoring and hand-removal strategy to manage curly-leaf pondweed population in Harris Lake.

Timeframe: Continuation of current effort

Facilitator: HLA Board of Directors with assistance from NLDC (suggested)

Description: As is discussed within the Harris Lake Aquatic Plant Section, curly-leaf pondweed (CLP) was first discovered in Harris Lake in 2008. Following a combination of herbicide spot treatments (2011, 2012, 2013) and HLA volunteer hand-removal, the CLP population has been greatly reduced and remains small. In 2016, only three CLP plants were located and all were hand-removed by Onterra ecologists. Continued monitoring of Harris Lake's CLP population will ensure that any larger colonies are detected early and that the population is managed at a level which is not having an ecological impact to the lake.

Since 2009, professional CLP monitoring surveys have been completed on an annual basis by Onterra ecologists on Harris Lake. Surveys from 2009-2014 were funded via WDNR AIS-Early Detection and Response Grants, while surveys in 2015 and 2016 were funded under the WDNR AIS-Education, Planning and Prevention

Grants received for the Town of Winchester Lakes Management Planning Project. Professional monitoring is scheduled to continue in Harris Lake in 2017 and 2018 corresponding to the Phase III and IV portion of the town-wide management project.

Given the current population of CLP in Harris Lake is very small, it is conducive to hand-removal by HLA volunteers. During the planning meetings, the HLA Planning Committee indicated they wanted to continue annual volunteer monitoring and hand-removal of CLP. While the level of CLP located in 2016 was able to be removed by Onterra ecologists, if higher amounts of CLP are located in the future, the location of the plants will be relayed to the HLA volunteers for removal.

The objective of this management action is not to eradicate CLP from Harris Lake, as that is impossible with current tools and techniques. The objective is to maintain a CLP population that exerts little to no detectable impact on the lake's native aquatic plant community and overall ecology, recreation, and aesthetics. Monitoring is a key aspect of any AIS control project, both to prioritize areas for control and to monitor the strategy's effectiveness. The monitoring also facilitates the "tuning" or refinement of the control strategy as the control project progresses. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's lifespan. It must be noted that hand-removal methodology is still experimental, and success criteria for assessing the efficacy of hand-removal have not yet been defined. Because of this, the following series of steps to manage CLP via hand-removal in Harris Lake should remain flexible to allow for modifications as the project progresses. The series includes:

1. A professional lake-wide assessment of CLP (Early-Season AIS Survey) completed while the plant is at or near its peak growth (June). This meander-based survey of the lake's littoral zone is designed to locate all possible occurrences of CLP, and the findings would be compared to results from the previous year's Early-Season AIS Survey to assess the efficacy of the control strategy implemented (e.g. hand-harvesting or herbicide application).

2. Using CLP findings from the most recent survey, professional ecologists will work with the HLA to delineate defined CLP hand-harvesting sites (Site A, B, etc.). The hand-harvesters will then be able to record the amount of hours (effort) spent within each site, allowing for a more accurate assessment of the level of effort spent within each area.

3. Hand-removal efforts begin as soon as possible following the Early-Season AIS Survey (before plants senesce) using the finalized strategy that resulted from the ESAIS survey.

4. Professional Early-Season AIS Survey completed the following year to determine hand-removal efficacy and create new hand-removal sites/strategy.

5. Report generated on hand-removal success and recommendation for following year's strategy.

Typically, AIS control programs (mainly with herbicides) incorporate both established qualitative (CLP mapping) and quantitative (sub-sample point-intercept survey) evaluation methodologies. However, quantitative monitoring of hand-removal areas using sub-sample point-intercept methodology is not applicable at this time in Harris Lake as there are no areas of CLP large enough to attain the number of sampling locations required to meet the assumptions of statistical analyses. Therefore, each potential hand-removal site would be monitoring using qualitative methods.

The qualitative monitoring would be completed by comparing pre-hand-harvesting (summer before hand-harvesting) with post-hand-harvesting (summer immediately following hand-harvesting) Early-Season AIS Survey results. A hand-removal site would be deemed successful if the level of CLP is maintained at the point-based mapping level; for example, a site would be considered unsuccessful if it contained *single or few plants* (point-based mapping) prior to hand-harvesting and expanded to contain colonized CLP (polygons) following hand-harvesting.

As discussed, professional monitoring of CLP is scheduled to occur in Harris Lake in 2017 and 2018 under the Town of Winchester management planning project. However, the HLA should continue to monitor the lake's CLP population beyond 2018, and the HLA will have to decide if they would like to move forward with monitoring (professional, volunteer, or a combination of both).

Action Steps:

1. Retain qualified professional assistance for monitoring and management strategy design utilizing the methods described in 2017 and 2018.
2. HLA volunteers continue AIS monitoring in Harris Lake and report findings to resource managers.
3. HLA volunteers attend periodic NLDC AIS identification and monitoring training.
4. CLP control and monitoring strategy developed for 2019 and beyond following 2018 professional monitoring survey.

Management Action:	Initiate aquatic invasive species rapid response plan upon discovery of new infestation.
Timeframe:	Initiate upon invasive species discovery.
Facilitator:	HLA Board of Directors (suggested)
Description:	In the event that another aquatic invasive species such as Eurasian watermilfoil is located by the trained volunteers, the areas would be marked using GPS and the HLA should contact resource managers (NLDC, WDNR, etc.) immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals and the results would be used to develop potential control strategies.
Action Steps:	
1.	See description above.

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Harris Lake's public access location.
Timeframe:	Continuation of current effort
Facilitator:	HLA Board of Directors (suggested)
Description:	The HLA has been periodically conducting watercraft inspections at the public boat landing since 2007 through the Clean Boats Clean Waters (CBCW) program. In-kind time for watercraft inspections at Harris Lake is being provided through the WDNR grants as part of the four-year lake management planning project (2015-2018). However, the HLA would like to continue watercraft inspections beyond 2018. The intent of the boat inspections would not only be to prevent additional exotic species from entering the lake through the public access point, but also to prevent the infestation of other waterways with exotic species that originated in Harris Lake (e.g. CLP). The goal would be to monitor the during the busiest times (e.g. holiday weekends) in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of their spread. The HLA would like to continue watercraft inspections using volunteers. Often, it is difficult for lake groups to recruit and maintain a volunteer base to oversee CBCW inspections throughout the summer months. Recruitment outside of the HLA may be necessary in order to have sufficient coverage of the Harris Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW. Members of the HLA, as well as other volunteers, will need to be trained on CBCW protocols in order to participate in public boat

landing inspections. Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought to ensure monitoring occurs at the public boat landing. These paid inspectors may be purchased alone or in conjunction with volunteers through the HLA or in the community.

Action Steps:

1. Members of the HLA periodically attend CBCW training sessions through the WDNR to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.
3. Begin inspections during high-use weekends.
4. Report results to WDNR and HLA.
5. Promote enlistment and training of new volunteers to keep program fresh.

Management Goal 5: Enhance the fishery of Harris Lake

Management Action: Continue work with WDNR fisheries managers to enhance the fishery of Harris Lake.

Timeframe: Continuation of current effort

Facilitator: HLA Fisheries Committee (suggested)

Description: The majority of respondents to the Harris Lake stakeholder survey ranked fishing as their favorite recreational activity on the lake, and that walleye and smallmouth bass were the most sought-after fish. Harris Lake is listed as an Area of Special Natural Resource Interest (ASNRI) for harboring naturally reproducing populations of both walleye and muskellunge. The HLA understands that a multitude of factors such as changes in habitat, water levels, and fishing pressure affect fish communities, and the HLA would like to take an active role in maintaining a healthy fishery and ensuring Harris Lake remains a high-quality fishing lake for future generations.

Harris Lake is currently overseen by WDNR fisheries biologist Steve Gilbert (715.356.5211). In an effort to remain informed on studies pertaining to fisheries in Harris Lake, the HLA fisheries committee should contact Steve at least once per year (perhaps during the winter months when field work is not occurring) for a brief summary of activities. In addition, the HLA can discuss management options for maintaining and enhancing the lake's fishery, which may include changes in angling regulations and/or habitat enhancements.

Action Steps: See description above.

Please note that study methods and explanations of analyses for Hiawatha Lake can be found within the Town of Winchester Town-wide Management Plan document.

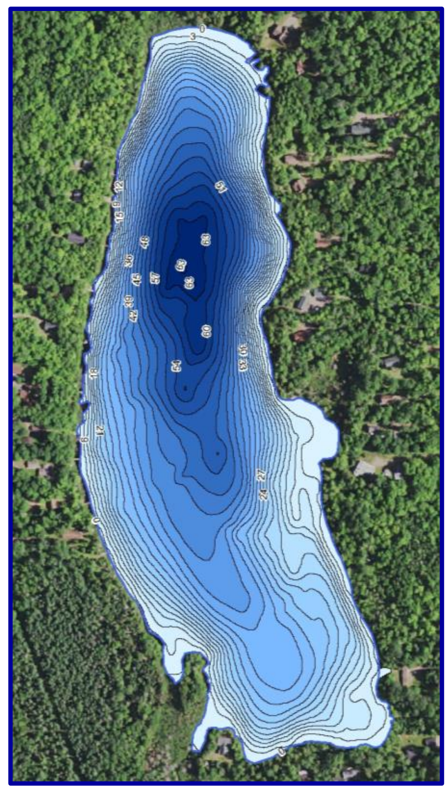
8.2 Hiawatha Lake

An Introduction to Hiawatha Lake

Hiawatha Lake, Vilas County, is a deep headwater, brown-water, mesotrophic drainage lake with a maximum depth of 58 feet, a mean depth of 32 feet, and a surface area of approximately 38 acres (Hiawatha Lake – Map 1). Its surficial watershed encompasses approximately 819 acres comprised mainly of intact forests and wetlands. Water from Hiawatha Lake flows out to Little Papoose Lake and into the Manitowish River. In 2015, 26 native aquatic plant species were located within the lake, of which rolled water moss (*Fontinalis sphagnifolia*) was the most common.

Lake at a Glance - Hiawatha Lake

Morphology	
LakeType	Deep, Headwater Drainage
Surface Area (Acres)	38
Max Depth (feet)	58
Mean Depth (feet)	32
Perimeter (Miles)	1.4
Shoreline Complexity	2.6
Watershed Area (Acres)	819
Watershed to Lake Area Ratio	21:1
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (μg/L)	17.4
Avg Summer Chl-α (μg/L)	4.6
Avg Summer Secchi Depth (ft)	5.7
Summer pH	7.2
Alkalinity (mg/L as $CaCO_3$)	14.6
Vegetation	
Number of Native Species	26
NHI-Listed Species	0
Exotic Species	0
Average Conservatism	7.2
Floristic Quality	25.8
Simpson's Diversity (1-D)	0.87



Descriptions of these parameters can be found within the town-wide portion of themanagement plan

8.2.1 Hiawatha Lake Water Quality

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

In 2015, a stakeholder survey was sent to 33 Hiawatha Lake riparian property owners. Approximately 42%, or 14 surveys were completed. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Hiawatha Lake, but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B. When asked about Hiawatha Lake's current water quality, 100% of respondents described the current water quality of Hiawatha Lake as *excellent* or *good* (Figure 8.2.1-1). When asked how water quality has changed in Hiawatha Lake since they first visited the lake, approximately 72% of respondents indicated water quality has *remained the same*, 14% indicated it has *somewhat improved*, and 14% indicated it has *somewhat degraded* (Figure 8.2.1-1).

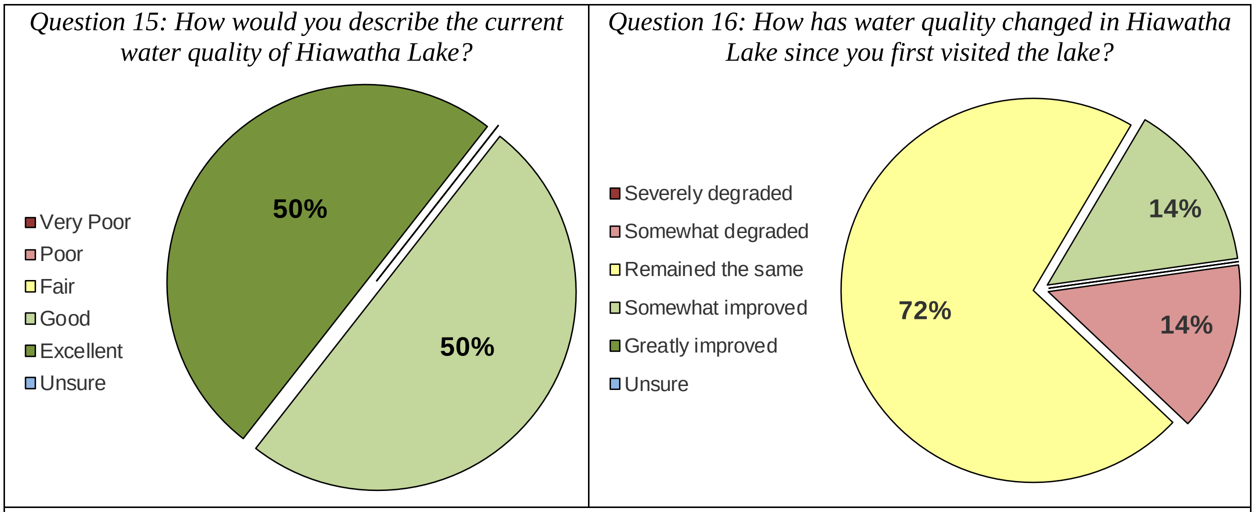


Figure 8.2.1-1. Hiawatha Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 14 (42%) respondents of 33 surveys distributed.

Near-surface total phosphorus data for Hiawatha Lake are available from 1979 and annually from 2000-2015 (Figure 8.2.1-2). Historical annual average near-surface total phosphorus concentrations range from *excellent* to *good* for deep, headwater drainage lakes in Wisconsin, and concentrations measured in 2015 fell into the *excellent* category. The weighted average of summer near-surface total phosphorus concentrations using all data that are available falls into the *excellent* category with a value of 17.4 µg/L, and is comparable to the median concentration for other deep, headwater drainage lakes in Wisconsin (17.0 µg/L) and slightly lower than the median concentration for all lake types within the Northern Lakes and Forests (NLF) ecoregion (21.0 µg/L).

Near-surface total phosphorus concentrations in Hiawatha Lake were slightly higher than average in 2010, 2011, 2013, and 2014; however, trends analysis indicates that these slightly elevated phosphorus concentrations to not represent a statistically valid trend. Precipitation data obtained from nearby Hurley, WI indicate that precipitation was above average in 2010, 2013, and 2014, and the increased runoff to Hiawatha Lake is the likely reason for these higher-than-average phosphorus concentrations (Figure 8.2.1-3). Large precipitation events likely 'flush' the large, coniferous wetland which drains to Hiawatha Lake from the north increasing the amount of phosphorus and other nutrients delivered to the lake. While there was a measured increase in total phosphorus in these years, these increases were not significant and are considered *good* for deep, headwater drainage lakes. As is discussed further in Hiawatha Lake Watershed Section, measured near-surface total phosphorus concentrations align with predicted concentrations based on watershed modeling.

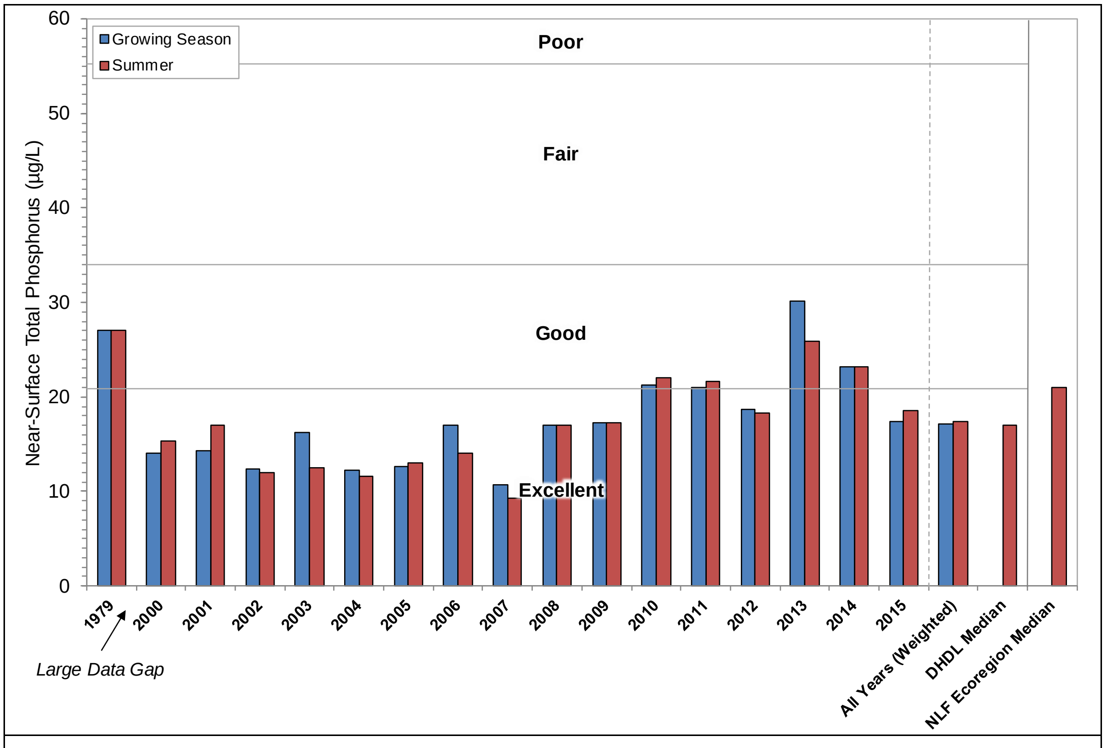


Figure 8.2.1-2. Hiawatha Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

The mid-summer total nitrogen to total phosphorus ratio measured from Hiawatha Lake in 2015 was 48:1, indicating that phosphorus is the limiting nutrient, or the nutrient controlling phytoplankton growth in Hiawatha Lake. Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Hiawatha Lake from 1979 and 2000-2015 (Figure 8.2.1-4). With the exception of 1979, 2012, and 2013, all historical data and the data collected in 2015 fall into the *excellent* category for deep, headwater drainage lakes. The average weighted summer chlorophyll-*a* concentration for Hiawatha Lake is 4.6 µg/L, which is comparable to the median chlorophyll-*a* concentration for other deep, headwater drainage lakes in Wisconsin (5.0 µg/L) and slightly lower than the median concentration for all lake types within the NLF ecoregion (5.6 µg/L). The low level of phytoplankton production in Hiawatha Lake is a result of the low concentrations of phosphorus, the nutrient regulating phytoplankton production.

The higher chlorophyll-*a* concentrations in 2012 and 2013 (and likely 1979) were likely the result of extremes in annual climatic variations. Lakes in northern Wisconsin had one of the earliest ice-off dates on record in 2012, and the summer of 2012 was one of the warmest on record in Wisconsin. While phosphorus concentrations were not higher than average in 2012, Hiawatha Lake's water temperature was likely higher which facilitates greater and more rapid phytoplankton production. In 2013, precipitation was approximately 20 inches above normal which likely delivered a higher amount of phosphorus to Hiawatha Lake from its watershed. With higher

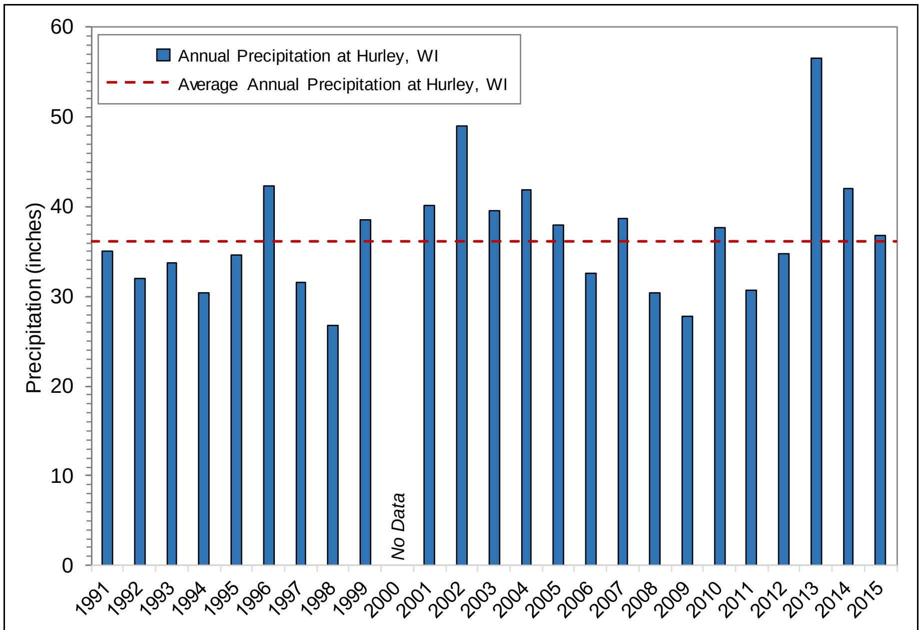


Figure 8.2.1-3. Total annual precipitation measured in Hurley, WI. Data obtained from National Oceanic and Atmospheric Administration website (https://www.ncdc.noaa.gov/cdo-web/).

phosphorus concentrations in 2013, more phytoplankton were produced. While chlorophyll-*a* concentrations were elevated in these years, they still fell within the *good* category for deep, headwater drainage lakes, and these variations in both phosphorus and chlorophyll-*a* are natural and expected given climatic changes from year to year. Overall, trends analysis indicates that like chlorophyll-*a* concentrations have remained relatively stable over the time period for which data are available, and no trends (positive or negative) are occurring over time.

Secchi disk transparency data from Hiawatha Lake are available from 1979 and 1998-2015 (Figure 8.2.1-5). Average annual growing season and summer Secchi disk transparency data range from *excellent* to *fair* for deep, headwater drainage lakes in Wisconsin. The weighted average summer Secchi disk transparency in Hiawatha Lake is 5.7 feet, falling below the median value for other deep, headwater drainage lakes in Wisconsin (10.8 feet) and the median value for all lake types within the NLF ecoregion (8.9 feet). Secchi disk transparency is lower than expected in Hiawatha Lake given the relatively low chlorophyll-*a* concentrations, and is an indication that another factor other than phytoplankton abundance is influencing the lake's clarity.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were below the limit of detection in Hiawatha Lake in 2015 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Hiawatha Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and indicates the level of dissolved material within the water. True color values measured from Hiawatha Lake in 2015 averaged 175 SU (standard units), indicating the lake's water is *highly tea-colored*. Based on Hiawatha Lake's chlorophyll-*a* concentrations, Secchi disk transparency is predicted to be approximately 9-10 feet; however, the high concentrations of dissolved organic acids in the lake reduce the water's clarity to the measured 5.7 feet.

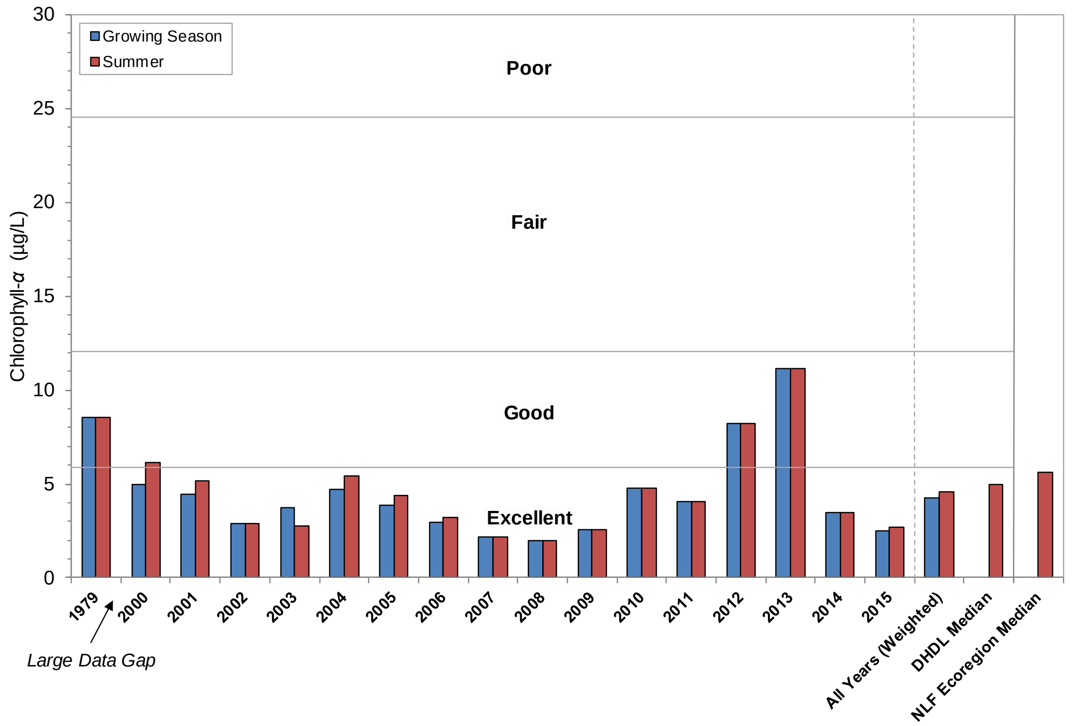


Figure 8.2.1-4. Hiawatha Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep, headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Water clarity in Hiawatha Lake has been below average since 2013, and is likely due to the increased precipitation in 2013 and 2014 which delivered higher amounts of dissolve organic acids from wetlands into the lake. While water clarity was considered *fair* in 2015, this is not an indication that Hiawatha Lake's water quality is degraded. It is important to understand that the staining of the lake's water is natural, and the level of staining is going to be highly dependent upon annual precipitation from year to year.

To determine if internal nutrient loading (discussed in town-wide section of management plan) occurs in Hiawatha Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on three occasions from Hiawatha Lake in 2015 and once in 2016, and historical near-bottom total phosphorus concentrations are available from 1979. (Figure 8.2.1-6). As illustrated, on some occasions near-bottom total phosphorus concentrations were slightly higher than those measured at the surface. Typically, internal nutrient loading is considered to be a significant source of phosphorus to a lake if near-bottom concentrations exceed 200 µg/L, and concentrations measured in 2015 did not exceed 40 µg/L. This indicates that internal nutrient loading is not a significant source of phosphorus to Hiawatha Lake.

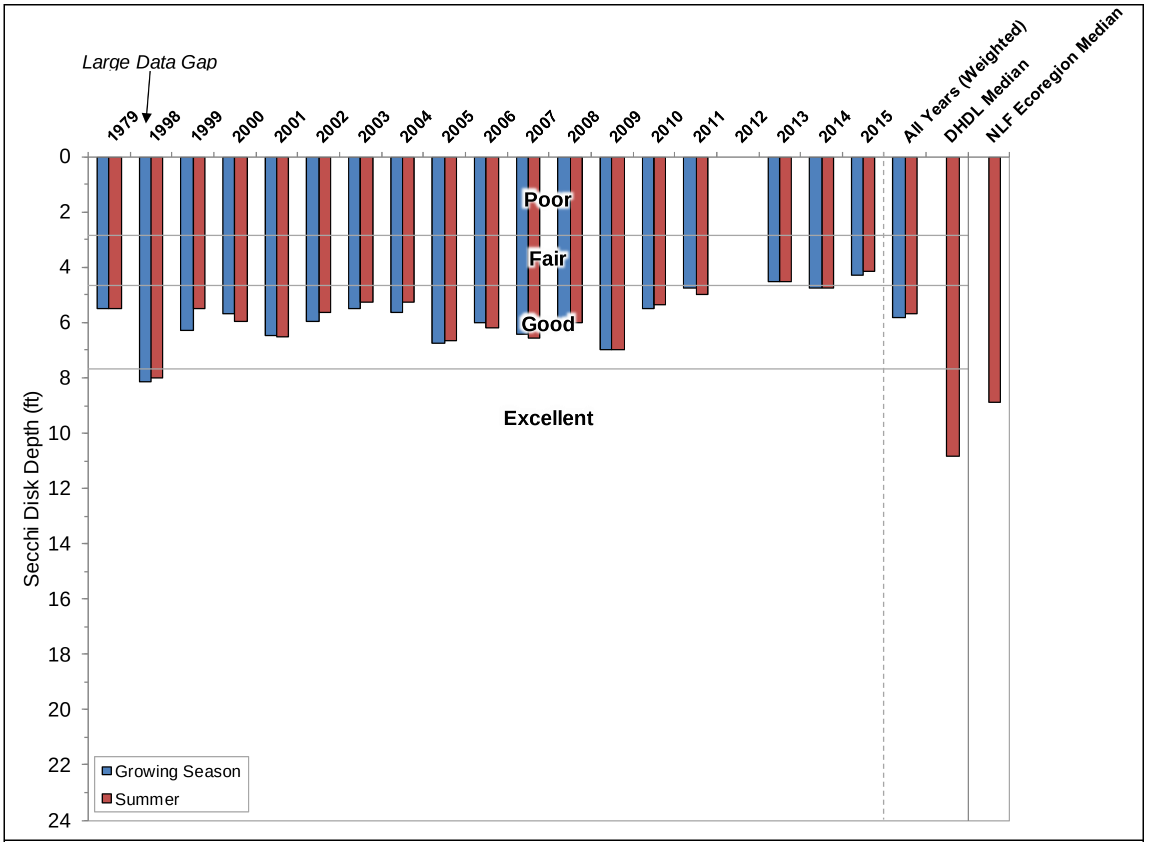


Figure 8.2.1-5. Hiawatha Lake average annual Secchi disk depths and median Secchi disk depths for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

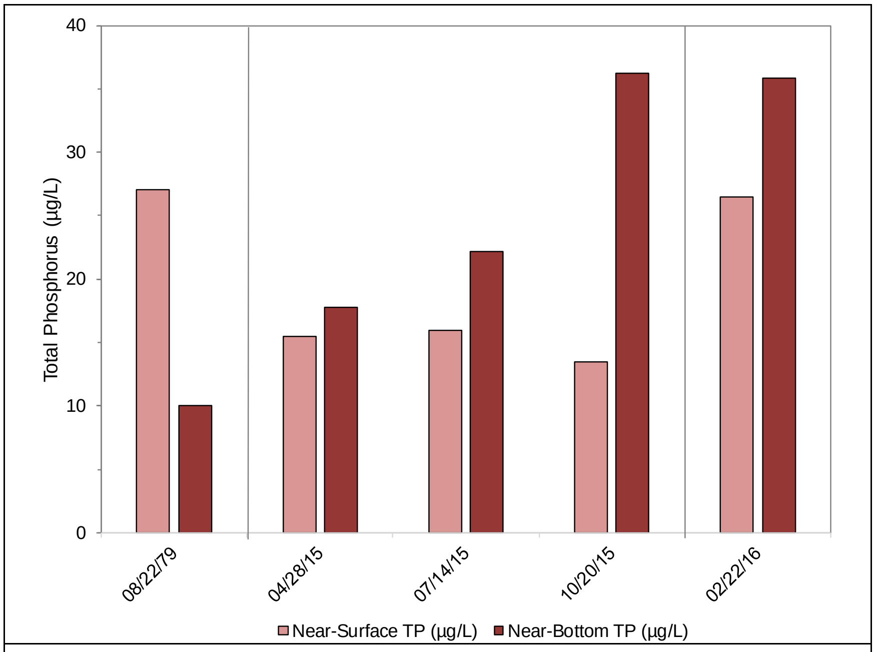


Figure 8.2.1-6. Hiawatha Lake available near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations.

Hiawatha Lake Trophic State

Figure 8.2.1-7 contains the weighted average Trophic State Index (TSI) values for Hiawatha 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 for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for phosphorus and chlorophyll-*a* in Hiawatha Lake indicate the lake is currently in a mesotrophic state. The fact that the TSI values for total phosphorus and chlorophyll-*a* are nearly identical is an indication that chlorophyll-*a* production is regulated by total phosphorus. In contrast, the weighted TSI value for Secchi disk transparency is higher, falling into the eutrophic category. The higher TSI value for Secchi disk transparency when compared to the TSI value for chlorophyll-*a* indicates that water clarity is influenced by another factor other than phytoplankton abundance. As discussed previously, dissolved organic acids that stain Hiawatha Lake's water are the primary factor influencing water clarity in Hiawatha Lake. The trophic state of Hiawatha Lake is comparable to other deep, headwater drainage lakes in Wisconsin and slightly lower when compared to all lake types within the NLF ecoregion.

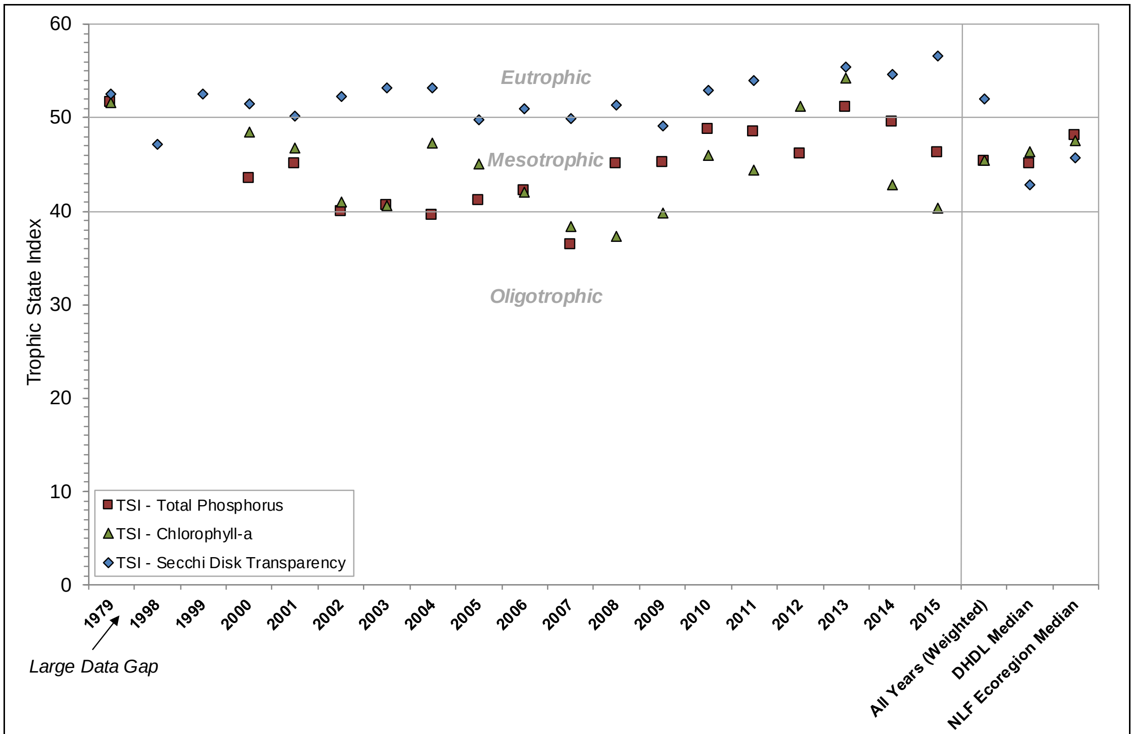


Figure 8.2.1-7. Hiawatha Lake, statewide deep, headwater drainage lakes (DHDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Hiawatha Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling event conducted by Onterra ecologists. These data are displayed in Figure 8.2.1-8. Hiawatha Lake is *dimictic*, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Hiawatha Lake's deeper nature, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer, upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen, and decomposition of organic matter within this layer depletes available oxygen.

In fall as surface temperatures cool, the entire water column is again able to mix which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. In February of 2016, oxygen concentrations remained above 2.0 mg/L throughout the majority of the water column, indicating that fishkills as a result of winter anoxia are likely not a concern in Hiawatha Lake.

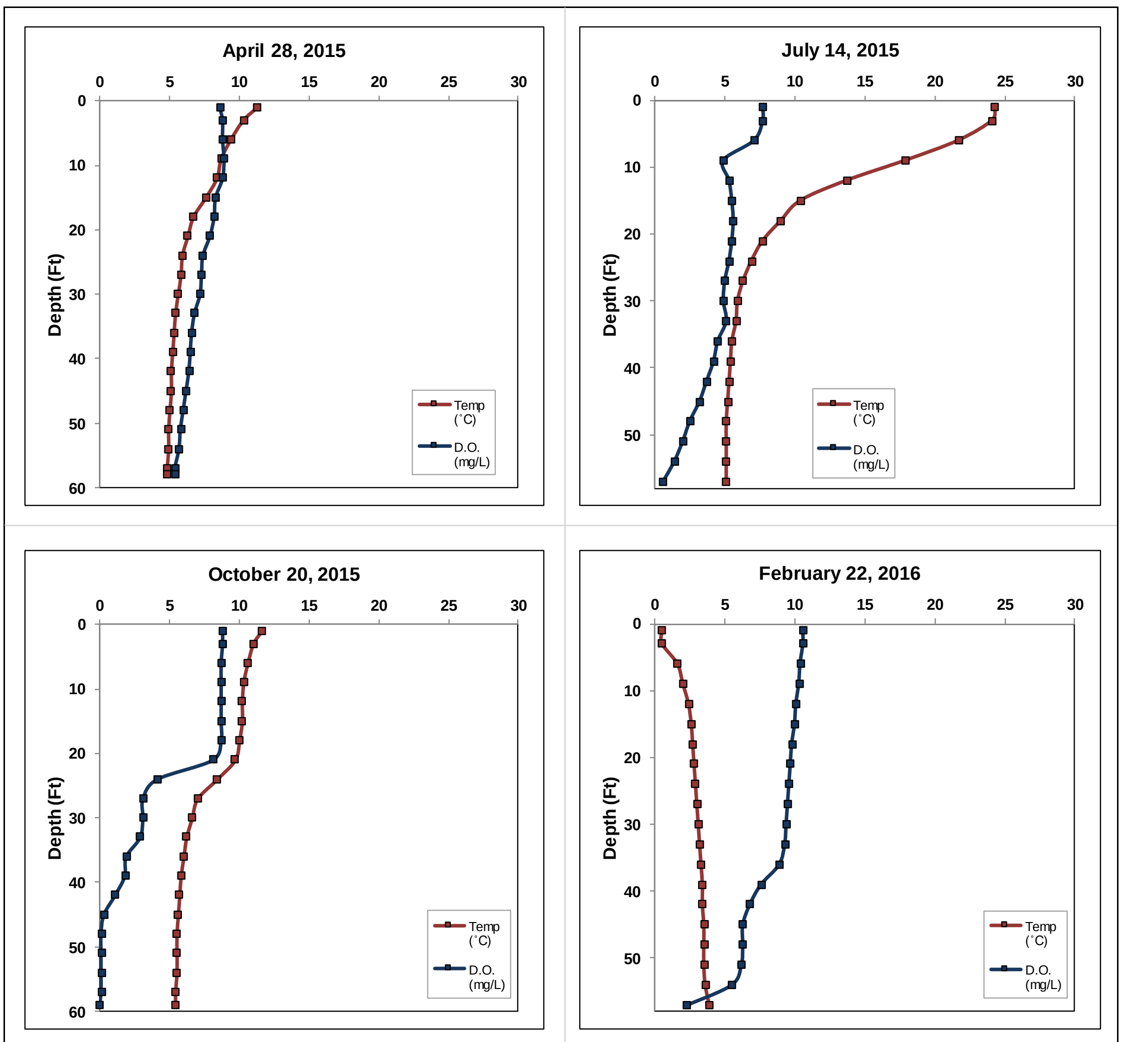


Figure 8.2.1-8. Hiawatha Lake 2015/16 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Hiawatha Lake

The previous 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 Hiawatha Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. Hiawatha Lake's mid-summer surface water pH was measured at roughly 7.2 in 2015. This value indicates Hiawatha Lake's water is near neutral and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Hiawatha Lake's average alkalinity measured in 2015 was 14.6 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that Hiawatha Lake has low sensitivity to fluctuations in pH from acid rain.

Water quality samples collected from Hiawatha Lake in 2015 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Hiawatha Lake's pH falls within this range. Hiawatha Lake's calcium concentration in 2015 was 6.1 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Hiawatha Lake in 2015 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veliger and for the invasive spiny water flea.

8.2.2 Hiawatha Lake Watershed Assessment

Hiawatha Lake's surficial watershed encompasses approximately 819 acres (Figure 8.2.2-1 and Hiawatha Lake – Map 2). The watershed is comprised mainly of natural land cover types including forests (78%), wetlands (17%), and the lake surface itself (5%) (Figure 8.2.2-1). Less than 1% is comprised of rural residential areas and pasture/grass. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Hiawatha Lake's residence time is approximately 1.3 years, or the water within the lake is completely replaced once every 1.3 years.

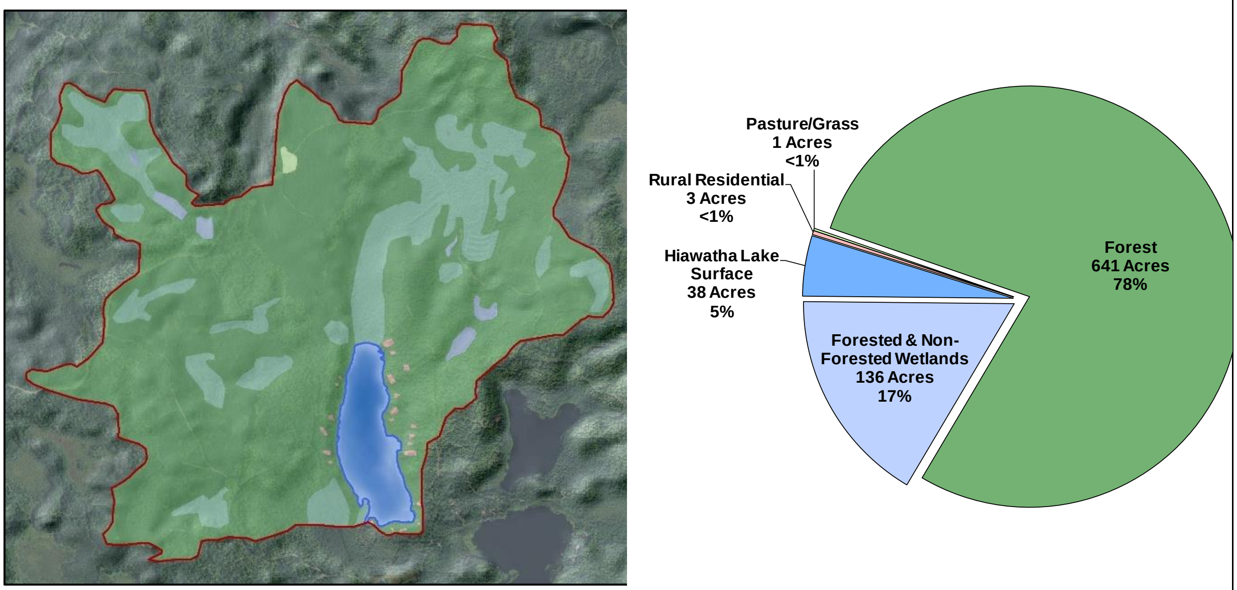


Figure 8.2.2-1. Hiawatha Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types and their acreages within Hiawatha Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Hiawatha Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Hiawatha Lake riparian property owners in 2015 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a total of approximately 76 pounds of phosphorus are delivered to Hiawatha Lake from its watershed on an annual basis (Figure 8.2.2-2).

Of the estimated 76 pounds of phosphorus being delivered to Hiawatha Lake on an annual basis, the majority (51 pounds - 67%) originates from forests, 13 pounds (17%) from wetlands, 11 pounds (15%) from atmospheric deposition directly onto the lake's surface, and 1 pounds (1%) from riparian septic systems. The phosphorus delivered from rural residential areas and pasture/grass were negligible. Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 16 µg/L, which is essentially identical to the measured growing season average total phosphorus concentration of 17.1 µg/L. The similarity between the predicted and measured total phosphorus concentrations in Hiawatha Lake is an indication that this is an accurate model of the lake's watershed and that there are no significant, unaccounted sources of phosphorus entering the lake.

Using the WiLMS model for Hiawatha Lake's watershed, scenarios can be run to determine how Hiawatha Lake's water quality would change given alterations to its watershed. For example, if 25% of the forests within Hiawatha Lake's watershed were converted to pasture/grass, phosphorus concentrations are predicted to increase from the current growing season concentration of 17.1 µg/L to 21 µg/L. This increase in total phosphorus would result in chlorophyll-*a* concentrations increasing from the current growing season average of 4.6 µg/L to 6.0 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 5.7 feet to 4.7 feet. In another scenario, if 25% of the forests in Hiawatha Lake's watershed were converted to row crop agriculture, phosphorus concentrations are predicted to increase to 34 µg/L, chlorophyll-*a* concentrations would increase to 12 µg/L, and Secchi disk transparency would decline to 3.0 feet. This modeling illustrates the importance of the natural land cover types within Hiawatha Lake's watershed in maintaining the lake's excellent water quality.

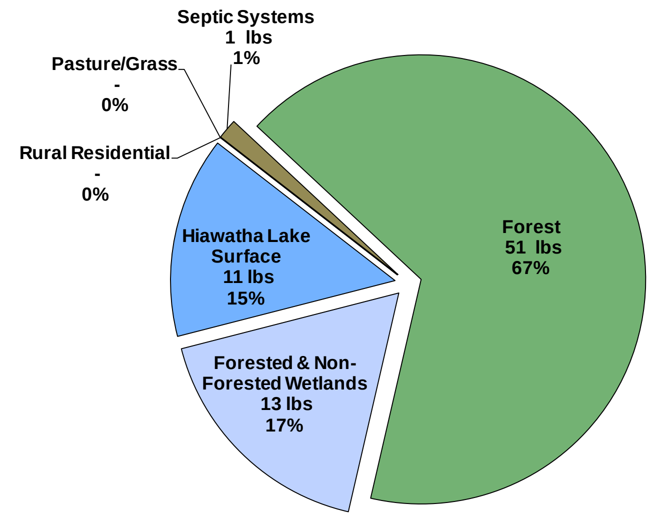


Figure 8.2.2-2. Hiawatha Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.2.3 Hiawatha Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the late-summer of 2015, the immediate shoreland of Hiawatha Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

The 2015 survey revealed that Hiawatha Lake has stretches of shoreland that fit four of the five shoreland assessment categories (Figure 8.2.3-1). In total, 1.0 miles (72%) of the 1.4-mile shoreland zone were categorized as natural/undeveloped or developed-natural, or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.04 miles (3%) of the shoreland was categorized as developed-unnatural, shorelands which provide little benefit to and may actually adversely impact the lake. If restoration of Hiawatha Lake's shoreland is to occur, primary focus should be placed on these shoreland areas. Hiawatha Lake – Map 3 displays the locations of these shoreland categories around the entire lake. No areas of Hiawatha Lake's shoreland zone were found to be in an urbanized state.

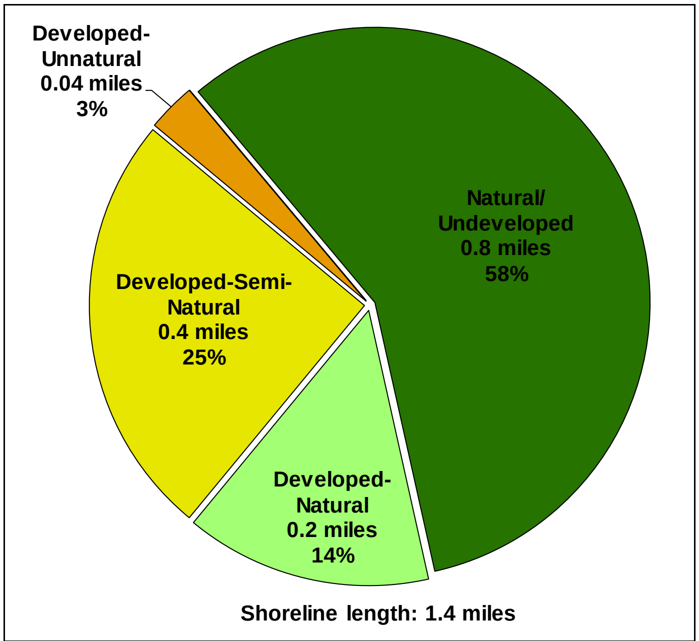


Figure 8.2.3-1. Hiawatha Lake shoreland categories and total lengths. Based upon a late-summer 2015 survey. Locations of these categorized shorelands can be found on Hiawatha Lake - Map 3.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Hiawatha Lake in 2015. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on Hiawatha Lake, a total of 144 pieces were observed along 1.4 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 103:1 (Figure 8.2.3-2). Onterra ecologists have been completing these surveys on Wisconsin's lakes for five years, and Hiawatha Lake has one the highest coarse woody habitat pieces per shoreline recorded on any Onterra project to date. Refraining from removing these woody habitats from the

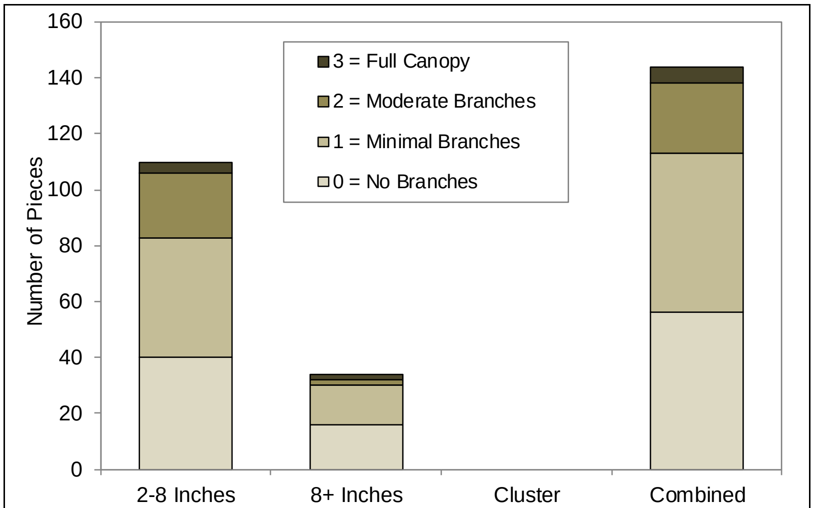


Figure 8.2.3-2. Hiawatha Lake coarse woody habitat survey results. Based upon a late-summer 2015 survey. Locations of Hiawatha Lake coarse woody habitat can be found on Hiawatha Lake – Map 4.

shoreland area will ensure this high-quality habitat remains in these lakes. The locations of these coarse woody habitat pieces are displayed on Hiawatha Lake – Map 4.

8.2.4 Hiawatha Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Hiawatha Lake on June 29, 2015. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate potential occurrences of the non-native curly-leaf pondweed, which should be at or near its peak growth at this time. No curly-leaf pondweed or any non-native aquatic plant species were located in Hiawatha Lake during this survey or any survey completed in 2015.

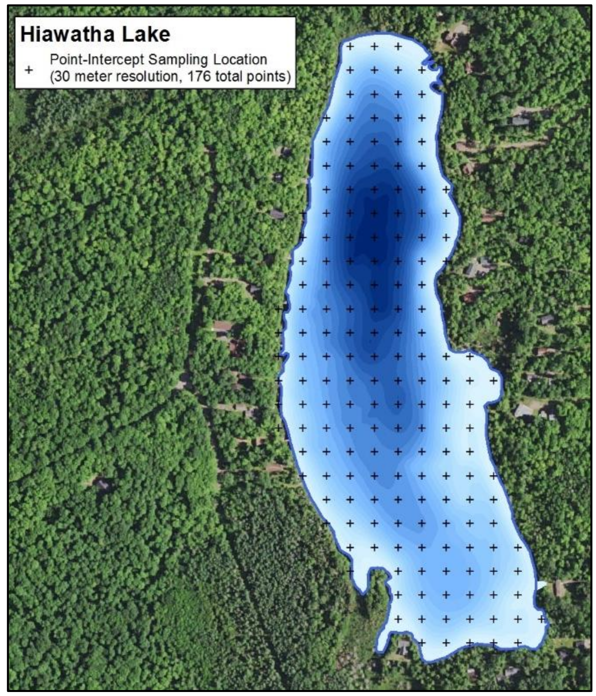


Figure 8.2.4-1. Hiawatha Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Hiawatha Lake by Onterra ecologists on August 18, 2015 (Figure 8.2.4-1). During these surveys, a total of 26 aquatic plant species were located, all of which are considered to be native species (Table 8.2.4-1). Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In early August of 2015, Onterra ecologists completed an acoustic survey on Hiawatha Lake (bathymetric results shown in introduction). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Hiawatha Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2015 acoustic survey reveals that Hiawatha Lake's average substrate hardness ranges from hard to moderately hard with few areas containing softer, flocculent sediments (Figure 8.2.4-2 and Hiawatha Lake – Map 5). Substrate hardness is highest within the shallowest areas of Hiawatha Lake. From 15 and deeper, substrate hardness remains relatively constant. Figure 8.2.4-3 illustrates the spatial distribution of substrate hardness in Hiawatha Lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.2.4-1. Hiawatha Lake 2015 list of aquatic plant species.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2015 (Onterra)
Emergent	*Carex aquatilis*	Long-bracted tussock sedge	7	I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9	I
	Carex utriculata	Common yellow lake sedge	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	X
	Equisetum fluviatile	Water horsetail	7	X
	Glyceria canadensis	Rattlesnake grass	7	I
	Juncus effusus	Soft rush	4	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Typha spp.	Cattail spp.	1	I
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I
FL	*Nuphar variegata*	Spatterdock	6	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submergent	*Callitriche palustris*	Common water starwort	8	I
	Chara spp.	Muskgrasses	7	X
	Eriocaulon aquaticum	Pipewort	9	X
	Fontinalis sphagnifolia	Rolled water moss	N/A	X
	Isoetes spp.	Quillwort spp.	8	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton spirillus	Spiral-fruited pondweed	8	X

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

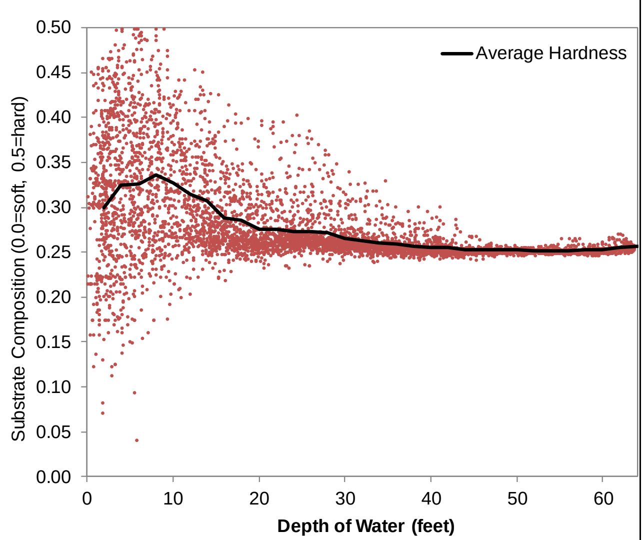


Figure 8.2.4-2. Hiawatha Lake substrate hardness across water depth. Individual data points are displayed in red. Creating using data from August 2015 acoustic survey.

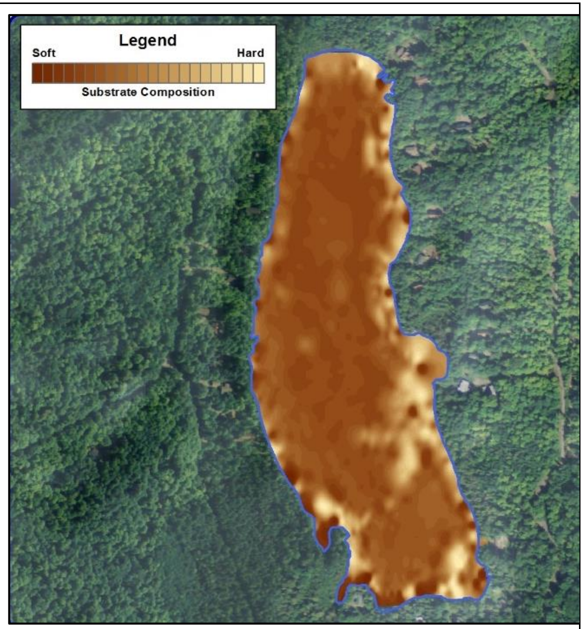


Figure 8.2.4-3. Hiawatha Lake substrate hardness. Created using data from August 2015 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2015 aquatic plant bio-volume data are displayed in Figure 8.2.4-4 and Hiawatha Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. These data indicate that Hiawatha Lake is sparsely vegetated. The majority of aquatic plant growth occurs within first 10 feet of water, and the presence of aquatic plants quickly diminished beyond 10 feet. Overall, the 2015 acoustic survey indicates that approximately 4% of Hiawatha Lake contains aquatic vegetation (Figure 8.2.4-4). The remaining area of the lake is too deep to support aquatic plant growth.

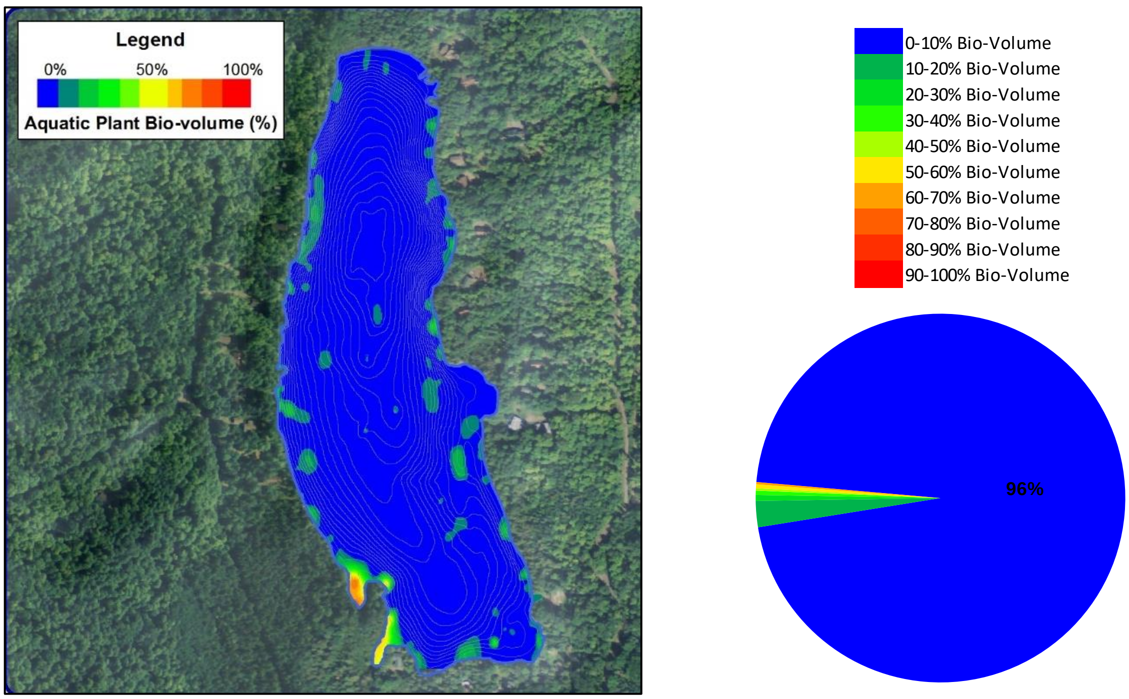


Figure 8.2.4-4. Hiawatha Lake 2015 aquatic plant bio-volume. Created using data from August 2015 acoustic survey data. Contour lines represent three-foot increments.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. During the 2015 aquatic plant point-intercept survey, the maximum depth recorded with aquatic plants was 11 feet. Of the 36 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (the littoral zone), approximately 50% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2015 indicates that 39% of the 36 sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 8% had a TRF rating of 2, and 3% had a TRF rating of 3 (Figure 8.2.4-5).

Of the 26 aquatic plant species located in Hiawatha Lake in 2015, 13 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.2.4-6). The remaining 13 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 13 species directly sampled with the rake during the point-intercept survey, rolled water moss, ribbon-leaf pondweed, slender pondweed, and slender naiad were the four-most frequently encountered aquatic plants, respectively (Figure 8.2.4-6).

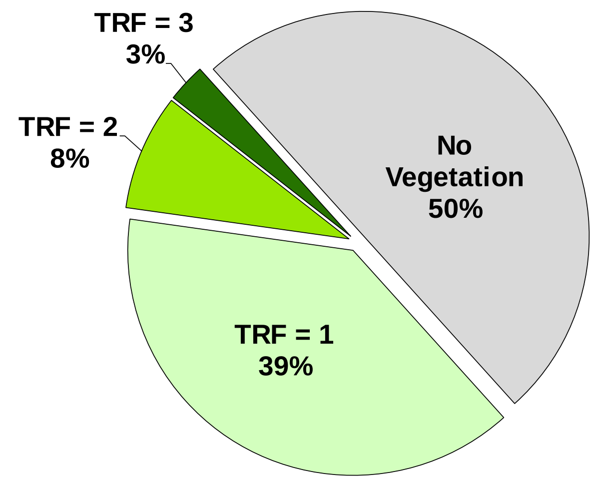


Figure 8.2.4-5. Hiawatha Lake 2015 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2015 whole-lake point-intercept survey (N = 36).

Rolled water moss was the most frequently encountered aquatic plant in Hiawatha Lake in 2015 with a littoral frequency of occurrence of approximately 33% (Figure 8.2-4-6). Like other aquatic bryophytes, rolled water moss is only able to utilize dissolved carbon dioxide for within the water for photosynthesis and is unable to use bicarbonate. Consequently, aquatic mosses tend to dominate in lakes like Hiawatha that have low bicarbonate concentrations and higher concentrations of dissolved carbon dioxide. The plants are also able to tolerate low-light conditions, and rolled water moss was the deepest growing aquatic plant located in Hiawatha Lake in 2015. These plants provide valuable structural habitat to aquatic wildlife.

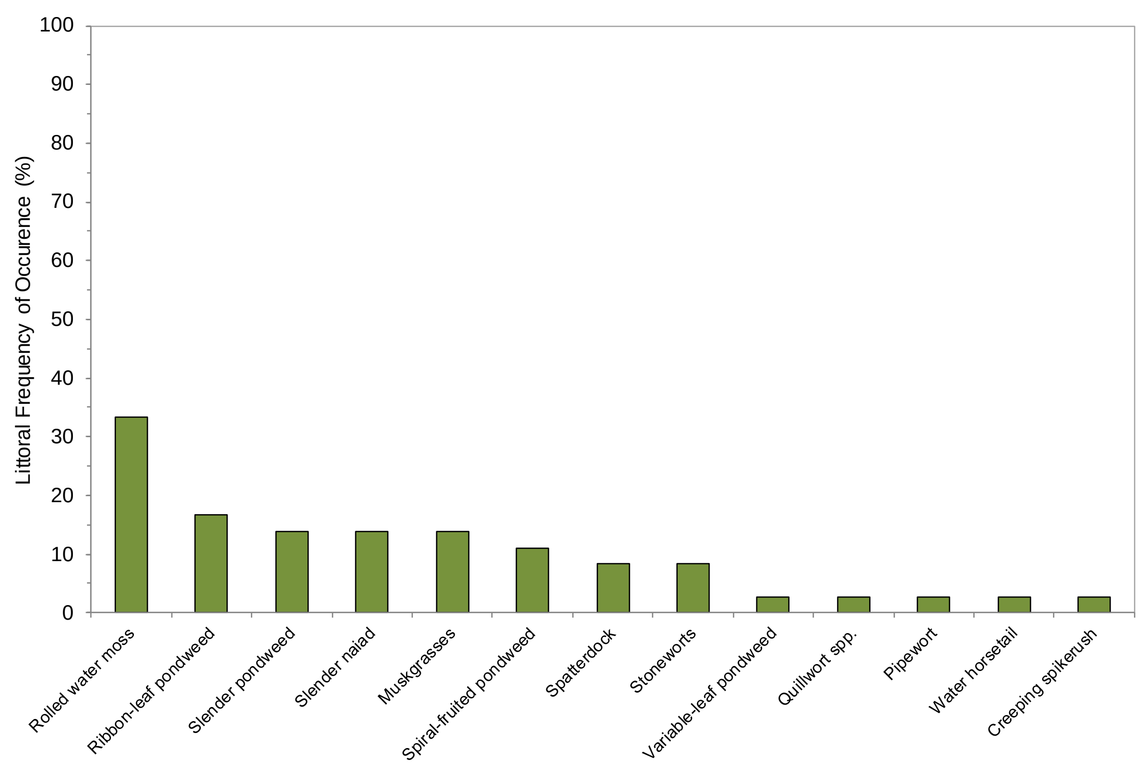


Figure 8.2.4-6. Hiawatha Lake 2015 littoral frequency of occurrence of aquatic plant species. Created using data from 2015 whole-lake point-intercept survey.

Ribbon-leaf pondweed (Photo 8.2.4-1), the second-most frequently encountered aquatic plant in Hiawatha Lake in 2015 with a littoral frequency of occurrence of approximately 17% is another aquatic plant species that is mainly found in lakes with lower alkalinity. This pondweed possesses long, ribbon-like submersed leaves, and as it grows near the surface it produces oval-shaped floating-leaves which aid in keeping the plants flowers above the surface where they can be pollinated. Like other aquatic plants, ribbon-leaf pondweed provides valuable structural habitat and its fruit provide a food source to wildlife.

Photo 8.2.4-1. Ribbon-leaf pondweed (*Potamogeton epihydrus*). The second-most frequently encountered plant in Hiawatha Lake. Photo credit Onterra.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.2.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.2.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with low to moderate alkalinity, like Hiawatha Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.


Photo 8.2.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

As discussed in the Town-wide section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2015 point-intercept survey and their conservatism values were used to calculate the FQI of Hiawatha Lake's aquatic plant community (equation shown below).

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Figure 8.2.4-7 compares the 2015 FQI components of Hiawatha Lake to median values of lakes within the Northern Lakes and Forests (NLF) ecoregion and lakes throughout Wisconsin. Hiawatha Lake's native species richness of 13, or the number of native aquatic plant species directly encountered on the rake, falls below the median values for lakes in the NLF ecoregion and for lakes throughout Wisconsin. This is to be expected given Hiawatha Lake's small littoral area, lower water clarity, and lower alkalinity. Only the aquatic plants that are adapted to the carbon-limited, low-light environment found in Harris Lake are going to be able to persist.

While native species richness is low, Hiawatha Lake's average conservatism is high with a value of 7.2. This value exceeds the median values for lakes in the NLF ecoregion and lakes throughout Wisconsin, and indicates that Hiawatha Lake contains a higher number of aquatic plant species that have a higher sensitivity to environmental degradation and require high-quality environments. Using the native species richness and average conservatism yields and FQI value of 25.8, which falls below the median value for lakes in the NLF ecoregion but within the interquartile range for lakes throughout Wisconsin. While Hiawatha Lake contains a lower number of aquatic plant species, the species that are present are of high-quality and are indicative of a healthy lake environment.

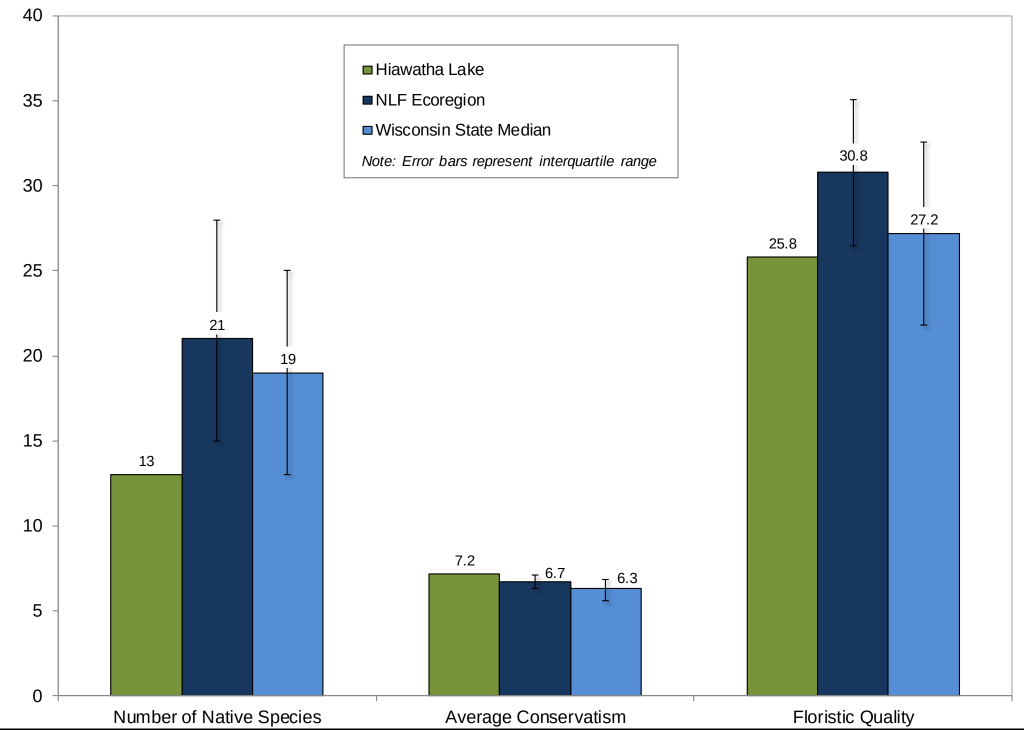


Figure 8.2.4-7. Hiawatha Lake Floristic Quality Assessment. Created using data from Onterra 2015 whole-lake point-intercept surveys. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Hiawatha Lake contains a lower number of native aquatic plant species, one may assume the aquatic plant community also has low species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Hiawatha Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLF ecoregion (Figure 8.2.4-8). Using the data collected from the 2015 point-intercept survey, Hiawatha Lake's aquatic plant is shown to have moderate species diversity with a Simpson's Diversity Index value of 0.87. This value is comparable to median species diversity for lakes within the NLF ecoregion and slightly higher than median species diversity for lakes throughout Wisconsin. In other words, if two individual aquatic plants were randomly sampled from Hiawatha Lake in 2015, there would be an 87% probability that they would be different species.

One way to visualize Hiawatha Lake's species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.2.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2015 whole-lake point-intercept survey and illustrates that rolled water moss comprises approximately 25% of the lake's plant community, while the remaining species are relatively evenly distributed. Because rolled water moss accounts for a quarter of Hiawatha's plant community, species diversity is moderate.

Each sampling location may contain numerous plant species, and 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 rolled water moss was found at 33% of the littoral sampling locations in Hiawatha Lake in 2015, its relative frequency of occurrence is 25%. Explained another way, if 100 plants were randomly sampled from Hiawatha Lake in 2015, 25 of would have been rolled water moss.

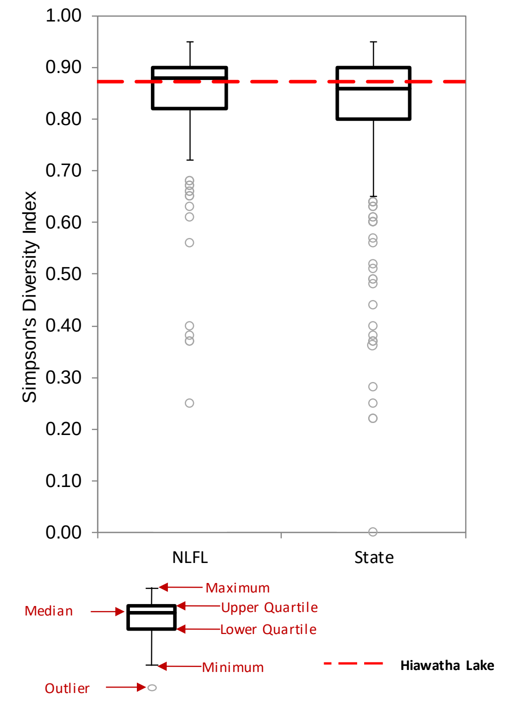


Figure 8.2.4-8. Hiawatha Lake species diversity index. Created using data from Onterra 2015 point-intercept survey.

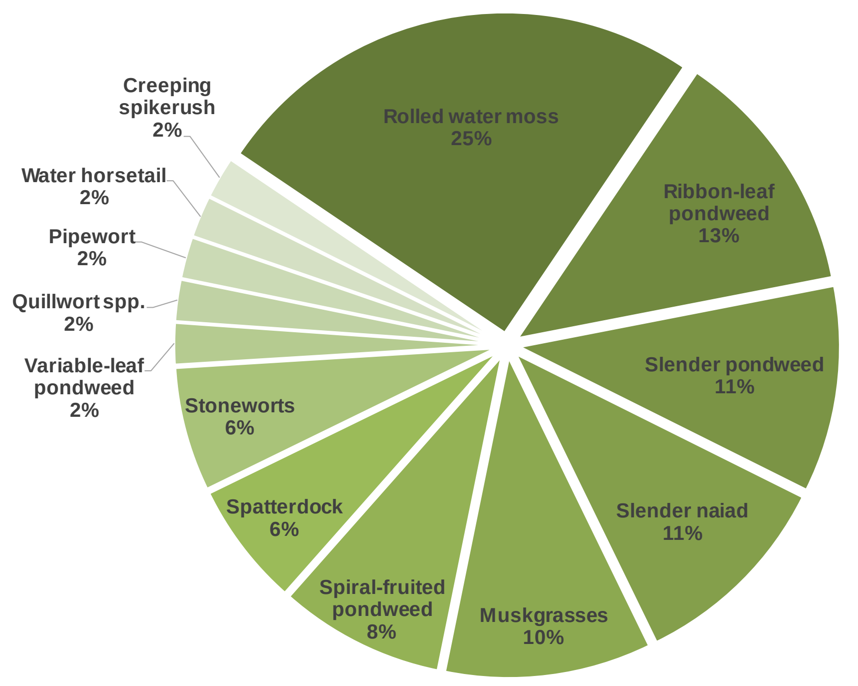


Figure 8.2.4-9. Hiawatha Lake 2015 relative frequency of occurrence of aquatic plant species. Created using data from 2015 point-intercept survey.

In 2015, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Hiawatha Lake. This survey revealed Hiawatha Lake contains approximately 0.8 acres of these communities comprised of 14 different aquatic plant species (Hiawatha Lake – Map 7 and Table 8.2.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines.

Table 8.2.4-2. Hiawatha Lake 2015 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2015 aquatic plant community mapping survey.

Hiawatha Lake	
Plant Community	**Acres**
Emergent	0.2
Floating-leaf	0.2
Mixed Emergent & Floating-leaf	0.4
Total	**0.8**

The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Hiawatha Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

8.2.5 Other Aquatic Invasive Species in Hiawatha Lake

As of 2016, no aquatic invasive species have been documented in Hiawatha Lake. As is discussed in previous sections, surveys completed by Onterra ecologists in 2015 did not reveal the presence of any non-native aquatic plants, and plankton tows completed in 2015 were negative for the presence of zebra mussel (*Dreissena polymorpha*) veligers and the spiny waterflea (*Bythrotrephes cederstroemi*). Nearby lakes within the Town of Winchester contain the non-native banded mystery snail (*Viviparus georgianus*), Chinese mystery snail (*Cipanogopaludina chinensis*), freshwater jellyfish (*Craspedacusta sowerbyi*), and the rusty crayfish (*Orconectes rusticus*). It is possible that Hiawatha Lake contains one or more of these non-native invertebrates and that they have just gone unreported.

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

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). The ecological impacts from freshwater jellyfish, which are believed to have been introduced from China, are not known. However, it is theorized that these jellyfish may have some impacts to zooplankton communities.

8.2.6 Hiawatha Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery as that is outside of the scope of this project. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected, the following information was compiled based upon data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2016B & GLIFWC 2016A and 2016B).

Hiawatha Lake 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 Hiawatha Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen, and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae and plants, and insects. Smaller fish called planktivores feed upon zooplankton and insects, and in turn become food for larger fish species. The species at the top of the food chain are called piscivores, and are the larger gamefish that are often sought after by anglers, such as bass and walleye.

A concept called energy flow describes how the biomass of piscovores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.2.6-1. As discussed in the Water Quality section, Hiawatha Lake is a mesotrophic lake, meaning it has a moderate nutrient content and thus a moderate level of primary productivity. Simply put, this means Hiawatha Lake should be able to support populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

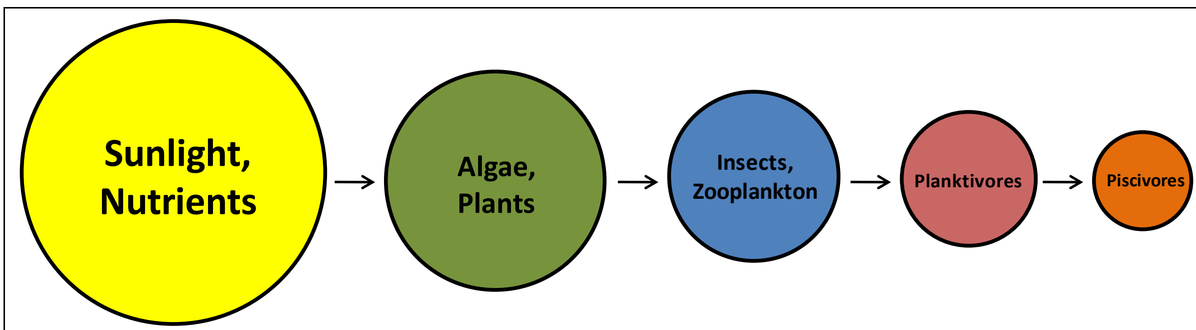


Figure 8.2.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

A fish population survey was completed by AquaTech USA in 2011 on Hiawatha Lake, and the species located during this survey as well as species located during previous assessments are found in Table 8.2.6-1. The report indicates that lake property owners have also indicated that muskellunge and lake trout may also be present. They reported walleye are a significant component of the Hiawatha Lake's fishery, and that natural reproduction occurs. Northern pike were the second-most abundant gamefish present, and the presence of tiger musky suggests the presence of muskellunge within the lake as well. The study concluded that additional information would need to be collected to determine if enhancement of the walleye population through stocking would be needed.

Table 8.2-1. Fish species recorded in Hiawatha Lake fisheries assessments.

Scientific Name	Common Name
Ambloplites rupestris	Rock bass
Castostomus commersoni	White sucker
Esox americanus subsp. *vermiculatus*	Grass pickerel
Esox lucius	Northern pike
Esox lucius x *masquinongy*	Tiger musky
Lepomis gibbosus	Pumpkinseed
Lepomis macrochirus	Bluegill
Micropterus salmoides	Largemouth bass
Notropis cornutus	Golden shiner
Perca flavescens	Yellow perch
Pomoxis nigromaculatus	Black crappie
Sander vitreus	Walleye

Hiawatha Lake Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.2.6-2). The Town of Winchester falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances.

In lakes where population estimates are out of date by 3 years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the "safe harvest level". Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the declaration, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009).

Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

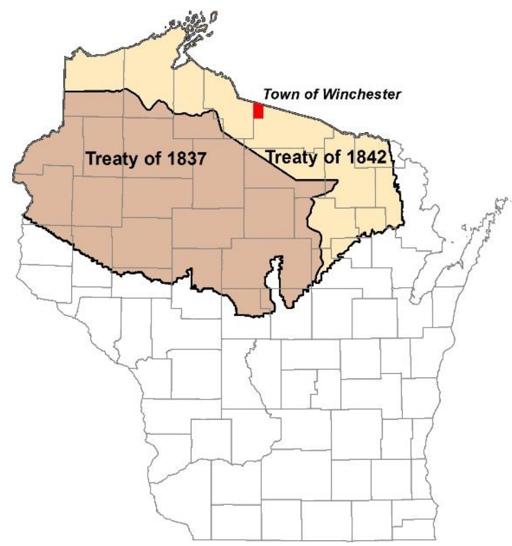


Figure 8.2.6-2. Location of the Town of Winchester within the Native American Ceded Territory (GLIFWC 2016A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Spear harvesters are able to 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 2016B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spear harvesters. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

While within the ceded territory, Hiawatha Lake has not experienced a spearfishing harvest. A small declaration for walleye harvest has been listed for Hiawatha Lake in recent years, however no spearing efforts have been undertaken likely due to the limited population of walleye in the lake and the lake's lack of public access.

Hiawatha Lake Fishing Regulations

The Town of Winchester Lakes are within the northern bass zone in Wisconsin. From May 7 – June 17, smallmouth bass are catch and release only whereas largemouth bass have a daily bag limit of 5 fish and a minimum length of 14 inches. From June 18 to March 5, five largemouth or smallmouth bass in combination may be kept and must be at least 14 inches in length. The Town of Winchester Lakes are in the northern management zone for muskellunge and northern pike. No minimum length limit exists for northern pike and five pike may be kept in a single day. Statewide regulations apply for all other fish species. Wisconsin species regulations are provided in each annual WDNR fishing regulations publication. Anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or visit their local bait and tackle shop to receive a free fishing pamphlet that would contain this information.

Hiawatha Lake Fish Stocking

Stocking of a lake is sometimes done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Fish can be stocked as fry, fingerlings or even as adults. Since Hiawatha Lake does not have public access, the WDNR does not actively stock gamefish in the lake and limited information exists regarding the fishery in Hiawatha Lake. Private stocking has been undertaken historically on the lake and is summarized in table 8.1.5-2. Dating back to 1985, walleye has been periodically stocked in Hiawatha Lake. Limited stocking of rainbow trout (1997) and largemouth bass (1999) have also occurred in the lake.

Table 8.1.5-2. Available Stocking History on Hiawatha Lake.

Hiawatha Lake Fish Stocking Summary			
Year	**Species**	**# Fish Stocked**	**Avg Fish Length (in)**
1985	Walleye	350	6
1997	Walleye	450	6
1997	Rainbow Trout	200	8
1999	Walleye	400	6
1999	Largemouth Bass	200	6
2001	Walleye	550	6
2011	Walleye	257	7-9
2014	Walleye	250	9

Hiawatha Lake Substrate Type

Substrate and habitat are critical to fish species that do not provide parental care to their eggs, in other words, the eggs are left after spawning and not tended to by the parent fish. Walleye is a species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well. According to the point-intercept survey conducted by Onterra, the majority (61%) of the substrate in Hiawatha Lake is composed of either sand or gravel/rock, whereas 39% is composed of a soft, mucky or organic substrate.

8.2.7 Hiawatha Lake Implementation Plan

The Implementation Plan presented below was created through the collaborative efforts of the Hiawatha Lake Association (HLA) Planning Committee, Onterra ecologists, and North Lakeland Discovery Center (NLDC) and WDNR staff. It represents the path the HLA 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 Hiawatha Lake stakeholders as portrayed by the members of the Planning Committee and the numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

<u>Management Action:</u>	Continue monitoring of Hiawatha Lake's water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Rolf Ethun (current CLMN volunteer)
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. As discussed in the Water Quality Section, Hiawatha Lake's water quality is excellent, and early detection of potential negative trends may lead to the reason as of why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the HLA have been collecting water quality data from Hiawatha Lake annually since 2000. The HLA realizes the importance of continuing this effort, which will supply them with valuable data about their lake. Moving forward, it is the responsibility of Rolf Ethun, current CLMN volunteer, to coordinate new volunteers as needed. When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.
Action Steps:	
1.	Rolf Ethun, current CLMN volunteer, recruits new volunteer(s) as needed.
2.	Volunteer contacts Sandy Wickman (715.365.8951) as needed.

3. Coordinator reports results to WDNR and to HLA members during annual meeting.

Management Action: Preserve natural and restore highly developed shoreland areas on Hiawatha Lake.

Timeframe: Initiate 2017

Facilitator: HLA Board of Directors (suggested)

Description: The 2015 Shoreland Condition Assessment found that approximately 72% (1.0 miles) of Hiawatha Lake's immediate shoreland zone contains little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 3% (0.04 miles) contains a higher degree of development categorized as *developed-unnatural*. It is important that the owners of properties with little development become educated on the benefits their shoreland is providing to Hiawatha Lake in terms of maintaining the lake's water quality and habitat, and that these shorelands remain in a natural or semi-natural state. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to Hiawatha Lake's water quality and contribution to habitat loss.

The HLA board of directors will work with appropriate entities such as the NLDC to research grant programs and other pertinent information that will aid the HLA in preserving and restoring Hiawatha Lake's shoreland. 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.

Action Steps:

1. HLA Board of Directors gathers appropriate information from entities listed above.
2. The HLA provides Hiawatha Lake property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural land cover within Hiawatha Lake's watershed beyond the immediate shoreland zone.

Timeframe: Initiate in 2017

Facilitator: HLA Board of Directors (suggested)

Description: As discussed within the Watershed Section, Hiawatha Lake's watershed or drainage basin is comprised primarily of natural land cover types, forests and wetlands. These natural land cover types export minimal amounts of phosphorus, retain soil, and maintain Hiawatha Lake's excellent water quality. The HLA recognizes the importance of maintaining natural land cover within Hiawatha Lake's watershed to maintain the lake's water quality for future generations.

As discussed in the previous management action, one way the HLA can preserve land within Hiawatha Lake's watershed is through the purchase of land and placement within a land trust. The HLA can also reach out to land owners of property within the lake's watershed and provide them with information on the HLA's mission and why preserving their land in a more natural state is beneficial for water quality. As of 2016, approximately 69% of the land within Hiawatha Lake's watershed is owned by The Forestland Group's Heartwood Forestland Partnership (Figure 8.2.7-1). This land is managed for sustainable logging and is overseen by regional trams working with local forestry consulting firms. The land within Hiawatha Lake's watershed is part of the Great Lakes Region Chippewa East Property. Shawn Hagan is the Senior Director for Forestland Operations (906.487.7491) of the Great Lakes Region for The Forestland Group, and the HLA can contact Shawn for more information on how this property within Hiawatha Lake's watershed is managed.

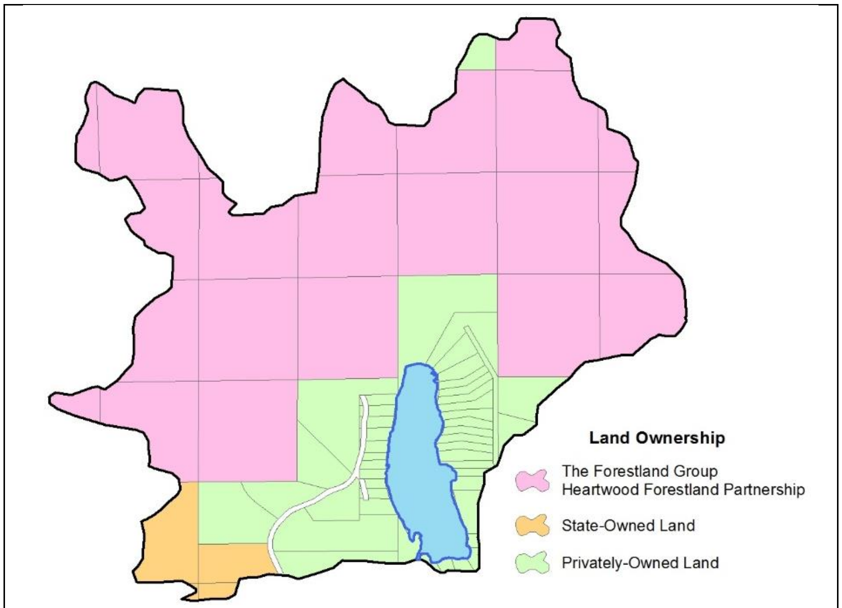


Figure 8.2.7-1. Land ownership within Hiawatha Lake's watershed.

Approximately 4% of the land within Hiawatha Lake's watershed is owned by the Wisconsin Department of Natural Resources, while the remaining 27% is comprised of 45 privately-owned parcels. Of these 45 parcels, 39 border Hiawatha Lake and seven are currently privately-owned trusts. In an effort to preserve natural land cover on these properties, the HLA can include information on the benefits of maintaining these properties in a natural state along with information on the benefits of maintaining a natural shoreline as discussed in the previous management action.

Action Steps:

1. See description above.

Management Goal 2: Assure and Enhance the Communication and Outreach of the Hiawatha Lake Association with Hiawatha Lake Stakeholders

Management Action: Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Hiawatha Lake.

Timeframe: Continuation of current effort

Facilitator: HLA Board of Directors (suggested)

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The HLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the HLA regularly publishes and distributes an electronic newsletter three to four times per year that provides association-related information including current association projects and updates, meeting times, and educational topics. This is an excellent source for communication to association members. In addition, the HLA reaches out to new property owners to inform them about the benefits of becoming an association member.

The majority of Hiawatha Lake stakeholder survey respondents indicated that the HLA keeps them highly informed regarding issues with the lake and its management. The HLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Hiawatha Lake and its preservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter or distributed as separate educational materials. In addition, the HLA can invite professionals who work within these topics to come and speak at the association's annual meeting or hold workshops if available.

Example Educational Topics

- Shoreline restoration and protection
- Effect lawn fertilizers/herbicides have on the lake
- Importance of maintaining course woody habitat

- Fishing rules and regulations
- Catch-and-release fishing
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention
- Water quality monitoring updates from Hiawatha Lake
- Septic system maintenance
- Littering on the ice and year-round

Action Steps:

1. See description above.

Management Goal 3: Prevent Aquatic Invasive Species Introductions to Hiawatha Lake

Management Action: Continue HLA volunteer aquatic invasive species monitoring using the shoreline monitors.

Timeframe: Continuation of current effort.

Facilitator: HLA Board of Directors (suggested)

Description: To date, no aquatic invasive species have been documented in Hiawatha Lake. However, nearby lakes such as Big Lake and the Manitowish Chain of Lakes harbor populations of curly-leaf pondweed, while nearby Presque Isle Lake contains a population of Eurasian watermilfoil. While Hiawatha Lake does not contain public access, lake property owners need to be vigilant that they are not introducing aquatic invasive species to Hiawatha Lake when launching their watercraft.

In lakes without Eurasian watermilfoil and curly-leaf pondweed, early detection of these can often lead to successful control, and in instances with small infestations, possible even eradication. Currently, HLA volunteers have received aquatic invasive species identification and monitoring training and perform shoreline surveys in which volunteers are responsible for periodically monitoring specific areas of the lake. This methodology allows the entire lake to be monitored for the presence of non-native species.

Action Steps:

1. HLA volunteers updated their identification and monitoring skills by attending training sessions provided by the NLDC (877.543.2085).
2. Trained volunteers recruit and train additional association members.
3. Complete monitoring surveys following protocols.

Management Action:	Initiate aquatic invasive species rapid response plan upon discovery of new infestation.
Timeframe:	Initiate upon invasive species discovery.
Facilitator:	HLA Board of Directors (suggested)
Description:	In the event that an aquatic invasive species such as Eurasian watermilfoil is located by the trained volunteers, the areas would be marked using GPS and the HLA should contact resource managers immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase and the results would be used to develop potential control strategies.
Action Steps:	
1.	See description above.

Management Goal 4: Enhance the fishery of Hiawatha Lake

Management Action:	Continue work with WDNR fisheries managers to enhance the fishery of Hiawatha Lake.
Timeframe:	Continuation of current effort
Facilitator:	HLA Fisheries Committee (suggested)
Description:	The Hiawatha Lake stakeholder survey indicated that walleye are the most sought after gamefish for Hiawatha Lake stakeholders. As is discussed in the Hiawatha Lake Fisheries Data Integration Section, a population survey in 2011 found that walleye were the most abundance gamefish present in Hiawatha Lake. The report indicated that natural reproduction of walleye is occurring, but additional surveys would be needed to determine if stocking would be needed to enhance the population. While the majority of survey respondents indicated that current quality of fishing on Hiawatha Lake is *fair* or *good*, the planning committee indicated that the HLA would like to work to enhance the lake's fishery, specifically the lake's walleye population. Hiawatha Lake is currently overseen by WDNR fisheries biologist Steve Gilbert. The HLA Fisheries Committee should contact Mr. Gilbert regarding enhancement of the lake's walleye population, which has included stocking in the past. In addition, the committee should contact Mr. Gilbert on an annual basis (perhaps during the winter months when field work is not occurring) for a brief summary of any activities that took place or are planned for Hiawatha Lake. Additionally, the HLA Fisheries Committee may discuss options for improving the fishery in Hiawatha Lake, which may include changes in angling regulations and habitat enhancements.
Action Steps:	
1.	See description above.

Please note that study methods and explanations of analyses for Birch Lake can be found within the Town of Winchester Town-wide Management Plan document.

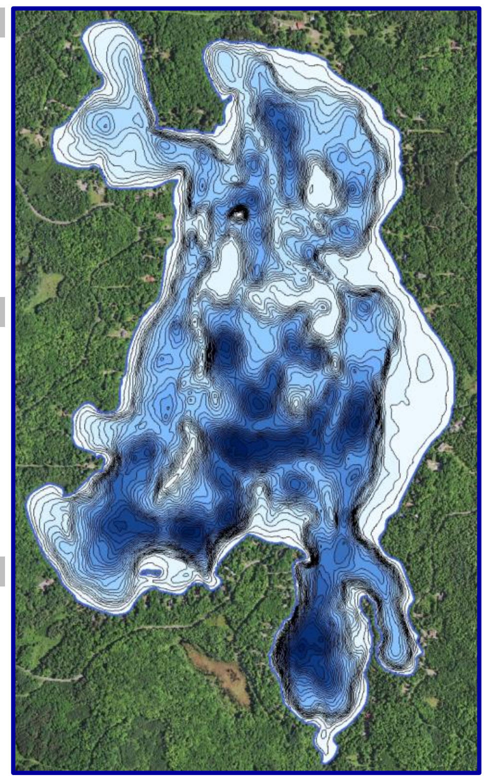
8.3 Birch Lake

An Introduction to Birch Lake

Birch Lake, Vilas County, is a 528-acre deep lowland, brown-water, mesotrophic drainage lake with a maximum depth of 52 feet and mean depth of 18 feet (Birch Lake – Map 1). Its surficial watershed encompasses approximately 4,178 acres and is comprised mainly of intact forests and wetlands. Birch Lake is a headwater lake within the Flambeau River Watershed, and water from Birch Lake flows out through Tambier Creek northwest into downstream Tamarack Lake. In 2016, 36 native aquatic plant species were located within the lake, of which wild celery (*Vallisneria americana*) was the most common. No non-native, invasive aquatic plant species were located during the 2016 surveys. However, the lake is known to harbor populations of the non-native wetland plant aquatic forget-me-not and non-native invertebrates including the Chinese and banded mystery snails and rusty crayfish.

Lake at a Glance - Birch Lake

Morphology	
LakeType	Deep Lowland Drainage
Surface Area (Acres)	528
Max Depth (feet)	52
Mean Depth (feet)	18
Perimeter (Miles)	6.5
Shoreline Complexity	4.1
Watershed Area (Acres)	4,178
Watershed to Lake Area Ratio	7:1
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	18.6
Avg Summer Chl-α (µg/L)	5.4
Avg Summer Secchi Depth (ft)	7.8
Summer pH	7.7
Alkalinity (mg/L as $CaCO_3$)	36.8
Vegetation	
Number of Native Species	37
NHI-Listed Species	None
Exotic Species	None
Average Conservatism	7.1
Floristic Quality	31.8
Simpson's Diversity (1-D)	0.80



Descriptions of these parameters can be found within the town-wide portion of themanagement plan

8.3.1 Birch Lake Water Quality

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

In 2016, a stakeholder survey was sent to 129 Birch Lake riparian property owners. Approximately 39%, or 50 surveys were completed. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Birch Lake, but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B. When asked about Birch Lake's current water quality, the majority of respondents (88%) described the current water quality of Birch Lake as *excellent* or *good*, 10% described it as *fair*, and 2% described it as *poor* (Figure 8.3.1-1). When asked how water quality has changed in Birch Lake since they first visited the lake, approximately 67% of respondents indicated water quality has *remained the same*, 25% indicated it has *somewhat degraded*, 4% indicated it has *somewhat improved*, and 4% were *unsure* (Figure 8.3.1-1).

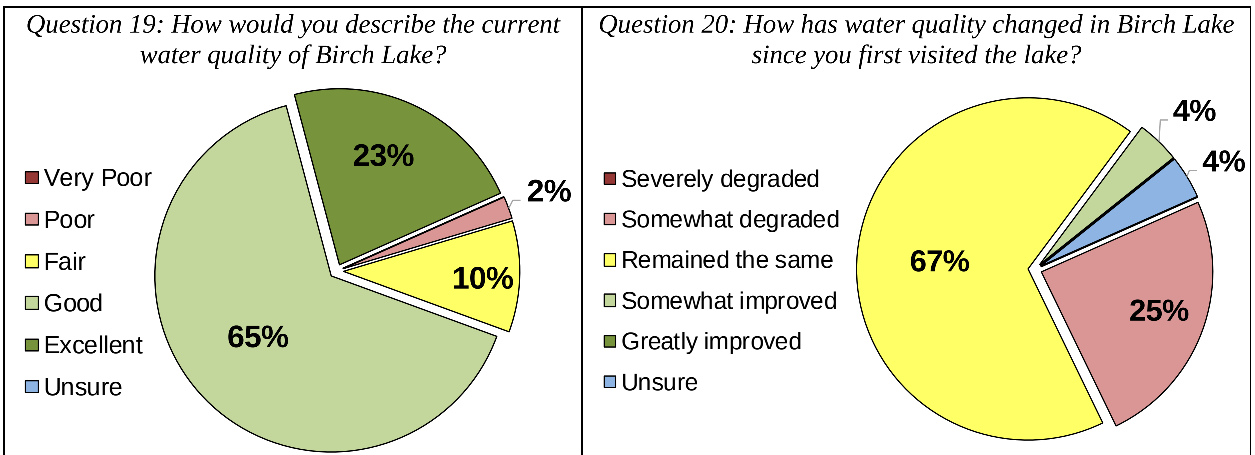


Figure 8.3.1-1. Birch Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 50 (39%) respondents of 129 surveys distributed.

Near-surface total phosphorus data for Birch Lake are available from 1979 and annually from 2000-2016 (Figure 8.3.1-2). Average summer total phosphorus concentrations are moderately variable, and range from *excellent* to *good* for deep lowland drainage lakes in Wisconsin. The weighted average summer total phosphorus concentration of 18.6 µg/L using all data falls within the *excellent* category for deep lowland drainage lakes in Wisconsin. Phosphorus concentrations measured in 2016 were slightly higher than the historical average. Birch Lake's total phosphorus concentrations fall below median concentrations for other deep lowland drainage lakes in Wisconsin (23.0 µg/L) and for all lake types within the Northern Lakes and Forests (NLF) ecoregion (21.0 µg/L).

While phosphorus concentrations in Birch Lake are variable from year to year, there are no apparent trends (positive or negative) occurring over the time period for which data are available. The variation in phosphorus concentrations between years is likely due to differences in annual precipitation and the amount of surface runoff from the watershed. The stained water in Birch lake is an indication that the lake receives a significant portion of its water from surface sources within its watershed, primarily water that has passed through forests and wetlands.

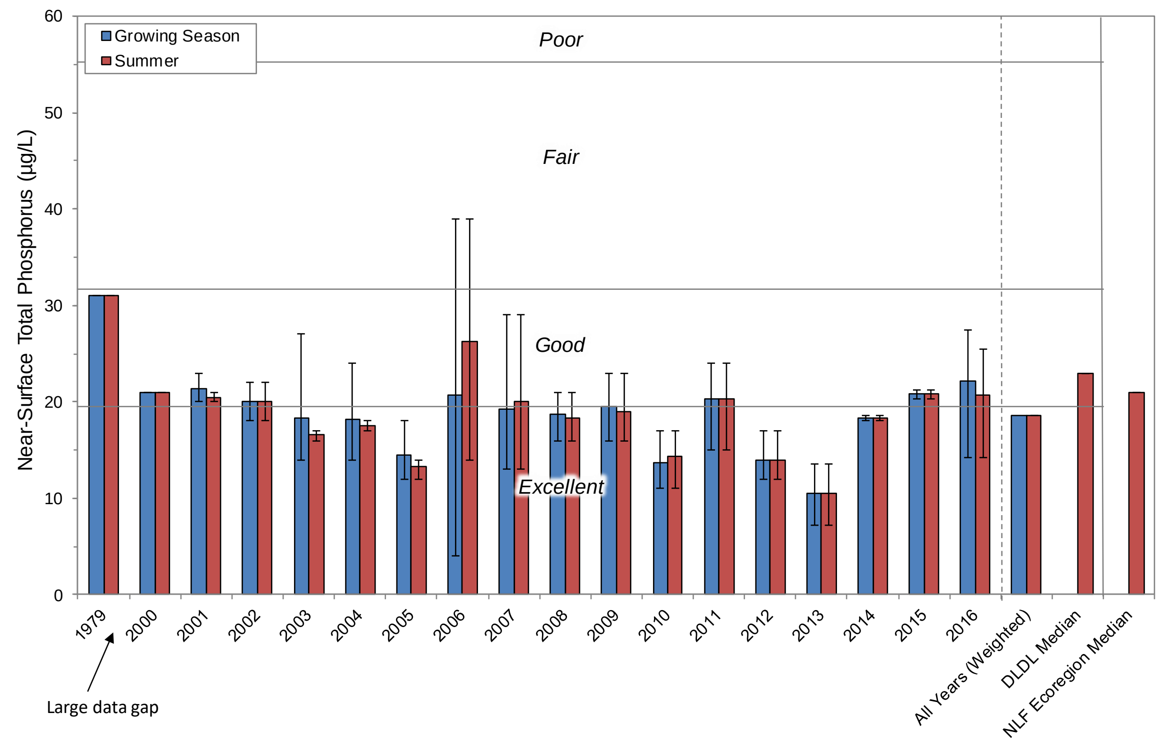


Figure 8.3.1-2. Birch Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Birch Lake from 1979 and annually from 2000-2016 (Figure 8.3.1-3). Like total phosphorus concentrations, chlorophyll-*a* concentrations are moderately variable from year to year, ranging from *excellent* to *good* for deep lowland drainage lakes in Wisconsin. Overall, the weighted average summer chlorophyll-*a* concentration is low at 5.4 µg/L, straddling the line between *excellent* and *good*. Chlorophyll-*a* concentrations measured in 2016 were lower than the historical average, with a growing season average of 4.0 µg/L. Birch Lake's chlorophyll-*a* concentrations fall below median concentrations for other deep lowland drainage lakes in Wisconsin (7.0 µg/L) and for all lake types within the NLF ecoregion (5.6 µg/L). The low level of phytoplankton production in Birch Lake is a result of the low concentrations of phosphorus, the nutrient regulating phytoplankton production. Trends analysis indicates that like total phosphorus, chlorophyll-*a* concentrations have remained stable over the time period for which data are available, and no trends (positive or negative) are occurring over time.

Secchi disk transparency data from Birch Lake are available from 1979 and in most years from 1997-2016 (Figure 8.3.1-4). Average annual Secchi disk depths fall range from *good* to *excellent* for deep lowland drainage lakes in Wisconsin. The weighted summer average Secchi disk depth in Birch Lake is 7.8 feet, falling into the *good* category for Wisconsin's deep lowland drainage lakes. Birch Lake's average summer Secchi disk depth falls lightly below the median values for deep lowland drainage lakes in Wisconsin and for all lake types within the NLF ecoregion. Water clarity in Birch Lake is lower than expected based upon the low chlorophyll-*a* concentrations, and is an indication that a factor other than phytoplankton is influencing water clarity.

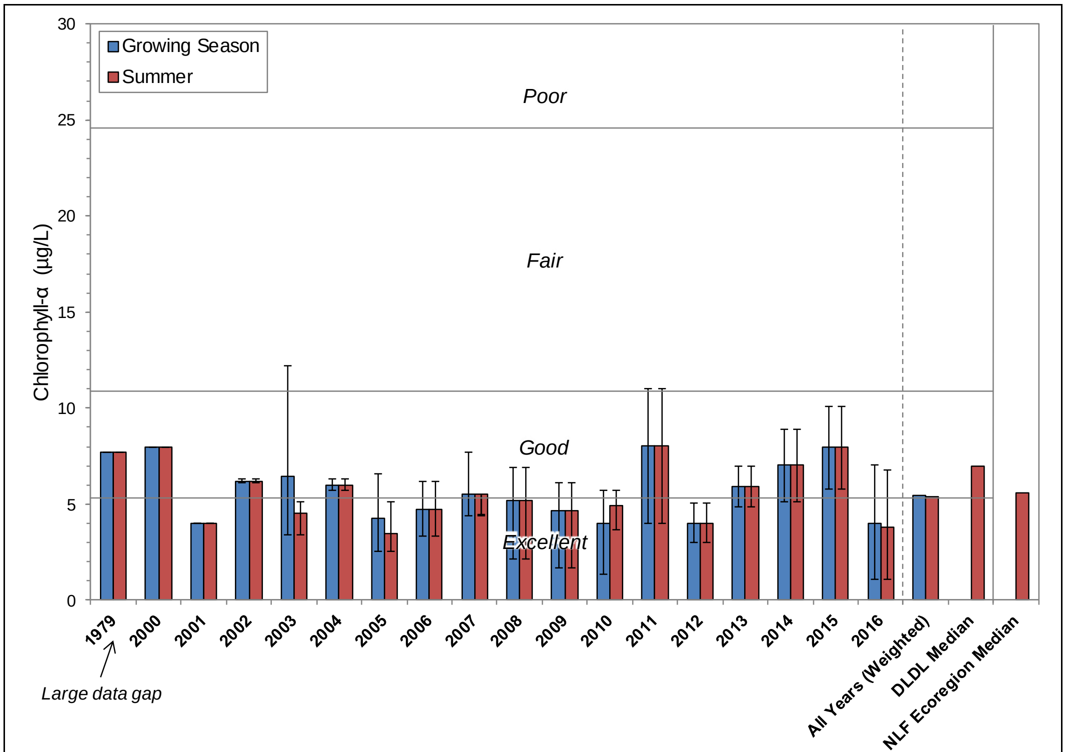


Figure 8.3.1-3. Birch Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in Birch Lake in 2016 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Birch Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Birch Lake in 2016 averaged 60 SU (standard units), indicating the lake's water is *tea-colored*. Based on Birch Lake's chlorophyll-*a* concentrations measured in 2016, Secchi disk transparency was predicted to be approximately 10 feet; however, the high concentrations of dissolved organic acids in the lake reduce the water's clarity to the measured growing season average of 5.5 feet. It is important to note that the tea-colored water in Birch Lake is natural, and is not an indication of degraded conditions.

While total phosphorus and chlorophyll-*a* concentrations have remained relatively stable in Birch Lake, the Secchi disk transparency data indicate that water clarity since 2011 has been lower when compared to historical data going back to 1997. The average growing season Secchi disk depth from 1997-2010 was 9.3 feet compared to an average of 6.3 feet from 2011-2016. However, this decline in average Secchi disk depth of 3.0 feet does not correspond with an increase in chlorophyll-*a* concentrations over this same time period, indicating that an increase in phytoplankton abundance is not the cause of decreased water clarity within the lake.

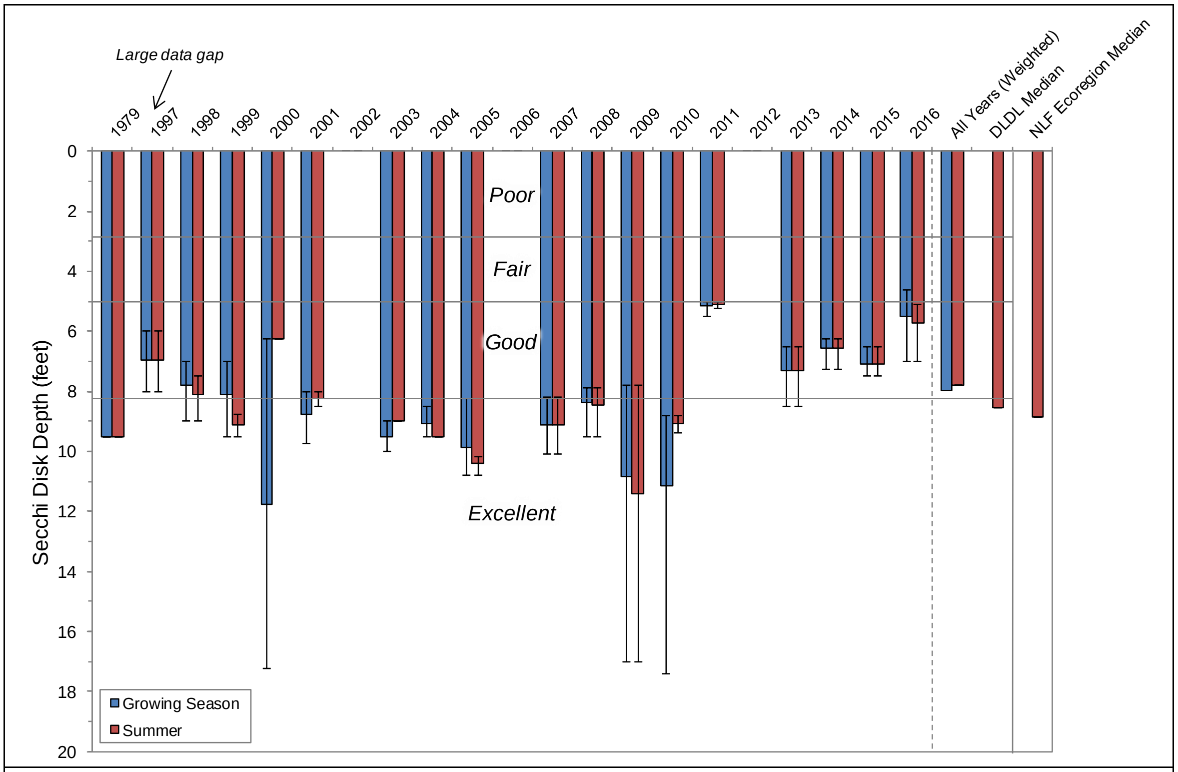


Figure 8.3.1-4. Birch Lake average annual Secchi disk depths and median Secchi disk depths for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Precipitation data obtained from nearby Hurley, WI indicate that annual precipitation has been above average in four of the six years since 2011 (Figure 8.3.1-5). This increase in precipitation likely flushed a greater amount of dissolved organic compounds from coniferous forests and wetlands in Birch Lake's watershed into the lake, resulting in reduced water clarity. Precipitation in 2016 was above average, and despite low chlorophyll-*a* concentrations, water clarity was reduced due to increased staining of the water by these dissolved compounds. Given the large areas of coniferous wetlands in Birch Lake's watershed, it is to be expected that larger amounts of these dissolved compounds will be delivered to the lake during years with higher precipitation. The lower water clarity in recent years has also been observed in Harris, Hiawatha, and Rainbow lakes and is believed to be the result of increased precipitation and input of dissolved organic compounds.

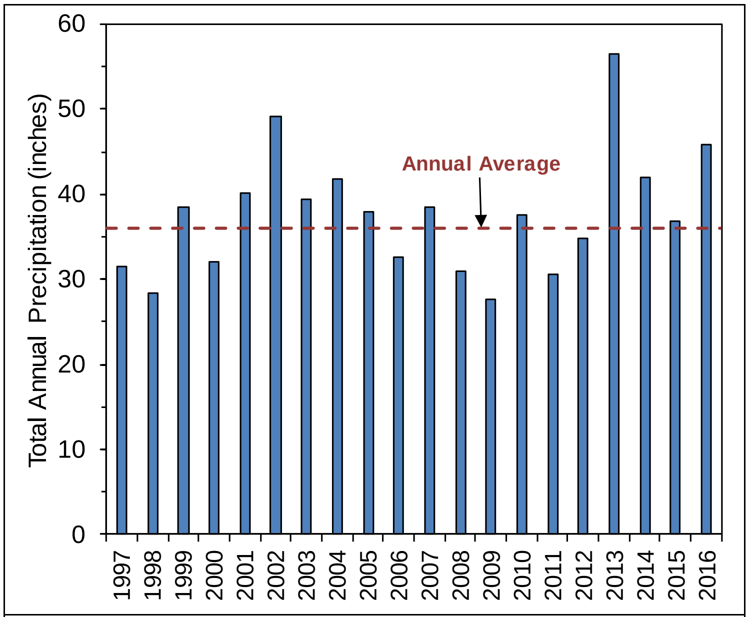


Figure 8.3.1-5. Total annual precipitation measured in Hurley, WI. Data obtained from Midwestern Regional Climate Center (2016).

To determine if internal nutrient loading (discussed in town-wide section of management plan) is a significant source of phosphorus in Birch Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on five occasions from Birch Lake in 2016 and once in 2017, and historical near-bottom total phosphorus concentrations are available from 1979 (Figure 8.3.1-6). As illustrated, on some occasions near-bottom total phosphorus concentrations are similar to those measured near the surface, while on other occasions near-bottom concentrations are higher than near-surface concentrations. The higher concentrations of phosphorus near the bottom occurred when Birch Lake was stratified and the bottom layer of water (hypolimnion) was anoxic. These higher concentrations near the bottom are an indication that phosphorus is being released from bottom sediments into the overlying water during periods of anoxia, or that internal nutrient loading is occurring.

While phosphorus is likely being released from bottom sediments into the hypolimnion during periods of stratification and anoxia in the summer, near-surface concentrations indicate that this sediment-released phosphorus is not being mixed into surface waters. Birch Lake is *dimictic*, meaning the lake completely mixes or turns over two times per year; once in spring and again in fall. While phosphorus is released from bottom sediments into the hypolimnion during periods of anoxia in the summer, this phosphorus remains 'trapped' near the bottom as the hypolimnion is unable to mix with the warmer epilimnion above due to large differences in density. In fall when the epilimnion cools and its density becomes similar to the hypolimnion below, the lake turns over and the phosphorus released into the hypolimnion is mixed throughout the water column. While the internal loading of phosphorus during periods of stratification occurs in Birch Lake,

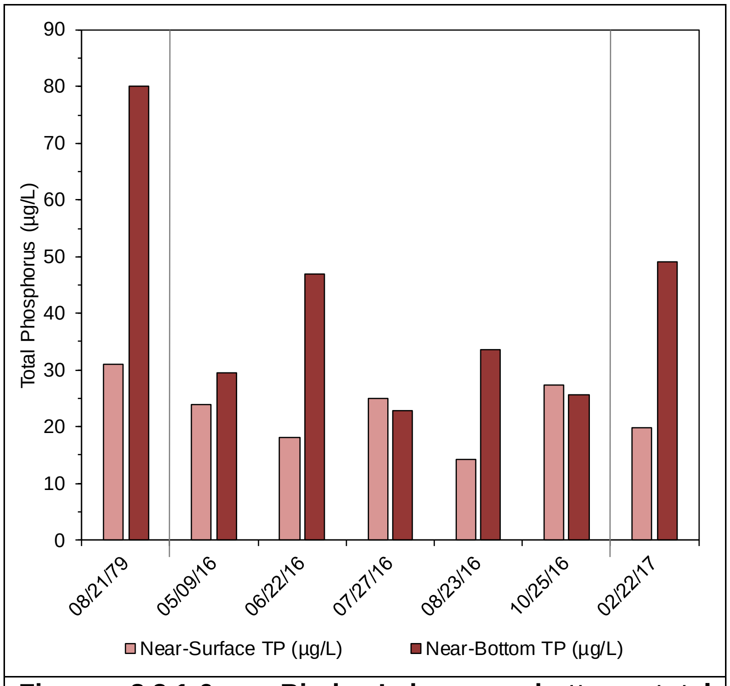


Figure 8.3.1-6. Birch Lake near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations.

the concentrations measured in near-bottom waters in 2016 indicate it is not a significant source of phosphorus to the lake.

Birch Lake Trophic State

Figure 8.3.1-7 contains the weighted average Trophic State Index (TSI) values for Birch 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 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 for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Birch Lake indicate the lake is at present in a mesotrophic, or moderately productive state. Birch Lake's productivity is lower when compared to other deep lowland drainage lakes in Wisconsin and of similar productivity to other lakes within the NLF ecoregion.

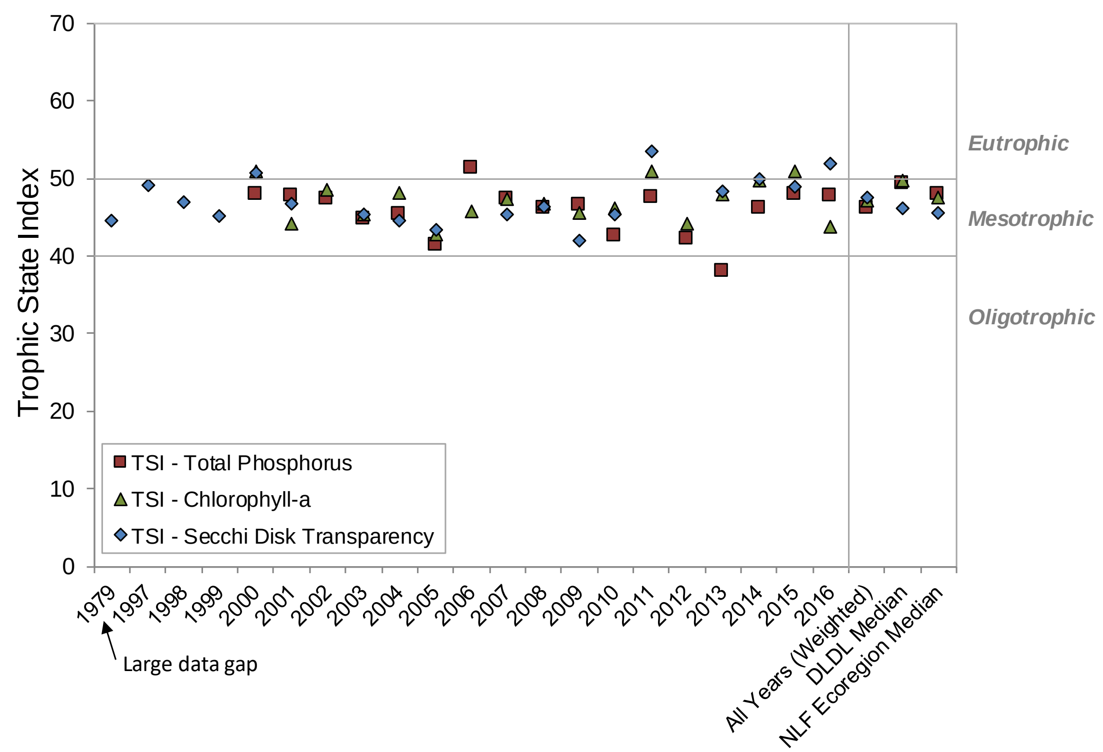


Figure 8.3.1-7. Birch Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Birch Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling event conducted by Onterra ecologists. These data are displayed in Figure 8.3.1-8. As mentioned previously, Birch Lake is dimictic, meaning the lake remains stratified during the summer (and winter) and completely mixes, or turns over, once in spring and once in fall. During the summer, the surface of the lake warms and becomes less dense than the cold layer below, and the lake thermally stratifies. Given Birch Lake is deeper, wind and water movement are not sufficient during the summer to mix these layers together, only the warmer, upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen, and decomposition of organic matter within this layer depletes available oxygen. Once anoxia sets in, phosphorus (and other nutrients) are released from bottom sediments into the overlying hypolimnion.

In fall as surface temperatures cool, the entire water column is again able to mix which re-oxygenates the hypolimnion and delivers sediment-released nutrients to the surface. During the winter, the coldest temperatures are found just under the overlying ice, while oxygen gradually declines once again towards the bottom of the lake. In February of 2016, oxygen concentrations remained above 2.0 mg/L throughout the majority of the water column, indicating that fishkills as a result of winter anoxia are not a concern in Birch Lake.

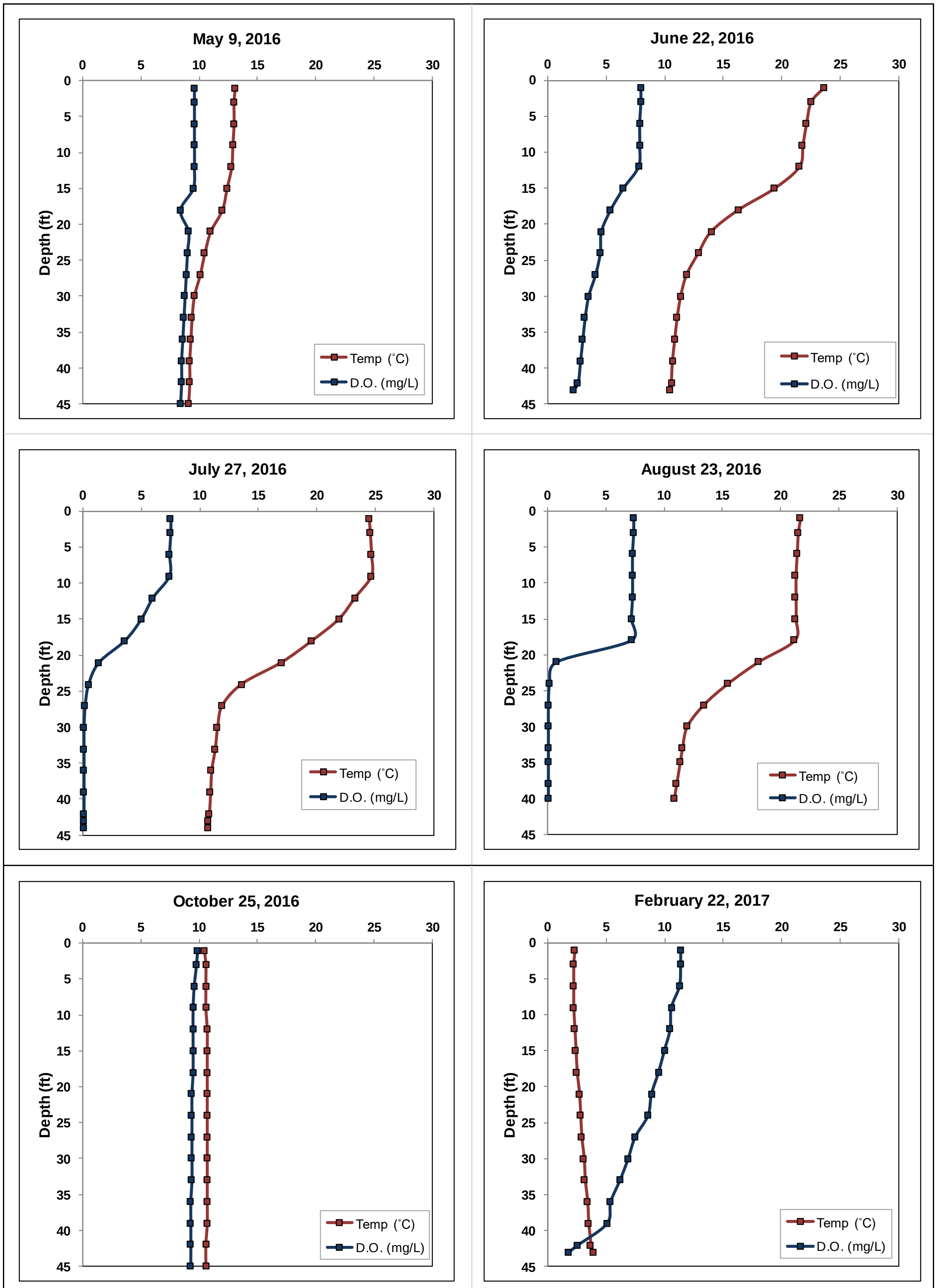


Figure 8.3.1-8. Birch Lake 2016/17 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Birch Lake

The previous section is centered on parameters relating to Birch Lake's trophic state. 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 Birch Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. Birch Lake's mid-summer surface water pH was measured at roughly 7.7 in 2016. This value indicates Birch Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Birch Lake's average alkalinity measured in 2016 was 37.3 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while Birch Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from Birch Lake in 2016 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Birch Lake's pH falls within this range. Birch Lake's calcium concentration in 2016 was 11.3 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Birch Lake in 2016 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys.

8.3.2 Birch Lake Watershed Assessment

Birch Lake's surficial watershed encompasses approximately 4,178 acres (Figure 8.3.2-1 and Birch Lake – Map 2) yielding a watershed to lake area ratio of 7:1. The watershed is comprised of land cover types including forests (51%), wetlands (23%), the lake surface itself (13%), pasture/grass/rural open space (13%), and rural residential areas (<1%) (Figure 8.3.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Birch Lake's residence time is approximately 2.2 years, or the water within the lake is completely replaced once every 2.2 years.

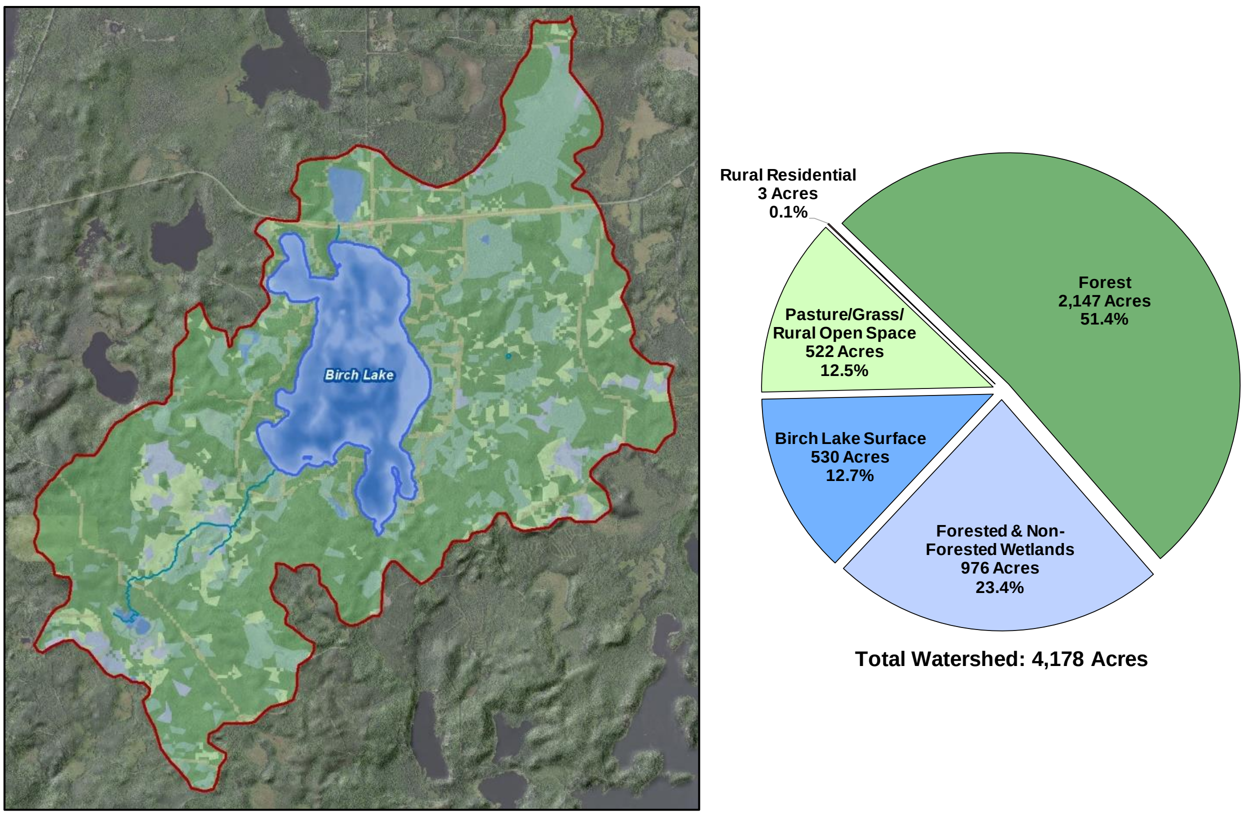


Figure 8.3.2-1. Birch Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types and their acreages within Birch Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Birch Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Birch Lake riparian property owners in 2016 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a total of approximately 550 pounds of phosphorus are delivered to Birch Lake from its watershed on an annual basis (Figure 8.3.2-2).

Of the estimated 550 pounds of phosphorus being delivered to Birch Lake on an annual basis, approximately 172 pounds (31%) originates from forests, 141 pounds (26%) through direct atmospheric deposition into the lake, 139 pounds (25%) from areas of pasture/grass/rural open space, 86 pounds (16%) from wetlands, 12 pounds (2%) from riparian septic systems, and a

negligible amount from rural residential areas (Figure 8.3.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total
phosphorus concentration of 19 µg/L, which is essentially identical to the measured growing season average total phosphorus concentration of 18.6 µg/L. The similarity between the predicted and measured total phosphorus concentrations in Birch Lake is an indication that this is an accurate model of the lake's watershed and that there are no significant, unaccounted sources of phosphorus entering the lake.

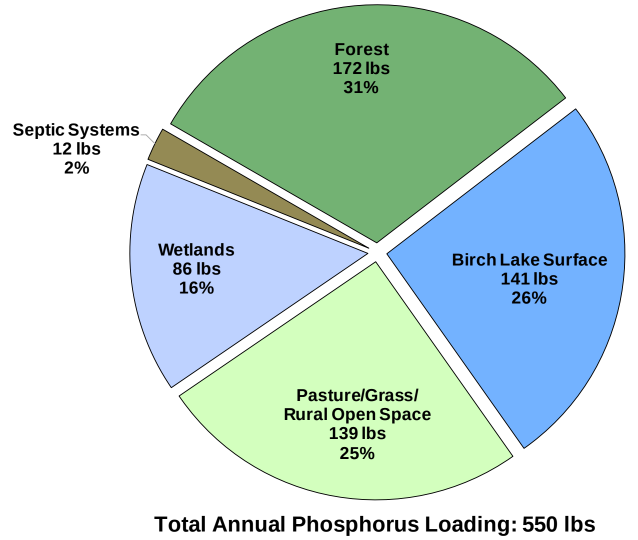


Figure 8.3.2-2. Birch Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the WiLMS model for Birch Lake's watershed, scenarios can be run to determine how Birch Lake's water quality would change given alterations to its watershed. For example, if 25% of the forests within Birch Lake's watershed were converted to row crop agriculture, phosphorus concentrations would be predicted to increase from the current growing season concentration of 18.6 µg/L to 30.0 µg/L. This increase in total phosphorus would result in chlorophyll-*a* concentrations increasing from the current growing season average of 5.4 µg/L to 11.0 µg/L, and Secchi disk transparency is predicted to decline from the current growing season average of 8.0 feet to 5.6 feet. This modeling illustrates the importance of the natural land cover types within Birch Lake's watershed in maintaining the lake's excellent water quality.

Birch Lake Water Levels

Lake water levels can fluctuate naturally over varied timescales due to changes in precipitation and/or changes in human land use. Natural seasonal and long-term changes in water levels in lakes are beneficial as they generally create more diverse plant and animal communities. Water level fluctuations in drainage lakes, like Birch Lake, tend to be more moderate when compared to seepage lakes which lack input from streams or rivers and are largely tied to the level of the groundwater aquifer. Even during drier periods, rivers and streams still provide a source of water to drainage lakes. Drainage lakes may show increases in water levels relatively quickly following large rain events.

Beginning in 2010, the NLDC and Birch Lake volunteers began monitoring Birch Lake's water levels annually during the open water season (Figure 8.3.2-2). Over the course of this monitoring, Birch Lake's water levels fluctuated a maximum of 27 inches, with a minimum water level recorded in 2011 and a maximum water level recorded in 2014. The average intra-annual water level variation from 2010-2017 is 11.8 inches. Water levels in 2016 were approximately 3.0 inches above the 2010-2017 average while water levels in 2017 were near the 2010-2017 average. The data collected from Birch Lake indicate that water levels tend to fluctuate both intra- and interannually with changes in precipitation levels. Ongoing collection of water level data at Birch Lake will allow for a better understanding of longer-term changes in water levels.

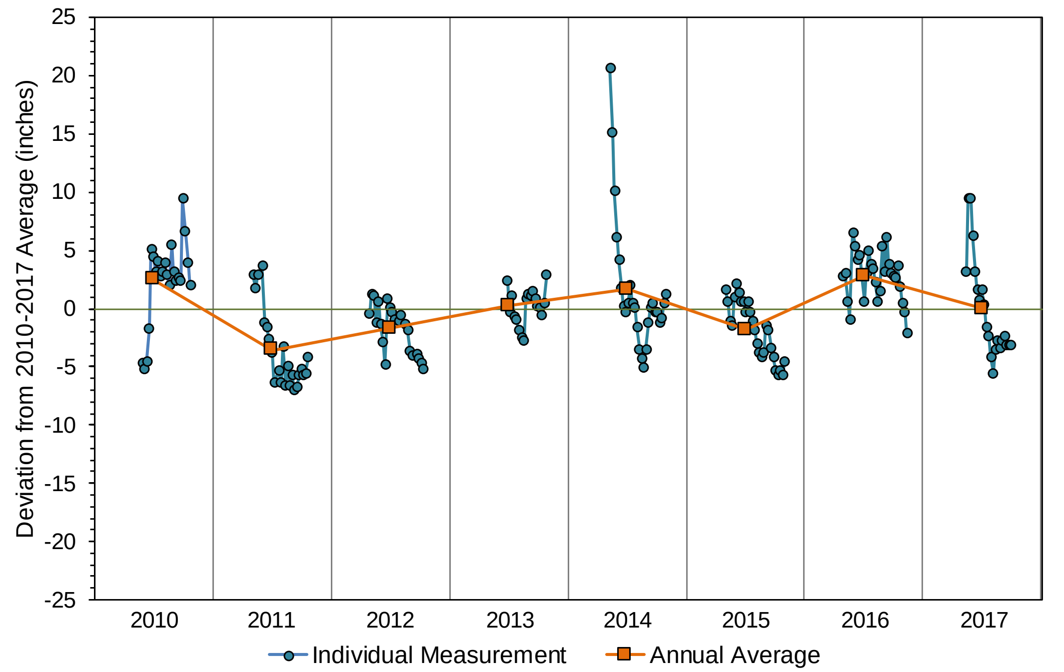


Figure 8.3.2-3. Birch Lake 2010-2017 water levels. Created using data provided by NLDC.

8.3.3 Birch Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the late-summer of 2016, the immediate shoreland of Birch Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

The 2016 survey revealed that Birch Lake has stretches of shoreland that fit all of the five shoreland assessment categories (Figure 8.3.3-1). In total, 4.5 miles (70%) of the 6.5-mile shoreland zone were categorized as natural/undeveloped or developed-natural, or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 1.0 mile (16%) of the shoreland was categorized as developed-unnatural or urbanized, shorelands which provide little benefit to and may actually adversely impact the lake. If restoration of Birch Lake's shoreland is to occur, primary focus should be placed on these shoreland areas. Birch Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

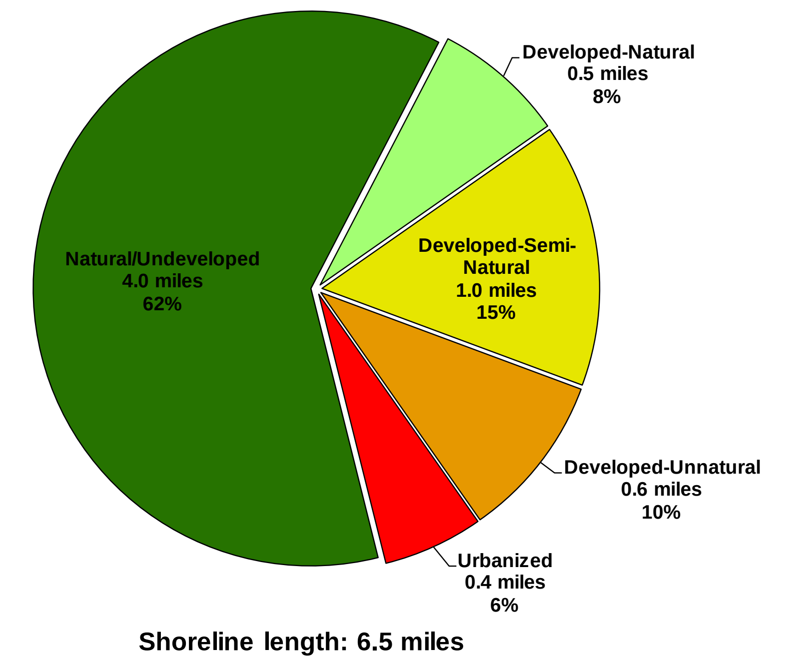


Figure 8.3.3-1. Birch Lake shoreland categories and total lengths. Based upon a late-summer 2016 survey. Locations of these categorized shorelands can be found on Birch Lake - Map 3.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Birch Lake in 2016. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on Birch Lake, a total of 278 pieces were observed along 6.5 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 42:1 (Figure 8.3.3-2). Onterra ecologists have been completing these surveys on Wisconsin's lakes for five years, and Birch Lake falls in the 87th percentile for the number of coarse woody

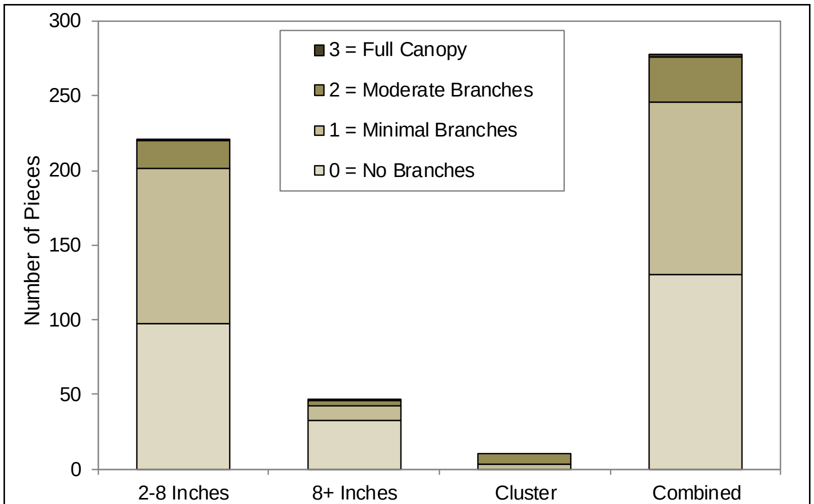


Figure 8.3.3-2. Birch Lake coarse woody habitat survey results. Based upon a late-summer 2016 survey. Locations of Birch Lake coarse woody habitat can be found on Birch Lake – Map 4.

habitat pieces per shoreline mile of 75 lakes studied. Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in these lakes. The locations of these coarse woody habitat pieces are displayed on Birch Lake – Map 4.

8.3.4 Birch Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Birch Lake on June 27, 2016. 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. Fortunately, no curly-leaf pondweed was located in Birch Lake in 2016, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. Birch Lake users should familiarize themselves with curly-leaf pondweed and its identification as nearby Harris Lake contains a population of curly-leaf pondweed that was discovered in 2008.

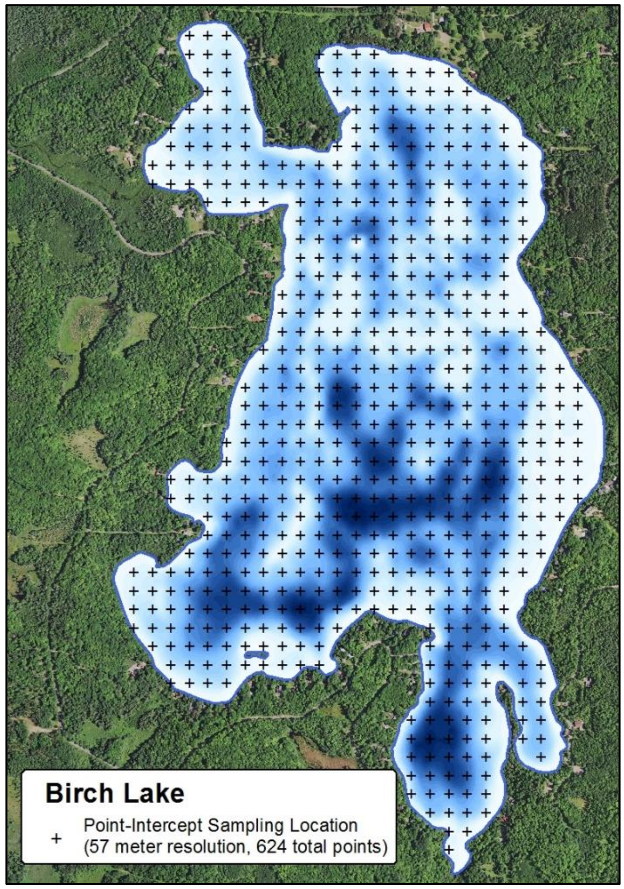


Figure 8.3.4-1. Birch Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Birch Lake by Onterra ecologists on July 20, 2016 (Figure 8.3.4-1). During these surveys, a total of 36 aquatic plant species were located, none of which are considered to be non-native, invasive species (Table 8.3.4-1). Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In early August of 2016, Onterra ecologists completed an acoustic survey on Birch Lake (bathymetric results on Birch Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Birch Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey revealed that shallower areas of Birch Lake tend to have the hardest substrates (sand and rock), and that substrate hardness decreases with depth from approximately 6.0 to 20.0 feet. Beyond 20.0 feet, substrate composition is relatively uniform and moderately hard. While the majority substrate within shallower areas of Birch Lake contains harder substrates, the areas with the softest substrates were also located in shallower areas. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.3.4-1. List of aquatic plant species located in Birch Lake during Onterra 2016 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Acorus americanus*	Sweetflag	7	I
	Calamagrostis canadensis	Bluejoint grass	5	I
	Carex comosa	Bristly sedge	5	I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9	I
	Carex utriculata	Common yellow lake sedge	7	I
	Cladium mariscoides	Smooth sawgrass	10	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Iris versicolor	Northern blue flag	5	I
	Phragmites australis subsp. *americanus*	Common reed	5	I
	Pontederia cordata	Pickerelweed	9	X
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Sparganium americanum	American bur-reed	8	I
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Persicaria amphibia	Water smartweed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	8	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum echinatum	Spiny hornwort	10	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	I
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X

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

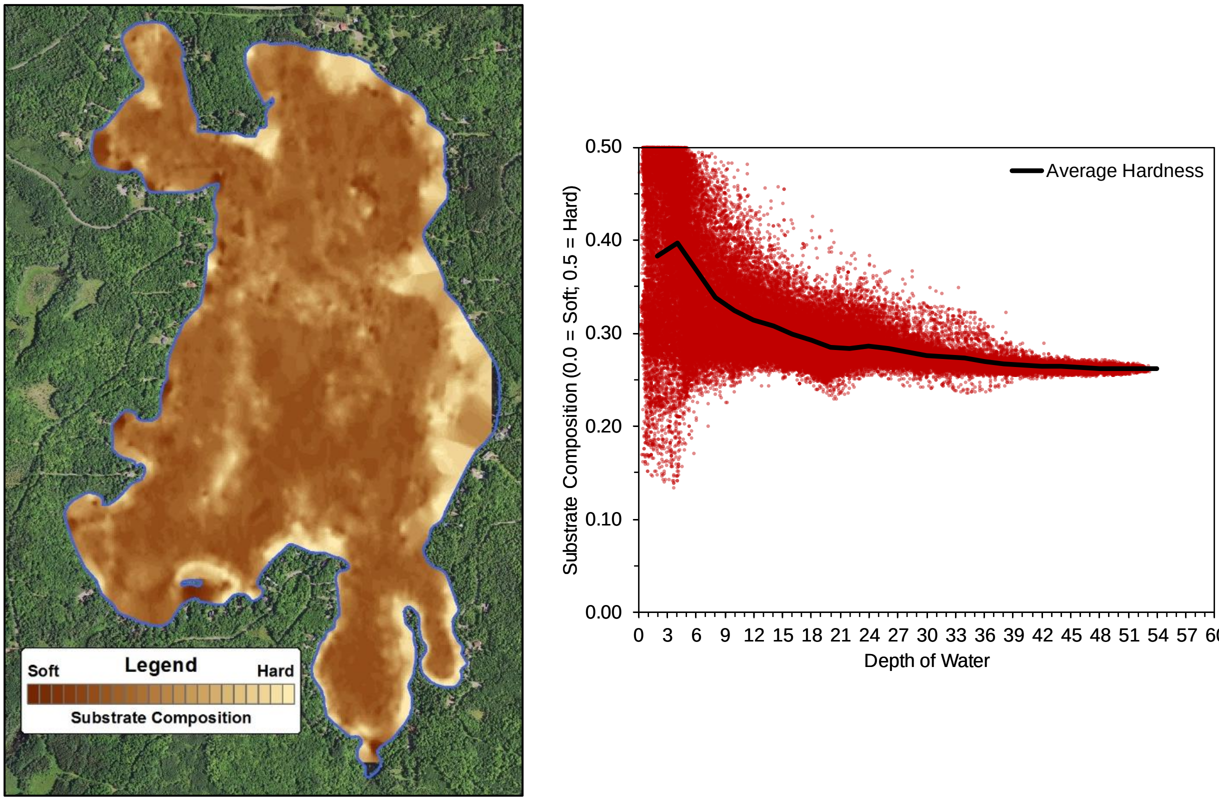


Figure 8.3.4-2. Birch Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Individual data points are displayed in red. Creating using data from August 2016 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 8.3.4-3 and Birch Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The areas of green in deeper areas of Birch Lake represent a level of error within the acoustic monitoring in deeper water, and do not actually represent aquatic plants at these depths. The 2016 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 11 feet. However, the majority of aquatic plant growth occurs within the first 8.0 feet of water. The 2016 acoustic survey indicated approximately 33% of Birch Lake's area contains aquatic vegetation, while the remaining 77% of the lake is too deep and light-limited to support aquatic plant growth.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. As mentioned, aquatic plants were recorded growing to a maximum depth of 11 feet in 2016. Of the 180 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 66% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 48% of the 180 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 15% had a TRF rating of 2, and 3% had a TRF rating of 3 (Figure 8.3.4-5). These data indicate that aquatic plant density in Birch Lake is low throughout most areas where plants occur.

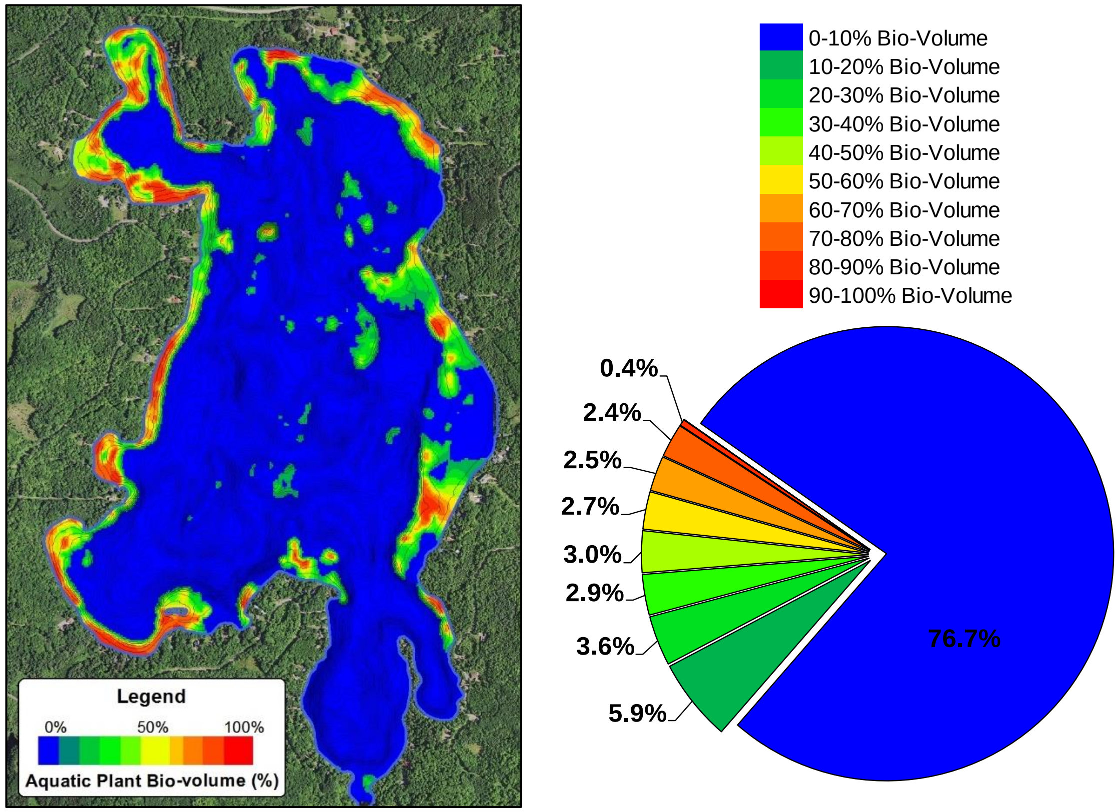


Figure 8.3.4-4. Birch Lake 2016 aquatic plant bio-volume. Created using data from August 2016 acoustic survey data. Contour lines represent two-foot increments.

Of the 36 aquatic plant species located in Birch Lake in 2016, 20 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.3.4-6). The remaining 16 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 20 species directly sampled with the rake during the point-intercept survey, wild celery, hardstem bulrush, and clasping-leaf pondweed the three-most frequently encountered aquatic plants (Figure 8.3.4-6).

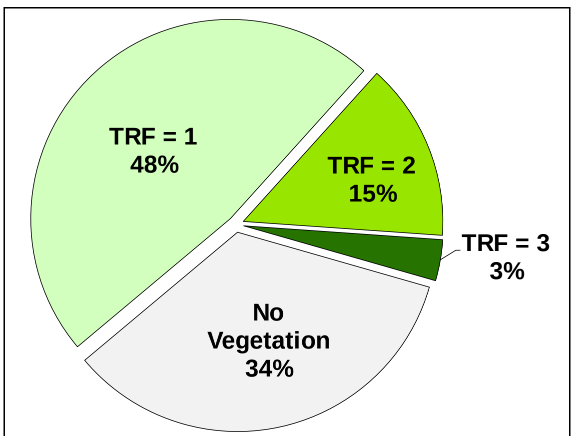


Figure 8.3.4-5. Birch Lake 2016 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2016 whole-lake point-intercept survey (N = 180).

Wild celery, also known as tape or eel grass, was the most frequently encountered aquatic plant species in Birch Lake in 2016 with a littoral frequency of occurrence of 41% (Figure 8.3.4-6). Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. Birch Lake's expansive areas of sand and low light conditions as a result of its stained water favor the dominance of the plant community by wild celery. In 2016, wild celery was most abundant over hard substrates in deeper areas of the littoral zone within 5.0 to 8.0 feet of water.

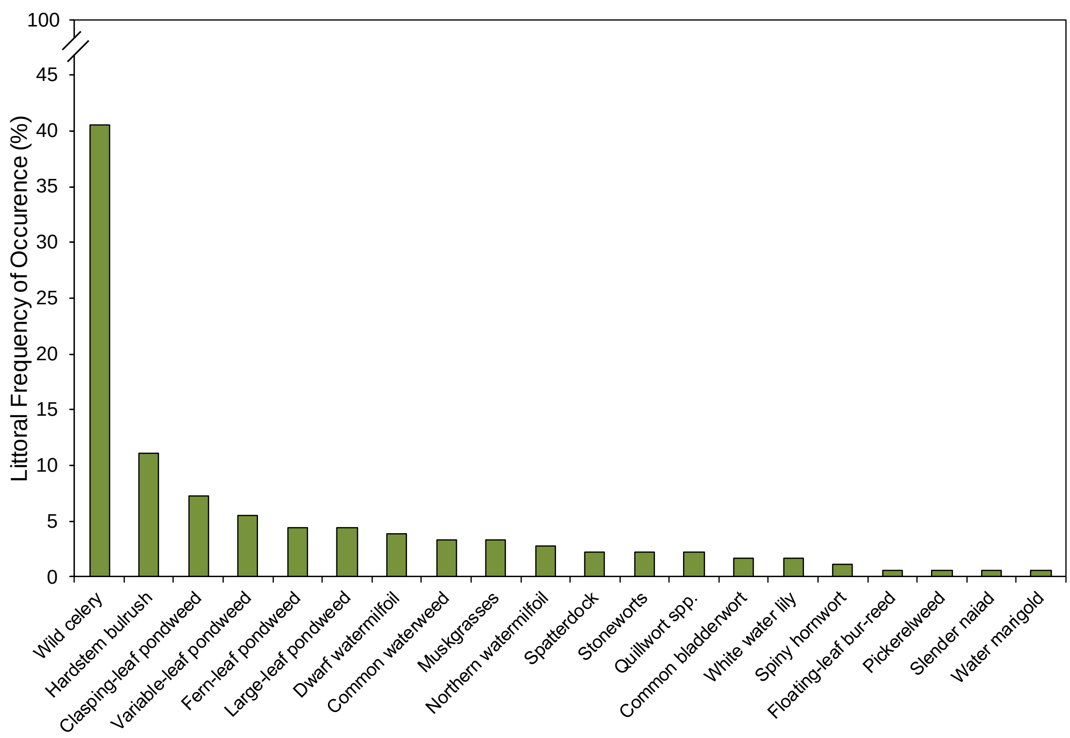


Figure 8.3.4-6. Birch Lake 2016 littoral frequency of occurrence of aquatic plant species. Created using data from 2016 whole-lake point-intercept survey.

Hardstem bulrush was the second-most frequently encountered aquatic plant in Birch Lake in 2016 with a littoral frequency of occurrence of approximately 11%. Contrary to its name, hardstem bulrush is not a rush (family *Juncaceae*) but is actually a tall, giant sedge in the family *Cyperaceae*. Birch Lake possesses large colonies of hardstem bulrush in shallow sandy waters around the lake (Birch Lake – Map 7). These communities of hardstem bulrush provide important structural habitat, stabilize bottom and shoreland sediments, and are food sources for wildlife.

Clasping-leaf pondweed was the third-most frequently encountered aquatic plant in Birch Lake in 2016 with a littoral frequency of occurrence of 7% (Figure 8.3.4-6). As its name indicates, the submersed leaves of clasping-leaf pondweed clasp or partially wrap around the stem. Like wild celery, clasping-leaf pondweed is often found growing over harder substrates and is tolerant of low-light conditions, often one of the more abundant plants in lakes with stained water in northern Wisconsin. Clasping-leaf pondweed superficially resembles the non-native curly-leaf pondweed and is often misidentified as such. However, the leaf margins of curly-leaf pondweed are serrated where the leaves of clasping-leaf pondweed lack serration. Like other native aquatic plants, clasping-leaf pondweed provides important structural habitat, stabilizes bottom sediments, and its fruits and rhizomes are important sources of food for wildlife.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.3.4-1). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.3.4-1). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) found in Birch Lake is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum sibiricum*), also found in Birch Lake, are classified as elodeids.


Photo 8.3.4-1. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Birch Lake Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2016 point-intercept survey on Birch Lake and their conservatism values were used to calculate the FQI of Birch Lake's aquatic plant community (equation shown below).

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

Figure 8.3.4-7 compares the 2016 FQI components of Birch Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2016 (20) falls between the median species richness values for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The average conservatism of the 20 native aquatic plant species located in Birch Lake in 2016 was 7.1, exceeding the median average conservatism values for lakes within the NLFL ecoregion (6.7) and lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of Birch Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

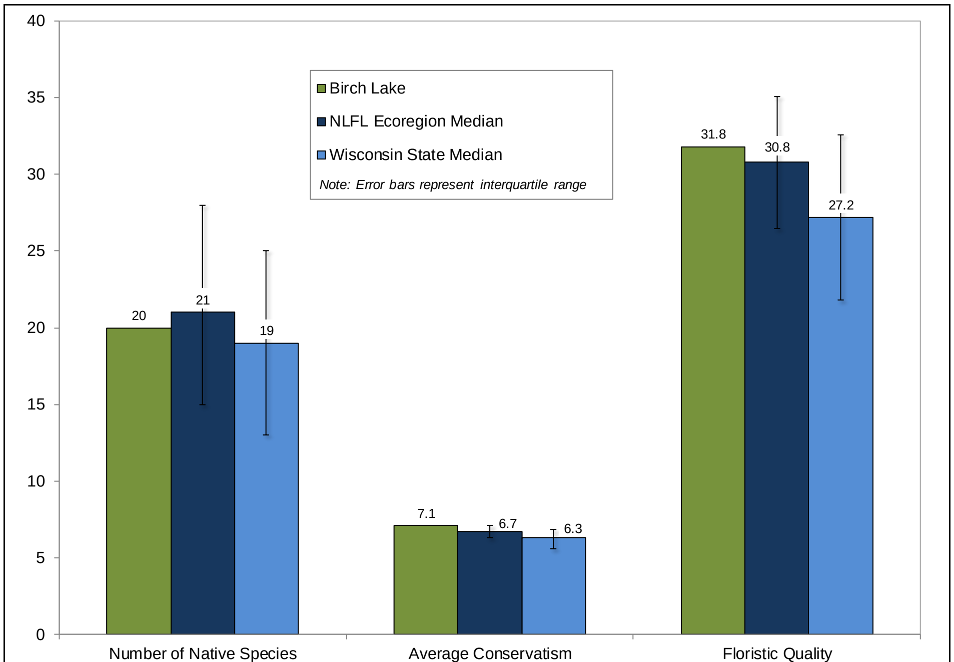


Figure 8.3.4-7. Birch Lake Floristic Quality Assessment. Created using data from Onterra 2016 whole-lake point-intercept survey. Analysis follows Nichols (1999).

Using Birch Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 31.8 (Figure 3.3-4-7). Birch Lake's FQI value exceeds the median value for lakes within the NLFL ecoregion (30.8) and the median value for lakes throughout Wisconsin (27.2).

Overall, the FQI analysis indicates that the aquatic plant community found in Birch Lake is of higher quality than the majority of lakes within the NLFL ecoregion and lakes throughout the state.

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Birch Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

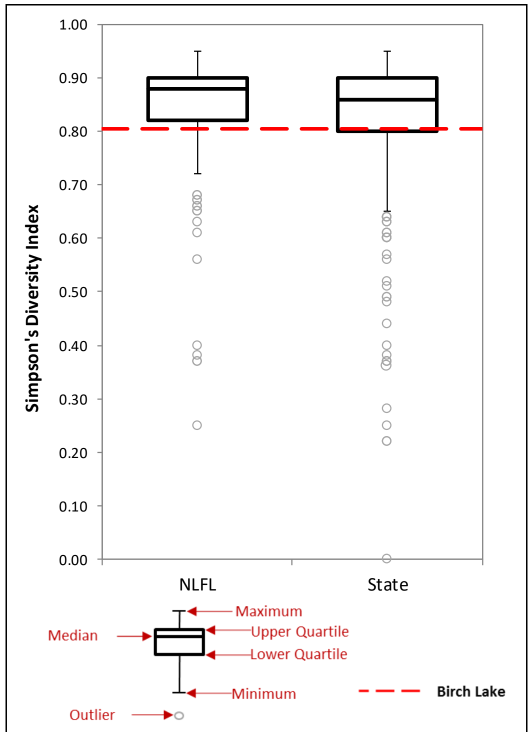


Figure 8.3.4-8. Birch Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Birch Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.3.4-8). Using the data collected from the 2016 point-intercept survey, Birch Lake's aquatic plant was found to have low species diversity with a Simpson's Diversity Index value of 0.80. In other words, if two individual aquatic plants were randomly sampled from Birch Lake in 2016, there would be an 80% probability that they would be different species. Birch Lake's Simpson's Diversity value falls below the lower quartile for lakes in the NLFL ecoregion and near the lower quartile for lakes throughout Wisconsin.

One way to visualize Birch Lake's lower species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.3.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey. While Birch Lake contains a higher number of species, approximately 41% of the plant community is comprised of one species, wild celery. The remaining 19 species are in relatively low abundance. Explained another way, if 100 plants were randomly sampled from Birch Lake, 41 would be wild celery, 11 would be hardstem bulrush, etc. The uneven distribution of aquatic plant species within the community and dominance by one species yields low species diversity. However, the low species diversity of Birch Lake's aquatic plant community is not an indication of degraded conditions. Rather, the combination of the lake's primarily sandy substrate in the littoral areas and low-light conditions reduce the number of habitat types available. Wild celery competes against other species well under these conditions which leads to a dominance of this plant within the community.

In 2016, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Birch Lake. This survey revealed Birch Lake contains approximately 73 acres of these communities comprised of 20 different aquatic plant species (Birch Lake – Map 7 and Table 8.3.4-2). The majority of these communities are comprised of emergent species, primarily hardstem bulrush. These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Birch Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

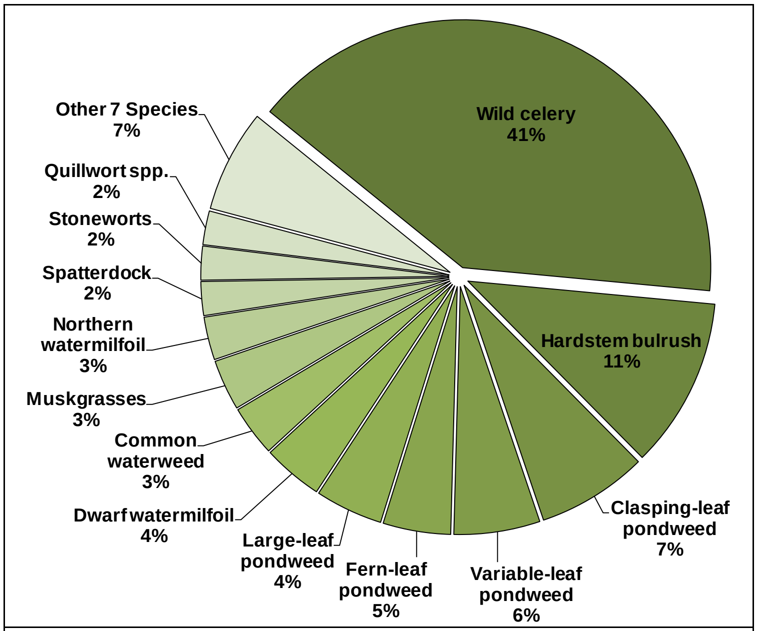


Figure 8.3.4-9. Birch Lake 2016 relative frequency of occurrence of aquatic plant species. Created using data from 2016 point-intercept survey.

Table 8.3.4-2. Birch Lake 2016 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2016 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	27.0
Floating-leaf	3.8
Mixed Emergent & Floating-leaf	42.0
Total	**72.8**

8.3.5 Aquatic Invasive Species in Birch Lake

As of 2016, Birch Lake has been confirmed to harbor populations of non-native plant aquatic forget-me-not (*Myosotis scorpiodes*), the non-native Chinese (*Cipanogopaludina chinensis*) and banded (*Viviparus georgianus*) mystery snails, and the non-native rusty crayfish (*Orconectues rusticus*). Aquatic forget-me-not is small wetland plant often found growing in shorelines or in standing, quiet water. Onterra ecologists were not able to locate any aquatic forget-me-not along the shorelines of Birch Lake in 2016. 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). While it is possible rusty crayfish are present in Birch Lake, their presence has not been officially verified.

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

8.3.6 Birch Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery as those aspects are currently being conducted by the fisheries biologists overseeing the lake. The goal of this section is to provide an overview 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 2017) and personal communications with DNR Fisheries Biologists Steve Gilbert and Hadley Boehm.

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 Birch Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton which are tiny crustaceans that feed upon phytoplankton. 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 piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.3.6-1.

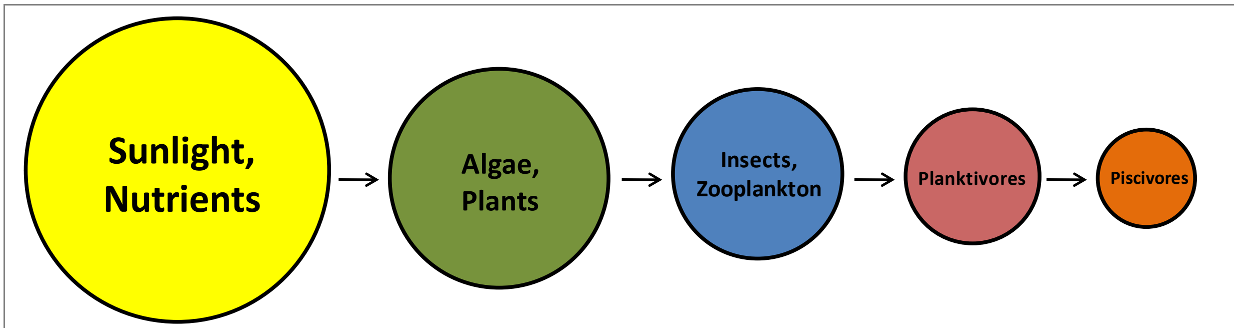


Figure 8.3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Birch Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Birch Lake should be able to support an appropriately sized population of predatory fish (piscovores) when compared to eutrophic or oligotrophic systems. Table 8.3.6-1 contains a list of the popular game fish present in Birch Lake.

Table 8.3.6-1. Gamefish present in Birch Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
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
Panfish (*Lepomis*)	10	Dependent on species	Dependent on species	Dependent on species

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 common passive trap used is a fyke net (Photo 8.3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and 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 and sort the captured fish.

The other commonly used sampling method is electroshocking (Photo 8.3.6-1). 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, *galvanotaxis* stimulates their nervous system and involuntarily causes them to swim toward the electrodes. When the fish are in the vicinity of the electrodes, they undergo *narcosis* (stunned), making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell, fish generally recover within minutes.

Once fish are captured using the appropriate method, data such as count, species, length, weight, sex, tag number, and aging structures may be recorded and the fish released. Fisheries biologists use this data to make recommendations and informed decisions on managing the future of the fishery.

Photo 8.3.6-1. Fyke net positioned in the littoral zone of a Wisconsin lake (right) and an electroshocking boat (left).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling, or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photo 8.3.6-2). Stocking of 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. Historical stocking efforts for Birch Lake have included walleye and muskellunge and these data are displayed in Table 8.3.6-2.

Photo 8.3.6-2. Fingerling Muskellunge.

Table 8.3.6-2. WDNR stocking data of fish species available for Birch Lake (1972-1980).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1980	Muskellunge	Fingerling	1,000	8
1972	Walleye	Fingerling	13,200	3
1976	Walleye	Fingerling	10,000	3
1978	Walleye	Fingerling	14,400	2

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fish biologists can estimate populations and determine trends of captured fish species. The data collected and calculated is then used by fish biologists to determine the best management plan for the lake or chain. One method that is used involves calculating abundance and size structure of the fish populations and comparing to area lakes with the same species.

Birch Lake Fish Habitat

Substrate Composition

Just as forest wildlife requires 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 2016, 59% of the substrate sampled in the littoral zone of Birch Lake was sand sediments, 33% was soft with the remaining 8% composed of rock substrate.

Coarse Woody Habitat & Fish Sticks Program

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 2006).

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. 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. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 survey documented 278 pieces of coarse woody along the shores of the Birch Lake, resulting in a ratio of approximately 42 pieces per mile of shoreline.

Regulations and Management

Current (2016-2017) regulations for Birch Lake gamefish species are displayed in Table 8.3.6-3. 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 8.3.6-3. WDNR fishing regulations for Birch Lake (2016-2017).

Species	Season	Regulation
Panfish	Open All Year	None, Daily bag limit 25
Largemouth bass and smallmouth bass	June 18, 2016 to March 5, 2017	14", Daily bag limit 5
Northern pike	May 7, 2016 to March 5, 2017	None, Daily bag limit 5
Walleye, sauger, and hybrids	May 7, 2016 to March 5, 2017	Only 1 fish over 14", Daily bag limit 3
Bullheads	Open All Year	None, Unlimited
Rough fish	Open All Year	None, Unlimited

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 8.3.6-2. 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 than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 8.3.6-2. 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/).

Birch Lake Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.3.6-3). The Town of Winchester falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process.

This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a *total allowable catch* is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by three or more years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the *safe harvest level*.

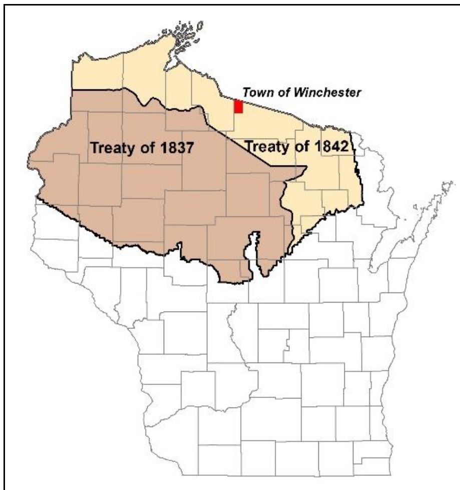


Figure 8.3.6-3. Location of the Town of Winchester within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the *declaration*, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to 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 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Available walleye open water spear harvest records from Birch Lake are provided in Figure 8.3.6-4. 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 (GLIWC 2015). This regulation limits the harvest of the larger, spawning female walleye. Figure 8.3.6-5 displays the Native American open water muskellunge spear harvest since 1989. Since 1989, 27 muskellunge have been harvested on Birch Lake during the open water spear fishery.

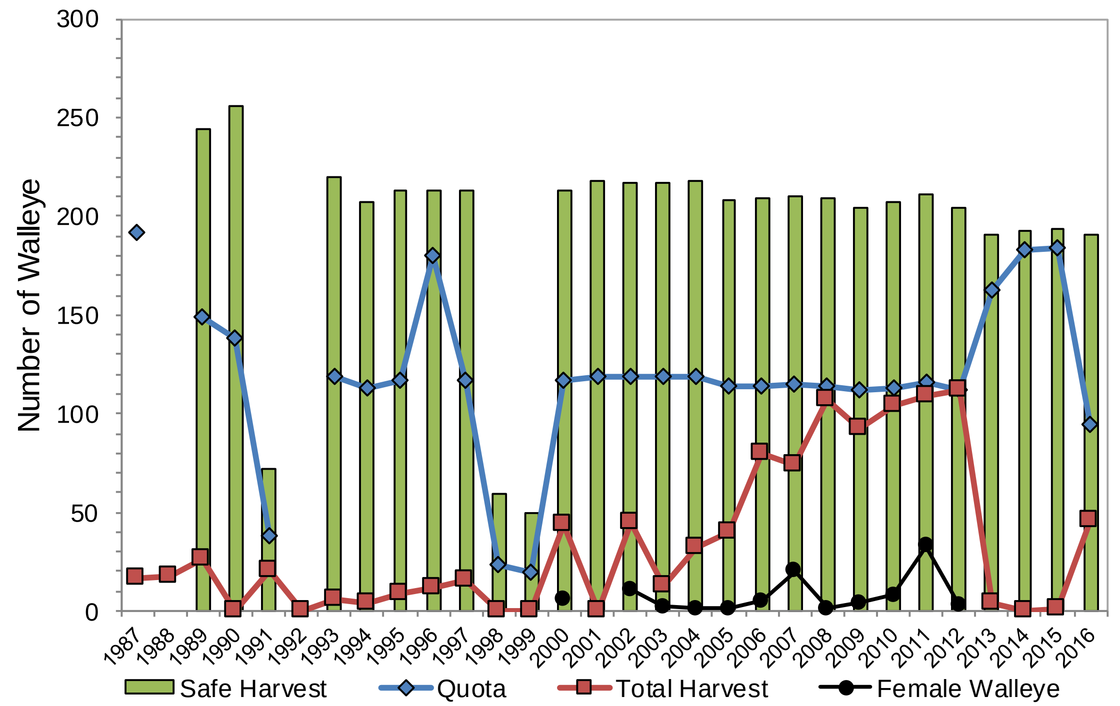


Figure 8.3.6-4. Birch Lake walleye spear harvest data. Annual total walleye harvest statistics are displayed since 1987 from WDNR records (T. Cichosz, personal communication).

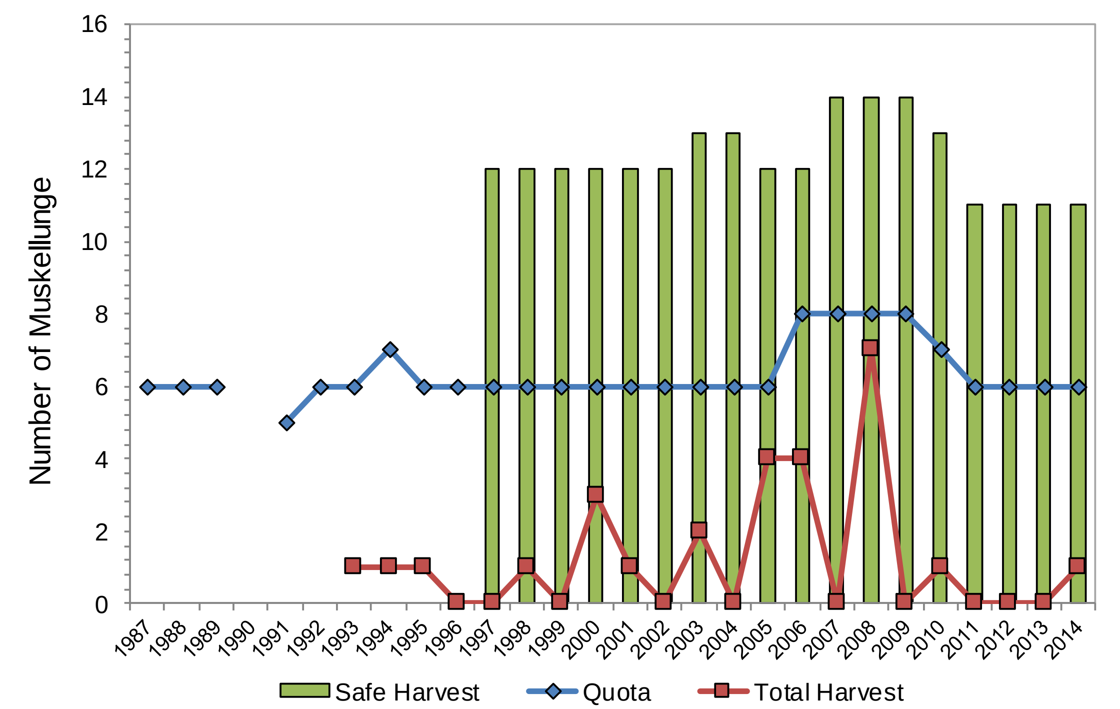


Figure 8.3.6-5. Birch Lake muskellunge spear harvest data. Annual total muskellunge harvests are displayed since 1989 from WDNR records.

8.3.7 Birch Lake Implementation Plan

The Implementation Plan presented in this section was created through the collaborative efforts of the Birch Lake Association (BLA) and Tamarack Lake riparians Planning Committee, Onterra ecologists, and North Lakeland Discovery Center (NLDC) and WDNR staff. It represents the path the BLA and Tamarack Lake riparians will follow in order to meet their lake management goals. Tamarack Lake has few riparian property owners and the BLA has included Tamarack Lake in their meetings, activities, and educational outreach. For this reason, the following Implementation Plan includes management goals and associated actions that both of these lakes will implement. This same Implementation Plan can also be found in the Tamarack Lake Individual Lake Report (Section 8.4).

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 Birch and Tamarack lake stakeholders as portrayed by the members of the Planning Committees and the numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

Management Action:	Continue monitoring of Birch and Tamarack lakes' water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Glen Wildenberg (current Birch Lake CLMN volunteer) and Martin Plutowski (current Tamarack Lake CLMN volunteer)
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. As discussed in the water quality sections, Birch and Tamarack lakes' water quality is good to excellent in all parameters measured. Continued monitoring will allow for early detection of potential negative trends and may lead to the reason as to why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the BLA have been measuring Secchi disk transparency in Birch Lake annually since 1997 and have been collecting samples for total phosphorus and chlorophyll-*a* annually since 2000. Volunteers from Tamarack Lake have been measuring Secchi disk transparency annually since 2016. Funding for advanced water quality monitoring (addition of total phosphorus and chlorophyll-*a*) has been increasing difficult to acquire, and it was suggested at the planning meetings that the Town of Winchester Lakes Committee may be able to provide funding for the collection of total

phosphorus and chlorophyll-*a* for the town's lakes in the future. Martin Plutowski (or the current Tamarack Lake volunteer) should work with the Town Lakes Committee to determine if funding would be available to conduct total phosphorus and chlorophyll-*a* monitoring on Tamarack Lake in addition to Secchi disk transparency in the future. Emily Heald, the current Water Program Coordinator at the NLDC, has indicated that the NLDC may be able to provide the water quality monitoring volunteers with a Secchi disk and temperature/dissolved oxygen probe for their use. Nearby Trout Lake Research Station may also lend water quality equipment to water quality monitoring volunteers.

The BLA and Tamarack Lake stakeholders realize the importance of continuing this monitoring effort which will supply them with valuable data about their lake. When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Glen Wildenberg and Martin Plutowski appoint/recruit new volunteer(s) as needed. If water quality equipment cannot be provided by WDNR, contact Emily Heald (715.543.2085) at the NLDC to inquire if the NLDC is able to lend equipment.
2. New volunteer(s) contact Sandy Wickman (715.365.8951) as needed.
3. Volunteer(s) reports results to WDNR SWIMS database.

Management Action: Continue monitoring Birch and Tamarack lakes' water levels through NLDC citizen science lake level monitoring program.

Timeframe: Continuation of current effort

Facilitator: Birch Lake: Joe and Dorla Osfar; Tamarack Lake: Martin Plutowski and available/interested Tamarack Lake stakeholders

Description: The NLDC currently administers a citizen-based lake level monitoring program where lake levels are monitored on area lakes. Seasonal and longer-term water level fluctuations are natural in Wisconsin's lakes and are often beneficial for lake health. Continued monitoring of lake levels provides for an understanding of what conditions lead to changes in water levels. Following ice-out in the spring, staff gauges are installed on Birch and Tamarack lakes and referenced to a fixed benchmark. Each week during the open-water season, volunteers record the current lake level. The staff gauges are removed in the fall and water level records are provided to NLDC staff. These lake level data are submitted to the WDNR's Surface Water Integrated

Monitoring System (SWIMS). The collection of lake level monitoring data must be a long-term, multiyear effort to accurately and precisely discern inter- and intra-annual patterns in water level fluctuations.

Action Steps:

1. Current BLA and Tamarack Lake volunteers record water level on staff gauges weekly during the open-water season.
2. Volunteers report water level data to NLDC at the end of each open-water season.
3. NLDC records water level data in WDNR SWIMS database.
4. Joe and Dorla Osfar and Martin Plutowski recruit new volunteers as needed or notify BLA if new water level monitors are needed.

Management Action: Preserve natural and restore highly developed shoreland areas on Birch and Tamarack lakes to improve habitat, reduce erosion, and protect water quality.

Timeframe: Initiate 2018

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: The 2016 Shoreland Condition Assessment found that approximately 70% (4.5 miles) of Birch Lake's immediate shoreland zone contains little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 16% (1.0 miles) contains a higher degree of development categorized as *developed-unnatural* or *urbanized*. On Tamarack Lake, approximately 93% (1.5 miles) of the lake's shoreland was delineated as *natural/undeveloped* while approximately 3% (0.05 miles) was delineated as *developed-unnatural* or *urbanized*. It is important that the owners of properties with little development become educated on the benefits their shoreland is providing to these lakes in terms of maintaining their water quality and habitat, and that these shorelands remain in a natural or semi-natural state. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to these lakes in terms of water quality and contribution to habitat loss.

The BLA board of directors will work with appropriate entities such as the NLDC and Vilas County Land and Water Department to research grant programs and other pertinent information that will aid the BLA and Tamarack Lake riparians in preserving and restoring the shoreland areas of these lakes. The NLDC has several restoration/rain/lakeshore/erosion gardens that can serve as examples and educational pieces for Birch and Tamarack Lake riparians to gather ideas for their properties. In addition, the NLDC can also help riparian property owners with planting ideas. 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. The BLA should contact Catherine Higley (cahigl@co.vilas.wi.us – 715.479.3738), Vilas County's Invasive Species Coordinator, to gather information on how to protect and restore areas of Birch Lake's shoreland.

Action Steps:

1. BLA Board of Directors gathers appropriate information from entities listed above.
2. The BLA provides Birch and Tamarack lake property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural land cover within Birch and Tamarack lakes' watershed beyond the immediate shoreland zone.

Timeframe: Initiate in 2018

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: As is discussed within the Watershed Section (8.3.2), changes in land use beyond the shoreland zone within a lake's watershed can impact water quality. Currently, Birch and Tamarack lakes' watershed is mainly comprised of natural land cover types, forests and wetlands. These natural land cover types export minimal amounts of phosphorus, retain soil, and maintain the good water quality found in these lakes. The BLA and Tamarack Lake stakeholders recognize the importance of maintaining natural land cover within the watershed of these lakes to maintain their water quality for future generations.

As discussed in the previous management action, one way the BLA and Tamarack Lake stakeholders can preserve land within the watershed is through the purchase of land and placement within a land trust. A number of land owners within the watershed have already put their land in a trust. The BLA can also reach out to land owners of property within these lakes' watersheds and provide them with information on the BLA's mission and why preserving their land in a more natural state is beneficial for water quality. In addition, because Birch, Tamarack, and Rainbow lakes share the same watershed, the BLA and Rainbow Lake Association may choose to work together to reach out to property owners throughout the entire watershed of these three lakes to provide them with information on how their land management can lead to the preservation of Birch, Tamarack, and Rainbow lakes.

As of 2017, approximately 40% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by The Forestland Group's Heartwood Forestland Partnership (Birch Lake – Map 8). This land is managed for sustainable logging and is overseen by regional teams working with local forestry consulting firms. The Forestland Group forest management is based on natural regeneration as opposed to planted silvicultural systems, and they were one of three recipients of a Corporate Sustainable Standard Setter Award by the Rainforest Alliance for leadership in the movement toward sustainable certification (TFG website: http://www.forestlandgroup.com/conservation/). The land within the Birch-Tamarack-Rainbow lake watershed is part of the Great Lakes Region Chippewa East Property. Shawn Hagan is the Senior Director for Forestland Operations (906.487.7491) of the Great Lakes Region for The Forestland Group, and the BLA can contact Shawn for more information on how this property within the watershed is managed.

Approximately 3% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by the Wisconsin Department of Natural Resources, while the remaining 57% is comprised of privately-owned parcels. In an effort to preserve natural land cover on these properties, the BLA can include information on the benefits of maintaining these properties in a natural state along with information on the benefits of maintaining a natural shoreline as discussed in the previous management action.

A valuable resource for land owners interested in putting their property in a trust in northern Wisconsin is the Northwoods Land Trust. For other available options, land owners should contact the Vilas County Land and Water Conservation Department. The websites for these groups can be found below:

- The Northwoods Land Trust Website: (www.northwoodslandtrust.org)
- Vilas County Land and Water Conservation Department Website: (http://www.vilasconservation.com/who_we_are.html)

Action Steps:

1. See description above.

Management Goal 2: Increase Navigation Safety on Birch and Tamarack Lakes

Management Action:	Consider the placement of waterway markers (non-regulatory danger buoys) to indicate areas in Birch and Tamarack lakes that are hazardous to vessel operation.
Timeframe:	Initiate 2018
Facilitator:	Birch Lake: BLA Board of Directors; Tamarack Lake: available/interested Tamarack Lake stakeholders
Description:	Birch and Tamarack lakes are visited by a number of lake users that recreate on the lake in different ways. Like many lakes, both of these lakes contain some areas that present navigation hazards to lake users. While it is the responsibility of lake users to familiarize themselves with the waterbody and employ safe boating practices, the Birch and Tamarack lake stakeholders would like to deploy non-regulatory danger markers in areas of these lakes that present navigation hazards. Non-regulatory markers are used to mark navigational channels, hazards, and other dangerous areas or to provide general information to the boating public (WDNR PUB-LE-317-2016). In Birch Lake, these markers would serve to warn lake users of the shallow water and/or rocks present in the area. The acoustic survey conducted in Birch Lake in 2016 identified three areas out from shore which were shallow (< 4 feet in depth) and may present navigation hazards to lake users (Birch Lake – Map 9). Marking these areas will likely also reduce direct impacts (i.e. bottom scarring) from motorboats to valuable native aquatic plant and benthic communities in these areas. Site 1 is a shallow rock bar in the southwest area of the lake approximately 1.0 acre in size. It is proposed that four non-regulatory danger markers be placed around the perimeter of this rock bar as illustrated on Birch Lake – Map 9. Site 2 and 3 are small areas of shallow water of approximately 0.05 acres in size each. It is proposed that a single non-regulatory danger buoy be placed in the center of each of these shallow areas. Currently, the BLA places three markers in the southwest area of the lake near the small island to indicate the slow, no wake area. Given that these three markers are close to shore, they are readily installed and taken out each year using a small row boat by BLA volunteers. The proposal for adding an additional six markers within the offshore areas previously discussed will make it more logistically challenging for the BLA to get these markers installed and taken out annually. This management action is currently considered as a proposal for marking hazardous areas in Birch Lake, and prior to seeking a permit for these markers the BLA will need to have continued discussions regarding how many additional markers they would like placed in the lake, their

location placement, and who and how these markers will be taken in and out of the lake annually.

In Tamarack Lake, one non-regulatory danger marker would be used to identify an area where large rocks are present near the surface and pose hazards to watercraft. It is proposed that one marker be placed at this location to notify lake users of the rocks in these areas (Tamarack Lake – Map 8). As with Birch Lake, Tamarack Lake stakeholders will need to discuss this further to determine sources of funding for the purchase of a marker and who will be responsible for taking this marker in and out of the lake annually.

These non-regulatory danger buoys would be placed in the lakes in spring following ice-out and removed in the fall prior to ice-on. If the BLA and/or Tamarack Lake stakeholder elect to move forward with placing these non-regulatory danger markers in their respective lakes, the initial installation of these markers involves the following requirements as listed in WDNR PUB-LE-317-2016 (http://dnr.wi.gov/files/PDF/pubs/le/LE0317.pdf):

- A WDNR Waterway Marker Application and Permit (Form 8700-58) must be completed.
- The "danger" buoy will be white with an orange diamond. Any information (e.g. "rock") will be printed on this buoy in black. It must by cylindrical in shape, a minimum of 36 inches above the waterline, with a minimum diameter of 7 inches.
- The buoys must be placed by individuals with authorization from the governing entity having jurisdiction over the waters involved.
- The permit must be accompanied by a map or diagram showing the proposed location of the markers (Birch Lake – Map 9 and Tamarack Lake – Map 8). Exact locations must be expressed in GPS coordinates or in specific feet distance from one or more fixed objects whose location is easily identifiable.
- Completed applications and information material should be sent to the WDNR Regional Recreational Safety Warden for Vilas County (Jeremy Cords – contact information below).

Action Steps:

1. The BLA and Tamarack Lake stakeholders have ongoing discussions regarding the addition of non-regulatory waterway markers in their respective lakes as discussed above.
2. If the BLA and/or Tamarack Lake holders elect to move forward with the addition of non-regulatory danger markers in their respective lakes, they would submit WDNR Waterway Marker Application and Permit (Form 8700-58) separately accompanied by Birch Lake – Map 9 and Tamarack Lake – Map 8 to Jeremy Cords (Jeremy.Cords@wi.gov;

920.366.1917), the WDNR Regional Recreational Safety Warden for Vilas County.

3. Following permit approval by the WDNR, the BLA and/or Tamarack Lake stakeholders would purchase non-regulatory danger markers that meet size, shape, and color regulations described for non-regulatory danger markers in WDNR PUB-LE-317-2016 (http://dnr.wi.gov/files/PDF/pubs/le/LE0317.pdf).
4. Individuals with proper authorization will place the markers in the lake following ice-out and will remove the markers prior to ice-on annually.

Management Action: Install signage at Birch and Tamarack lakes' public access location to inform lake users of watercraft regulations on these lakes.

Timeframe: Initiate in 2018

Facilitator: Birch Lake: BLA Board of Directors; Tamarack Lake: interested/available stakeholders

Description: As is discussed in the study results sections, of the 129 stakeholder surveys distributed to Birch Lake riparian property owners in 2016, 50 (39%) were completed. Given the lower response rate, the results of the survey cannot be interpreted as being statistically representative of the population sampled, and at best, the results may indicate possible trends and opinions about the stakeholder perceptions of Birch Lake. However, nearly 50% of respondents indicated that watercraft traffic is currently having a moderate to great negative impact on Birch Lake (Appendix B, Question 2). During the planning meetings, members of the Birch and Tamarack lakes Planning Committees expressed concern about motorboats and personal watercraft operating above slow, no wake speed within the designated setback from the shoreline (100 feet for boats and 200 feet for personal watercraft). The Planning Committee is concerned not only about recreational safety but about the impact to shoreland areas from watercraft operating above slow, no wake too close to shore.

In addition to informing Birch and Tamarack lake riparians on Wisconsin's watercraft regulations and responsible boating practices through their newsletter, a recommendation that no skiing/wakeboarding occur after 7:00 pm, the BLA and Tamarack Lake stakeholders will install signage at the public access point for each lake to provide lake users with a visual representation of the 100- and 200-foot slow, no wake setbacks in an effort to improve recreational safety on these lakes and reduce shoreline erosion/impacts to shoreline habitat. The access point for Tamarack Lake is a carry-in access location on Hwy W that is owned by the Town of Winchester. Members on the Tamarack Lake Planning Committee indicate that they will need to hold additional discussions with Tamarack Lake stakeholders to decide if they would like this type of signage at the carry-in access location.

Onterra will provide the BLA and Tamarack Lake stakeholders with a map similar to Birch Lake – Map 10 and Tamarack Lake – Map 9 displaying these setback areas. The BLA and Tamarack Lake stakeholders will need to provide this map to a sign/graphic design company to create a durable sign for outdoor use at the public access points. In addition, the BLA and Tamarack Lake stakeholders will likely also need to obtain the necessary permission from the Town of Winchester to install new signage at these public access locations.

Action Steps:

1. Onterra provides BLA and Tamarack Lake stakeholders with watercraft regulation maps.
2. Birch Lake and Tamarack Lake stakeholders work with sign/graphic design company to create sign for the public boat landing.
3. BLA and Tamarack Lake stakeholders obtain necessary permission from the Town of Winchester to install sign at the Birch Lake public boat landing.

Management Goal 3: Assure and Enhance the Communication and Outreach of the Birch Lake Association with Birch and Tamarack Lake Stakeholders

<u>Management Action:</u> Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Birch and Tamarack lakes.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The BLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the BLA publishes four newsletter issues per year – a hard copy issue once per year which is distributed to all Birch Lake riparian property owners and three electronic issues which are sent to Birch Lake Association members. These newsletters provide members and non-members with association-related information including current projects and updates, meeting times, and educational topics. In addition, the BLA also maintains a website, the Birch/Tamarack Lake Blog (http://birchlake.blogspot.com/), where lake users can find information on Birch and Tamarack lake, meeting times, information on the Town of Winchester lakes, along with a host of lake-related links. During the planning meetings with the Phase II lakes' planning committees, it was suggested that the Rainbow Lake Association (RLA) be included to the Birch/Tamarack lakes blog website after gaining a better understanding on the connectivity between these three lakes. The inclusion of the RLA in the Birch/Tamarack blog will facilitate increased communication between these groups and improve conservation efforts for these three connected lakes.

Eighty-eight percent of Birch Lake stakeholder survey respondents indicated that the BLA keeps them either fairly well informed or highly informed regarding issues with Birch Lake and its management. The BLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Birch Lake and its preservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter, distributed as separate educational materials, or posted on the association's website. The BLA has historically invited lake-related speakers to discuss lake topics at the annual Birch/Tamarack annual meeting on Labor Day weekend and they intend to continue to do so in the future in an effort to educate their membership on responsible lake stewardship. The BLA should also reach out to professionals from the NLDC, WDNR, Vilas County Lakes and Rivers Association, etc. to obtain educational pieces for their newsletter.

Example Educational Topics

- Shoreline restoration and protection
- Effect lawn fertilizers/herbicides have on the lake
- Importance of maintaining course woody habitat
- Fishing rules and regulations
- Tribal spear harvests
- Catch-and-release fishing
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention
- Water quality monitoring updates from Birch and Tamarack lake
- Septic system maintenance
- Water levels
- Littering on the ice and year-round

In addition to publishing a quarterly newsletter, the BLA will also create a mailing to riparian property owners that includes a summary of the 2016 study results along with information on the BLA's role in the management of Birch Lake and the benefits of being a member.

Every other year, the BLA updates and publishes their membership directory. The BLA will also be updating information on their introductory brochure that has been created for distribution to new association members.

Birch Lake Planning Committee members also expressed concern about the need to educate short-term renters on Birch Lake on responsible lake stewardship and watercraft use as these short-term users of the lake often have little vested interest in the lake beyond recreational activities. If the BLA is able to identify rental properties on Birch Lake, the BLA could reach out to these rental property owners to determine if they would be willing to include some type of BLA-created informational packet to their renters. This packet could include items such as the *Town of Winchester Lake User Guide* which provides information on common sense courtesies and watercraft regulations for lake users as well as steps to prevent AIS introductions. The packet could also include the watercraft regulation map for Birch Lake along with other interesting facts or figures about the lake.

The education of Birch Lake property owners who are not members of the BLA was also an issue brought forward by the Birch Lake Planning Committee. They indicated that while the BLA can readily inform its membership, the association has limited influence with non-members. The Town of Winchester Town Lakes Committee is currently having ongoing discussions regarding contracting the NLDC to conduct educational initiatives and monitoring. The Town Lakes Committee has been highly involved the Winchester Lakes Management Planning Project, and following the completing of this project, the committee will be looking to initiate new, smaller projects to help the Winchester lakes. The Town Lakes Committee can also host speakers at public events and publish newspaper and newsletter articles in an effort to maximize outreach to Winchester lakes' users.

Action Steps:

1. See description above.

Management Goal 4: Prevent New Aquatic Invasive Species Introductions to Birch and Tamarack Lake

Management Action: Continue volunteer aquatic invasive species monitoring using the shoreline monitors.

Timeframe: Continuation of current effort.

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: As of this writing, four non-native, invasive species have been documented in Birch Lake: the rusty crayfish, banded mystery snail, Chinese mystery snail, and aquatic forget-me-not. No non-native species have been documented to date in Tamarack Lake. As is discussed in the Other Aquatic Invasive Species in the Town of Winchester Lakes section (section 3.5), in high numbers rusty crayfish have the capacity to reduce aquatic plant abundance while the non-native snails have been shown to displace native snail species. Data on Birch Lake's non-native crayfish and snail populations are not available, so it is not known to what extent these species may be adversely affecting Birch Lake's ecology. The studies completed in 2016 indicate that Birch Lake's native aquatic plant community is very healthy, and the crayfish population may be having limited impacts on the lake's plants. While aquatic forget-me-not was not documented by Onterra along shoreland areas of Birch Lake in 2016, NLDC staff and several BLA volunteers observed this plant in 2017.

The BLA and Tamarack Lake stakeholders understand that it important to prevent future introductions of non-native species such as Eurasian watermilfoil and curly-leaf pondweed. Nearby waterbodies such as Harris Lake and the Manitowish Chain of Lakes contain populations of curly-leaf pondweed, while Presque Isle Lake contains a population of Eurasian watermilfoil. In lakes without Eurasian watermilfoil and curly-leaf pondweed, early detection of these can often lead to successful control, and in instances with small infestations, possibly even eradication. Currently, Birch and Tamarack lakes volunteers have received aquatic invasive species identification and monitoring training and perform shoreline surveys in which volunteers are responsible for periodically monitoring specific areas of the lake. This methodology allows the entire lake to be monitored for the presence of non-native species. In addition to volunteer monitoring, NLDC staff completes AIS surveys on Birch and Tamarack lakes two times per year.

Action Steps:

1. Birch and Tamarack lakes volunteers updated their identification and monitoring skills by attending training sessions provided by the NLDC (877.543.2085).
2. Trained volunteers recruit and train additional association members.

3. Complete monitoring surveys following protocols.

Management Action: Install aquatic invasive species (AIS) signage at Tamarack/Rainbow lakes public carry-in access location.

Timeframe: Initiate 2018

Facilitator: Interested/available Tamarack Lake stakeholders

Description: Tamarack Lake contains a carry-in public access owned by the Town of Winchester located on the northern side of the lake where County Hwy W crosses Rainbow Creek. At present, this public access location does not contain an AIS awareness sign to inform lake users on AIS prevention. The WDNR is currently offering these signs, posts, and hardware free of charge. Tamarack Lake Planning Committee members indicated they would have to have continued discussion with Tamarack Lake stakeholders to determine if they would like AIS signage posted at this carry-in access point. Tamarack Lake stakeholders should also work with the Rainbow Lake Association (RLA) as Rainbow Lake can also be accessed by this carry-in location. To request an AIS boat landing sign, Tamarack Lake stakeholders and the RLA should contact Tim Campbell (timothy.campbell@wisconsin.gov – 608.26.3531), WDNR AIS Education Specialist, to request a sign for the Tamarack/Rainbow lakes carry-in access.

Action Steps:

1. Please see above description.

Management Action: Initiate aquatic invasive species rapid response plan upon discovery of new infestation.

Timeframe: Initiate upon invasive species discovery.

Facilitator: Birch Lake: BLA Board of Directors (suggested); Tamarack Lake: interested/available stakeholders

Description: In the event that an aquatic invasive species such as Eurasian watermilfoil is located by the trained volunteers in Birch or Tamarack lake, the areas would be marked using GPS and the BLA or Tamarack Lake stakeholders should contact resource managers (NLDC) immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase and the results would be used to develop potential control strategies.

Action Steps:

1. BLA and/or Tamarack Lake stakeholders contact NLDC (877.543.2085) upon discovery of new invasive species in Birch or Tamarack lake.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Birch Lake's public access location.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors (suggested)

Description: The BLA has been periodically conducting watercraft inspections using volunteers at the public boat landing since 2007 through the Clean Boats Clean Waters (CBCW) program. In-kind time for watercraft inspections at Birch Lake is being provided through the WDNR grants as part of the four-year lake management planning project (2015-2018). However, the BLA would like to continue watercraft inspections beyond 2018. The intent of the boat inspections would not only be to prevent additional exotic species from entering the lake through the public access point, but also to prevent the infestation of other waterways with exotic species that originated in Birch Lake. The goal would be to monitor the during the busiest times (e.g. holiday weekends) in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of their spread.

The BLA would like to continue watercraft inspections using volunteers. Often, it is difficult for lake groups to recruit and maintain a volunteer base to oversee CBCW inspections throughout the summer months. Recruitment outside of the BLA may be necessary in order to have sufficient coverage of the Birch Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW.

Members of the BLA, as well as other volunteers, will need to be trained on CBCW protocols in order to participate in public boat landing inspections. Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought to ensure monitoring occurs at the public boat landing. These paid inspectors may be purchased alone or in conjunction with volunteers through the BLA or in the community.

Action Steps:

1. Members of the BLA periodically attend CBCW training sessions through the WDNR to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.
3. Begin inspections during high-use weekends.
4. Report results to WDNR and BLA.
5. Promote enlistment and training of new volunteers to keep program fresh.

Management Goal 5: Enhance the fishery of Birch and Tamarack Lakes

Management Action: Continue work with WDNR fisheries managers to enhance the fishery of Birch and Tamarack lakes.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: In the 2016 stakeholder survey, fishing was ranked second behind relaxing/entertaining by respondents when asked to rank their top three activities that are important reasons for owning or renting their property on or near Birch Lake (Appendix B, Question 17). Respondents indicated that walleye, muskellunge, and smallmouth bass were the top three most sought-after fish by anglers in Birch Lake, and 79% of respondents rated the current fishing on Birch Lake as either fair or good (Appendix B, Questions 11 and 12). Approximately 44% of respondents indicated the quality of fishing has gotten somewhat worse since they began fishing on Birch Lake, while 39% indicated the quality of fishing has remained the same (Appendix B, Question 13).

Birch Lake is currently listed as an Area of Special Natural Resource Interest (ASNRI) for harboring naturally reproducing populations of both walleye and muskellunge, while Tamarack Lake has a ASNRI designation for a naturally reproducing muskellunge population. The BLA and Tamarack Lake stakeholders understand that a multitude of factors such as changes in habitat, water levels, and fishing pressure affect fish communities, and the BLA and Tamarack Lake stakeholders would like to take an active role in maintaining a healthy fishery to ensure Birch and Tamarack lakes remain high-quality fishing lakes for future generations.

Both Birch and Tamarack lake are currently overseen by WDNR fisheries biologist Hadley Boehm (715.356.5211). In an effort to remain informed on studies pertaining to fisheries in these lakes, the BLA Board of Directors and interested/available Tamarack Lake stakeholders should contact Hadley at least once per year (perhaps during the winter months when field work is not occurring) for a brief summary of activities. In addition, the BLA can discuss management options for maintaining and enhancing the lakes' fishery, which may include changes in angling regulations and/or habitat enhancements.

Action Steps:

See description above.

Please note that study methods and explanations of analyses for Tamarack Lake can be found within the Town of Winchester Town-wide Management Plan document.

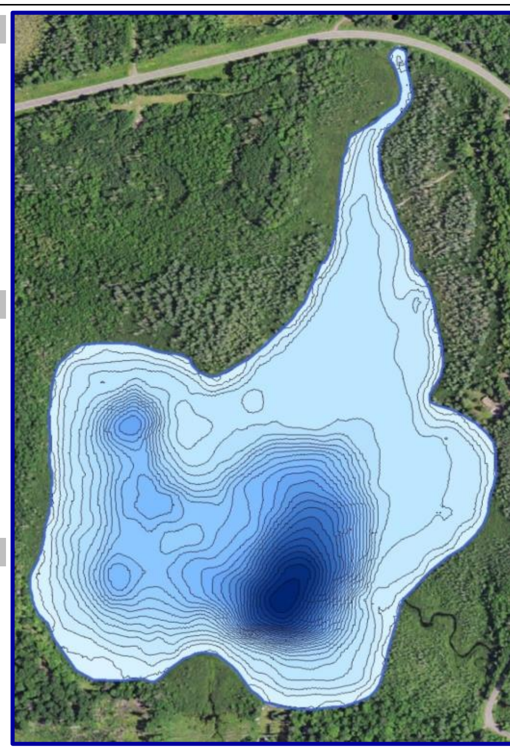
8.4 Tamarack Lake

An Introduction to Tamarack Lake

Tamarack Lake, Vilas County, is a 63-acre deep lowland, brown-water, meso-eutrophic drainage lake with a maximum depth of 27 feet and a mean depth of 7 feet (Tamarack Lake – Map 1). Its surficial watershed encompasses approximately 5,114 acres within the Flambeau River Watershed and is comprised mainly of intact forests and wetlands. Tamarack Lake is fed by upstream Birch Lake through Tambier Creek and upstream Deer Lake through Deer Creek. Water from Tamarack Lake flows into downstream Rainbow Lake through Rainbow Creek. In 2016, 31 native aquatic plant species were located within the lake, of which fern-leaf pondweed (*Potamogeton robbinsii*) was the most common. Non-native aquatic plant species were not located in Tamarack Lake in 2016, and no other non-native species have been documented within the lake.

Lake at a Glance - Tamarack Lake

Morphology	
LakeType	Deep Lowland Drainage
Surface Area (Acres)	63
Max Depth (feet)	27
Mean Depth (feet)	7
Perimeter (Miles)	1.7
Shoreline Complexity	2.1
Watershed Area (Acres)	5,114
Watershed to Lake Area Ratio	77:1
Water Quality	
Trophic State	Meso-eutrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	32.2
Avg Summer Chl-α (µg/L)	5.6
Avg Summer Secchi Depth (ft)	5.9
Summer pH	7.3
Alkalinity (mg/L as $CaCO_3$)	31.6
Vegetation	
Number of Native Species	32
NHI-Listed Species	None
Exotic Species	None
Average Conservatism	7.3
Floristic Quality	34.1
Simpson's Diversity (1-D)	0.83



Descriptions of these parameters can be found within the town-wide portion of themanagement plan

8.4.1 Tamarack Lake Water Quality

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

In 2016, a stakeholder survey was sent to five Tamarack Lake riparian property owners. Four of these five (80%) surveys were completed and returned. The full survey and results can be found in Appendix B. When asked about Tamarack Lake's current water quality, 100% of the respondents indicated the water quality is *good* (Figure 8.4.1-1). When asked how water quality has changed in Tamarack Lake since they first visited the lake, 75% of respondents indicated water quality has *remained the same* and 25% indicated they were *unsure* (Figure 8.4.1-1).

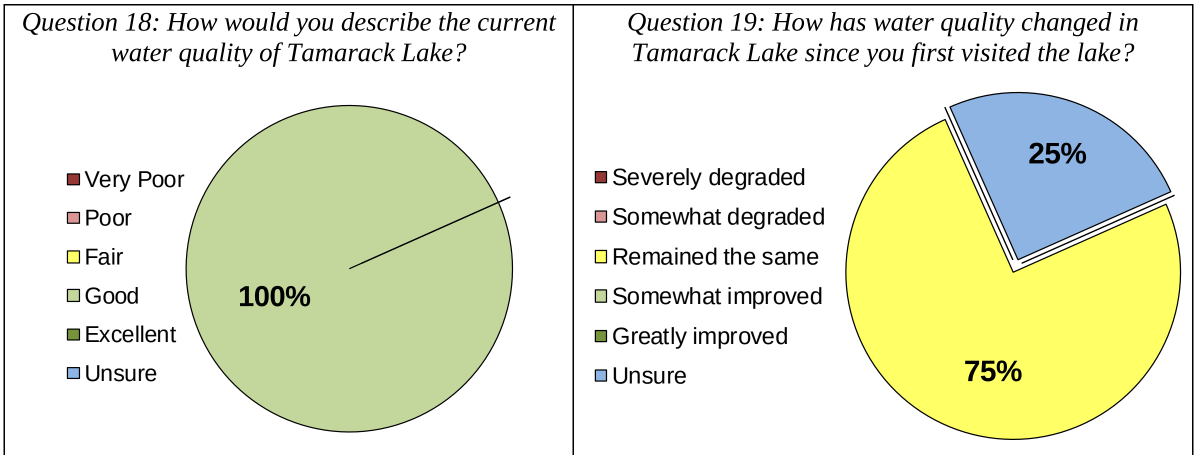


Figure 8.4.1-1. Tamarack Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 4 (80%) respondents of 5 surveys distributed.

The water quality data collected in 2016 represent the first time data have been collected from Tamarack Lake. Given historical data are not available, it cannot be said if or how water quality in Tamarack Lake has changed over time. However, the 2016 data provide information on the current condition of Tamarack Lake's water quality. The average summer total phosphorus concentration measured in Tamarack Lake in 2016 was 32.2 µg/L which straddles the threshold between the *good* and *fair* categories for deep lowland drainage lakes in Wisconsin (Figure 8.4.1-2). This average summer phosphorus concentration exceeds the median concentration for other deep lowland drainage lakes in Wisconsin (23.0 µg/L) and for all lake types within the NLF ecoregion (21.0 µg/L).

The average growing season total phosphorus concentration measured in Tamarack Lake in 2016 was approximately 37% higher than the predicted phosphorus concentration generated by watershed modeling. As is discussed in further detail within the Tamarack Lake Watershed Assessment Section (Section 8.4.2), it is believed the higher-than-predicted phosphorus concentrations are not the result of human activity and are likely the result of the model underestimating phosphorus input from Tamarack Lake's direct watershed. While phosphorus concentrations were higher than expected, chlorophyll-*a* concentrations were lower than expected given the level of phosphorus within the lake. As is discussed further, phytoplankton production in Tamarack Lake is likely light-limited due to the dark-stained water found in the lake.

The average summer chlorophyll-*a* concentration measured in Tamarack Lake in 2016 was 5.6 µg/L, falling on the threshold between *excellent* and *good* for deep lowland drainage lakes in

Wisconsin (Figure 8.4.1-2). The summer average chlorophyll-*a* concentration in Tamarack Lake is lower than the median concentration for other deep lowland drainage lakes in Wisconsin (7.0 µg/L) and the same as the median concentration for all lake types within the NLF ecoregion (5.6 µg/L). As mentioned, the measured chlorophyll-*a* concentrations from Tamarack Lake are lower than expected given the measured concentrations of phosphorus. This is an indication that another factor other than phosphorus is limiting phytoplankton production. It is likely that the phytoplankton are light-limited due to the dark-stained water found in Tamarack Lake. The sources of Tamarack Lake's stained water are discussed further in this section.

The average summer Secchi disk depth measured in Tamarack Lake in 2016 was 5.9 feet, falling in the *good* category for Wisconsin's deep lowland drainage lakes. Tamarack Lake's average summer Secchi disk depth falls below the median depth for other deep lowland drainage lakes in Wisconsin (8.5 feet) and the median depth for all lake types within the NLF ecoregion (8.9 feet). The measured Secchi disk depth in Tamarack Lake is lower than predicted based on measured chlorophyll-*a* concentrations, and is an indication that a factor other than phytoplankton is influencing water clarity in Tamarack Lake.

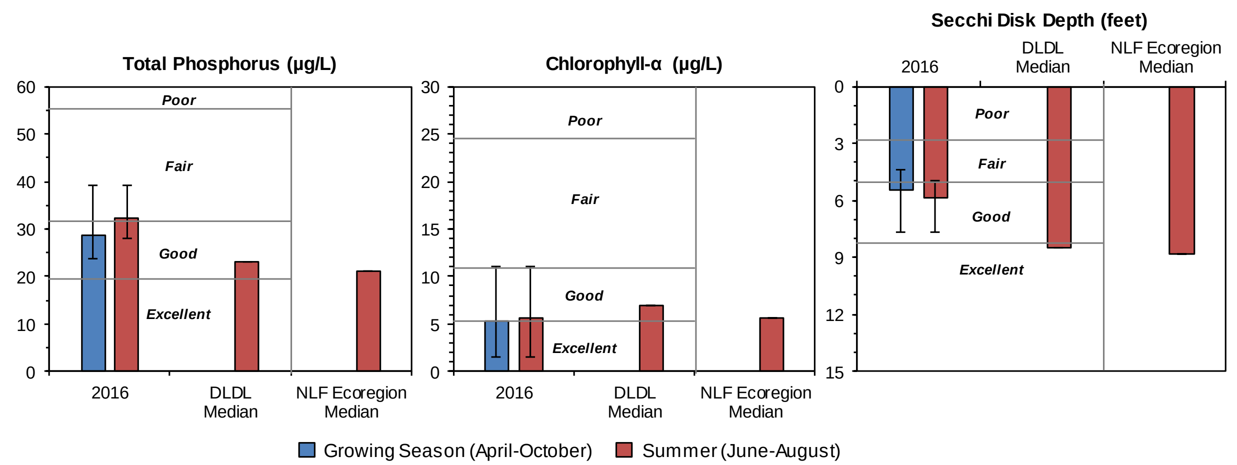


Figure 8.4.1-2. Tamarack Lake 2016 average growing season and summer total phosphorus, chlorophyll-α, and Secchi disk depth compared to median values for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in Tamarack Lake in 2016 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Tamarack Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Tamarack Lake in 2016 averaged 65

SU (standard units), indicating the lake's water is *tea-colored*. Based on Tamarack Lake's chlorophyll-*a* concentrations measured in 2016, Secchi disk transparency was predicted to be approximately 8.0 feet; however, the high concentrations of dissolved organic acids in the lake reduce the water's clarity to the measured growing season average of 5.9 feet. It is important to note that the tea-colored water in Tamarack Lake is natural, and is not an indication of degraded conditions.

To determine if internal nutrient loading (discussed in Town-Wide Section of management plan) is a significant source of phosphorus in Tamarack Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on five occasions from Tamarack Lake in 2016 (Figure 8.4.1-3). Near-bottom total phosphorus concentrations were relatively similar to those measured at the surface on all sampling occasions with the exception of samples collected in late-July. Near-bottom total phosphorus concentrations measured during this sampling event were approximately two times higher than those measured at the surface; however, the near-bottom total phosphorus concentration was well below 200 µg/L. While internal phosphorus loading occurs to some degree during summer stratification, there is no indication that that this near-bottom phosphorus is mobilized to surface waters during the summer. Additionally, even if this phosphorus was mobilized to surface waters, the amount is not at a level which would significantly impact water quality.

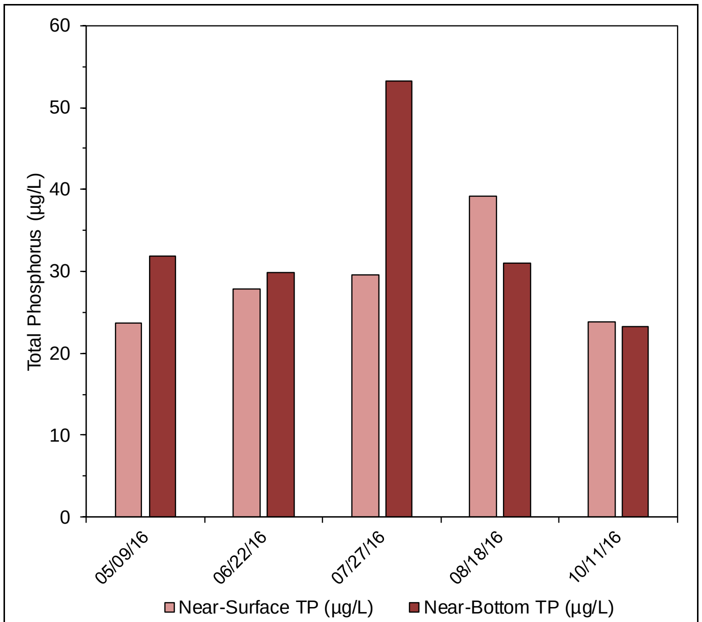


Figure 8.4.1-3. Tamarack Lake near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations measured in 2016.

Tamarack Lake Trophic State

Figure 8.4.1-4 contains the Trophic State Index (TSI) values for Tamarack Lake calculated from the data collected in 2016. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency 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 for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Tamarack Lake indicate the lake is at present in meso-eutrophic state. Tamarack Lake's productivity is similar to the productivity of other deep lowland drainage lakes throughout Wisconsin and slightly higher when compared to the productivity of all lake types within the NLF ecoregion.

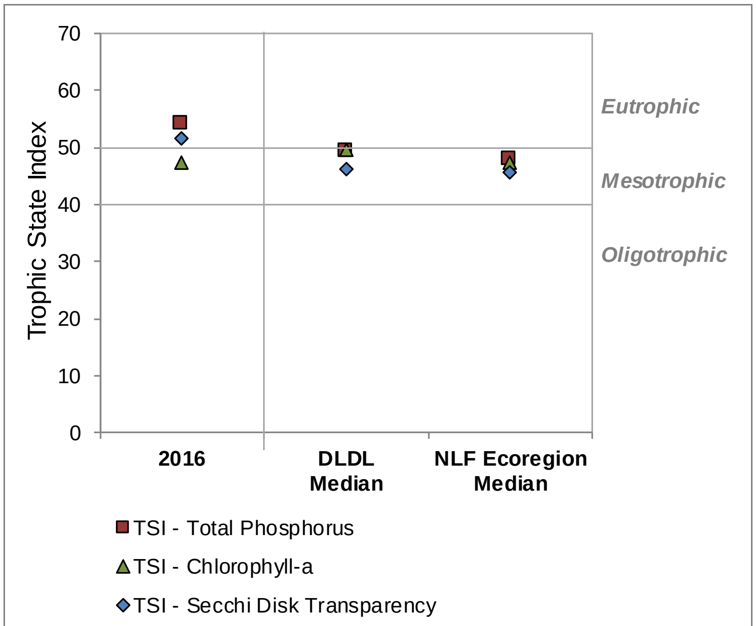
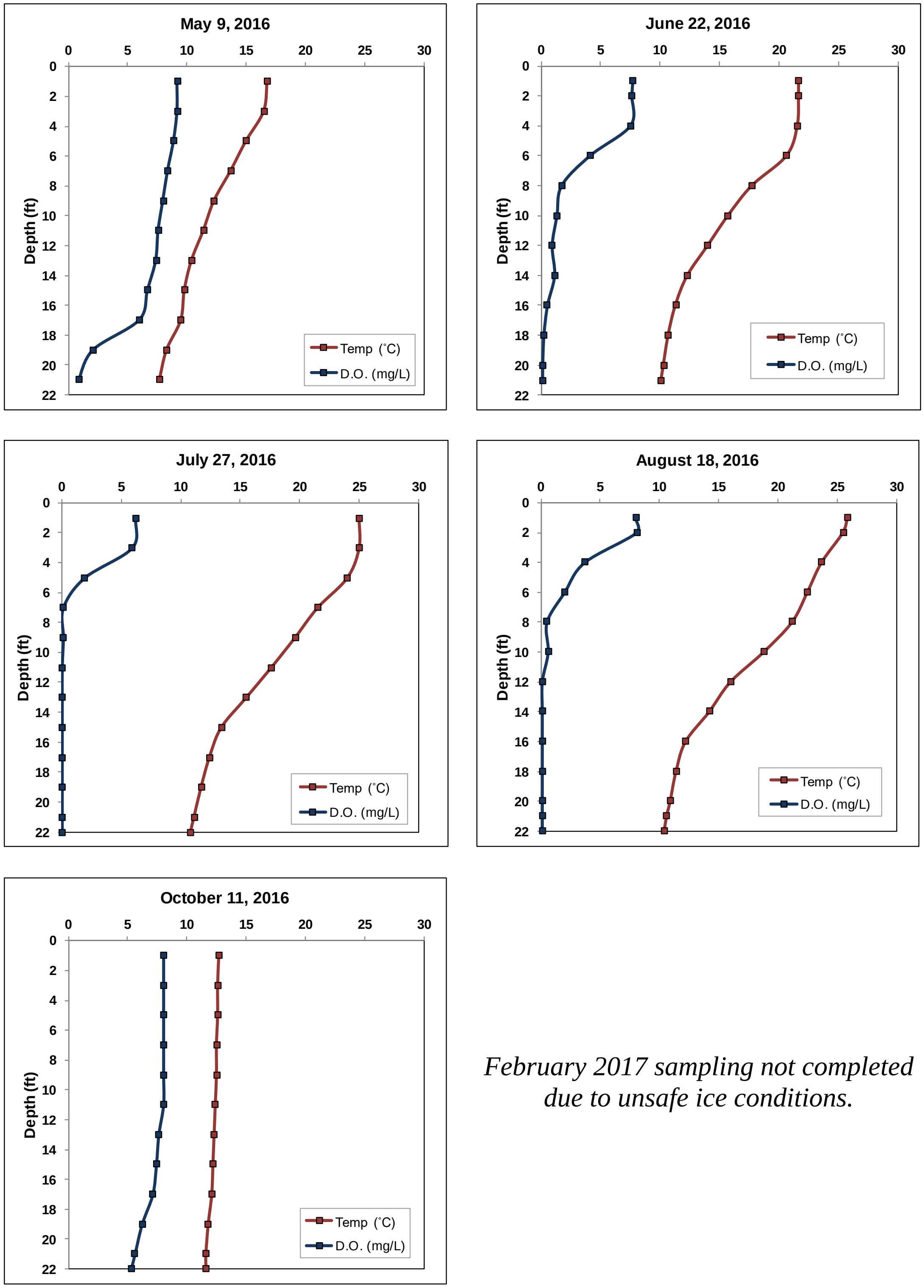


Figure 8.4.1-4. Tamarack Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Tamarack Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling event conducted by Onterra ecologists. These data are displayed in Figure 8.4.1-5. The temperature and dissolved oxygen data collected in 2016 indicate that the lake remains stratified throughout the summer and develops anoxia from 6.0 feet and deeper by mid-summer. By October, surface temperatures had cooled and the lake had mixed as indicated by relatively uniform temperature and dissolved oxygen throughout the water column. An attempt was made to collect water quality data through the ice in February 2017 on Tamarack Lake, but this sampling was not conducted due to unsafe ice conditions.



February 2017 sampling not completed due to unsafe ice conditions.

Figure 8.4.1-5. Tamarack Lake 2016/17 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Tamarack Lake

The previous section is centered on parameters relating to Tamarack Lake's trophic state. 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 Tamarack Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. Tamarack Lake's mid-summer surface water pH was measured at 7.3 in 2016. This value indicates Tamarack Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Tamarack Lake's average alkalinity measured in 2016 was 31.6 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while Tamarack Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from Tamarack Lake in 2016 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Tamarack Lake's pH falls within this range. Tamarack Lake's calcium concentration in 2016 was 9.9 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Tamarack Lake in 2016 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys.

8.4.2 Tamarack Lake Watershed Assessment

Tamarack Lake's surficial watershed encompasses approximately 5,114 acres (Figure 8.4.2-1 and Tamarack Lake – Map 2) yielding a watershed to lake area ratio of 77:1. The watershed is comprised of the Birch Lake subwatershed (4,178 acres) and the Tamarack Lake direct watershed (936 acres). For the watershed modeling, phosphorus data collected from Birch Lake were used along with the land cover types within the Tamarack Lake direct watershed. Tamarack Lake's direct watershed is comprised of land cover types including forests (44%), wetlands (37%), pasture/grass (12%), and the lake's surface itself (7%) (Figure 8.4.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Tamarack Lake's residence time is approximately 0.08 years, or the water within the lake is completely replaced approximately 13 times per year.

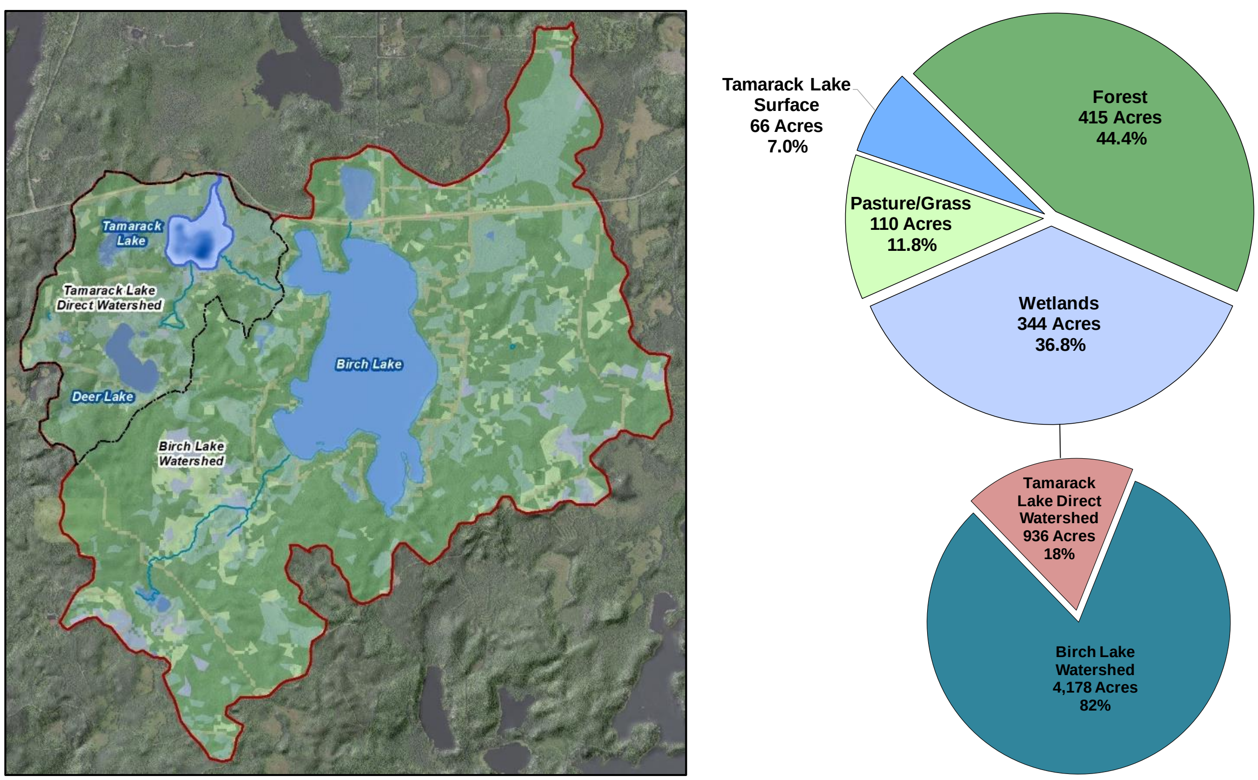


Figure 8.4.2-1. Tamarack Lake watershed boundary (red line) and proportion of land cover types. Tamarack Lake direct watershed is indicated by black dashed line. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types within Tamarack Lake's direct watershed and phosphorus data from Birch Lake, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Tamarack Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Tamarack Lake riparian property owners in 2016 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a total of approximately 328 pounds of phosphorus are delivered to Tamarack Lake from its watershed on an annual basis (Figure 8.4.2-2).

Of the estimated 328 pounds of phosphorus being delivered to Tamarack Lake on an annual basis, approximately 218 pounds (66%) originates from the Birch Lake subwatershed while the remaining 110 pounds (34%) originates from Tamarack Lake's direct watershed. Within the direct watershed, 33 pounds (10%) originate from forests, 31 pounds (10%) originate from wetlands, 29 pounds (9%) originate from areas of pasture/grass/rural open space, 18 pounds (5%) originate from direct atmospheric deposition onto the lake surface, and a negligible amount was estimated to originate from riparian septic systems (Figure 8.4.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 19 µg/L. The 2016 measured growing season total phosphorus concentration in Tamarack Lake was 28.8 µg/L, approximately 37% higher than the WiLMS predicted concentration. The higher concentration of phosphorus measured in Tamarack Lake is an indication that approximately 200 additional pounds of phosphorus are entering the lake each year that was not accounted for within the model.

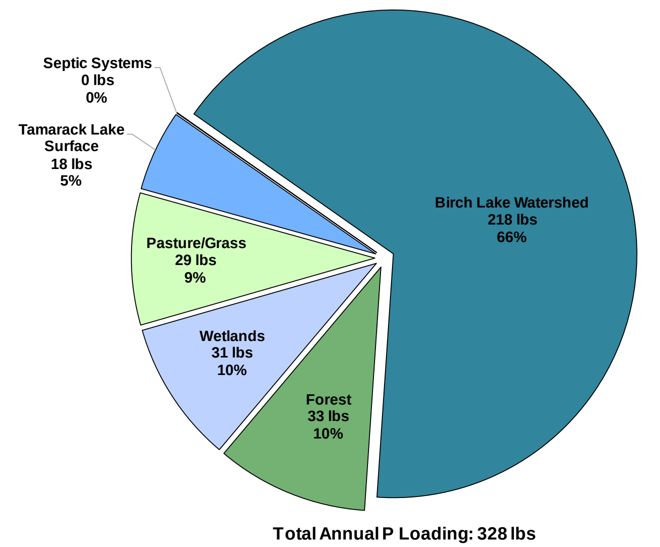


Figure 8.4.2-2. Tamarack Lake estimated potential annual phosphorus loading. Please note WiLMS estimated approximately 328 pounds of phosphorus are delivered to Tamarack Lake annually. However, based upon measured phosphorus concentrations, it is estimated approximately 526 pounds of phosphorus are loaded to the lake annually. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

In most instances in northern Wisconsin lakes when the measured phosphorus concentration is higher than that predicted by the model, it is an indication of internal nutrient loading. However, as is discussed in the Tamarack Lake Water Quality Section (Section 8.4.1), the data indicate that internal nutrient loading is not a significant source of phosphorus to Tamarack Lake and suggests that the unaccounted phosphorus is originating externally from the watershed. Given measured phosphorus concentrations from Birch Lake were used in the modeling, it is likely the predicted phosphorus loading from the Birch Lake subwatershed is highly accurate and it is not probable that the unaccounted phosphorus is originating from the Birch Lake subwatershed.

It is believed the unaccounted phosphorus resulting in higher than predicted phosphorus concentrations in Tamarack Lake is originating from the lake's direct watershed. Tamarack Lake's direct watershed is almost entirely comprised of natural land cover types, and it is likely that phosphorus export from the direct watershed is naturally higher than model predictions. It is also possible that the data collected from Tamarack Lake in 2016 represent a year with higher than average phosphorus concentrations as a result of increased precipitation. Regardless, the higher than predicted phosphorus concentrations in Tamarack Lake are not the result of anthropogenic activity and are believed to be the result of underestimation by the WiLMS model.

8.4.3 Tamarack Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the late-summer of 2016, the immediate shoreland of Tamarack Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

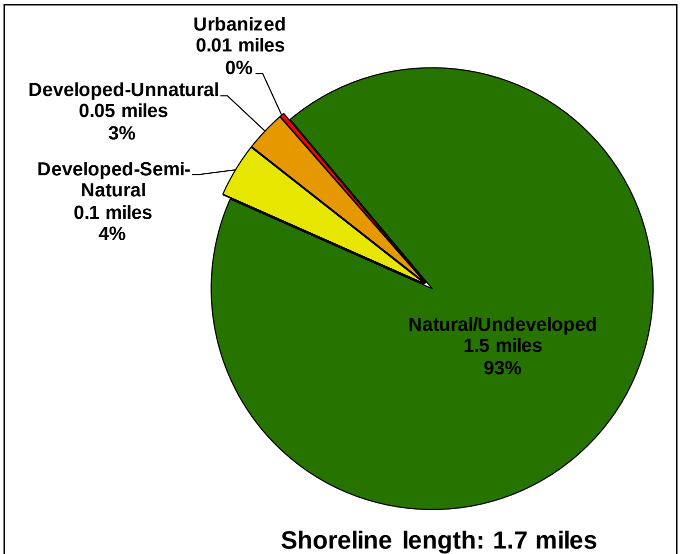


Figure 8.4.3-1. Tamarack Lake shoreland categories and total lengths. Based upon a late-summer 2016 survey. Locations of these categorized shorelands can be found on Tamarack Lake - Map 3.

The 2016 survey revealed that Tamarack Lake has stretches of shoreland that fit four of the five shoreland assessment categories (Figure 8.4.3-1). In total, 1.5 miles (93%) of the 1.7-mile shoreland zone were categorized as natural/undeveloped or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.06 miles (3%) of the shoreland was categorized as developed-unnatural or urbanized, shorelands which provide little benefit to and may actually adversely impact the lake. If restoration of Tamarack Lake's shoreland is to occur, primary focus should be placed on these shoreland areas. Tamarack Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Tamarack Lake in 2016. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, research

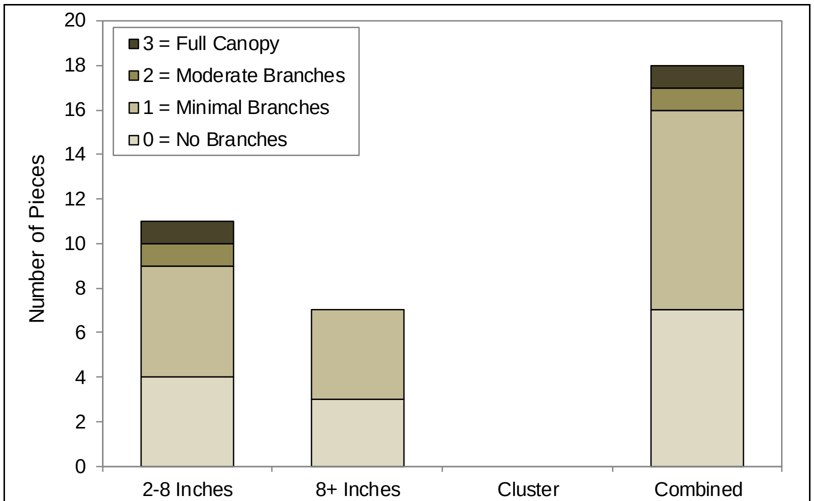


Figure 8.4.3-2. Tamarack Lake coarse woody habitat survey results. Based upon a late-summer 2016 survey. Locations of Tamarack Lake coarse woody habitat can be found on Tamarack Lake – Map 4.

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 the coarse woody habitat survey on Tamarack Lake, a total of 18 pieces were observed along 1.7 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 11:1 (Figure 8.4.3-2). Onterra ecologists have been completing these surveys on Wisconsin's lakes for five years, and Tamarack Lake falls in the 16th percentile for the number of coarse woody habitat pieces per shoreline mile of 75 lakes studied. While the majority of the shoreland zone around Tamarack Lake is natural, the lower number of coarse woody habitat pieces is due to non-forested wetlands which surround most of the lake and lack larger trees. Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in these lakes. The locations of these coarse woody habitat pieces are displayed on Tamarack Lake – Map 4.

8.4.4 Tamarack Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Tamarack Lake on June 28, 2016. 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. Fortunately, no curly-leaf pondweed was located in Tamarack Lake in 2016, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. Tamarack Lake users should familiarize themselves with curly-leaf pondweed and its identification as nearby Harris Lake contains a population of curly-leaf pondweed that was discovered in 2008.

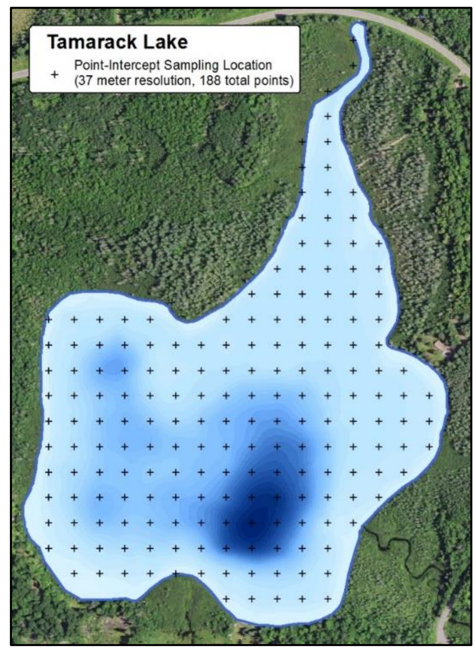


Figure 8.4.4-1. Tamarack Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Tamarack Lake by Onterra ecologists on July 20, 2016 (Figure 8.4.4-1). During these surveys, a total of 32 aquatic plant species were located, none of which are considered to be non-native, invasive species (Table 8.4.4-1). Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In early August of 2016, Onterra ecologists completed an acoustic survey on Tamarack Lake (bathymetric results on Tamarack Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Tamarack Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey showed that substrate hardness varies widely in shallow areas of Tamarack Lake with both the hardest and softest substrates in the lake occurring within 1.0-5.0 feet of water (Figure 8.4.4-2). The softer substrates occurred near the mouths of inlet creeks and in areas of adjacent wetlands while areas of harder substrates mainly occurred along the lake's northern shorelines. Average substrate hardness increased between 6.0-11.0 feet before declining slightly and remaining relatively constant to 27.0 feet. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.4.4-1. List of aquatic plant species located in Tamarack Lake during Onterra 2016 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2016 (Onterra)
Emergent	*Dulichium arundinaceum*	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Pontederia cordata	Pickerelweed	9	X
	Schoenoplectus acutus	Hardstem bulrush	5	I
	Sparganium americanum	American bur-reed	8	I
	Typha latifolia	Broad-leaved cattail	1	I
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	I
	Eriocaulon aquaticum	Pipewort	9	X
	Isoetes spp.	Quillwort spp.	8	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton praelongus	White-stem pondweed	8	I
	Potamogeton richardsonii	Clasping-leaf pondweed	5	I
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia minor	Small bladderwort	10	X
	Utricularia vulgaris	Common bladderwort	7	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	I
FF	*Lemna minor*	Lesser duckweed	5	I
	Lemna trisulca	Forked duckweed	6	X

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

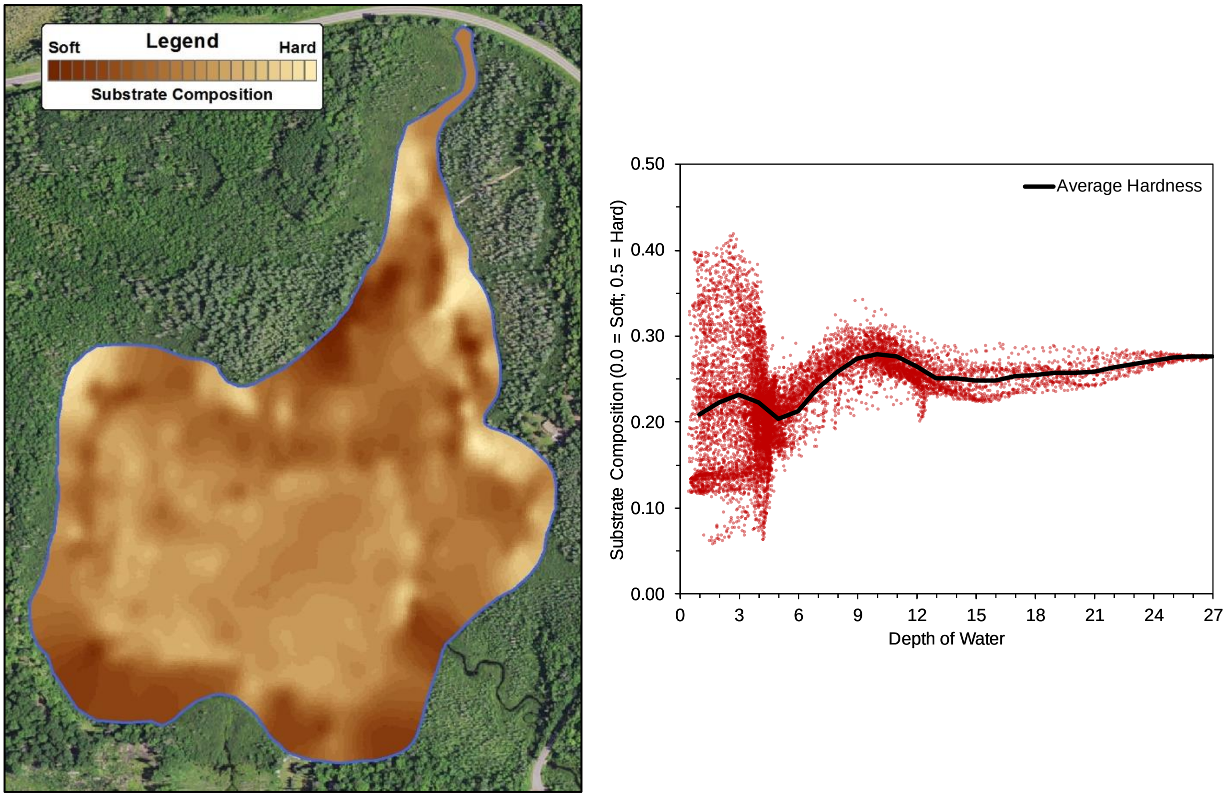


Figure 8.4.4-2. Tamarack Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Individual data points are displayed in red. Creating using data from August 2016 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 8.4.4-3 and Tamarack Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2016 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 10 feet. However, the majority of aquatic plant growth occurs within 2.0-6.0 feet of water. The 2016 acoustic survey indicated approximately 75% of Tamarack Lake's area contains aquatic vegetation, while the remaining 25% of the lake is too deep and light-limited to support aquatic plant growth.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. As mentioned, aquatic plants were recorded growing to a maximum depth of 10 feet in 2016. Of the 145 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 89% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 15% of the 145 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 21% had a TRF rating of 2, and 53% had a TRF rating of 3 (Figure 8.4.4-5). These data indicate that aquatic plant density in Tamarack Lake is high throughout most areas where plants occur.

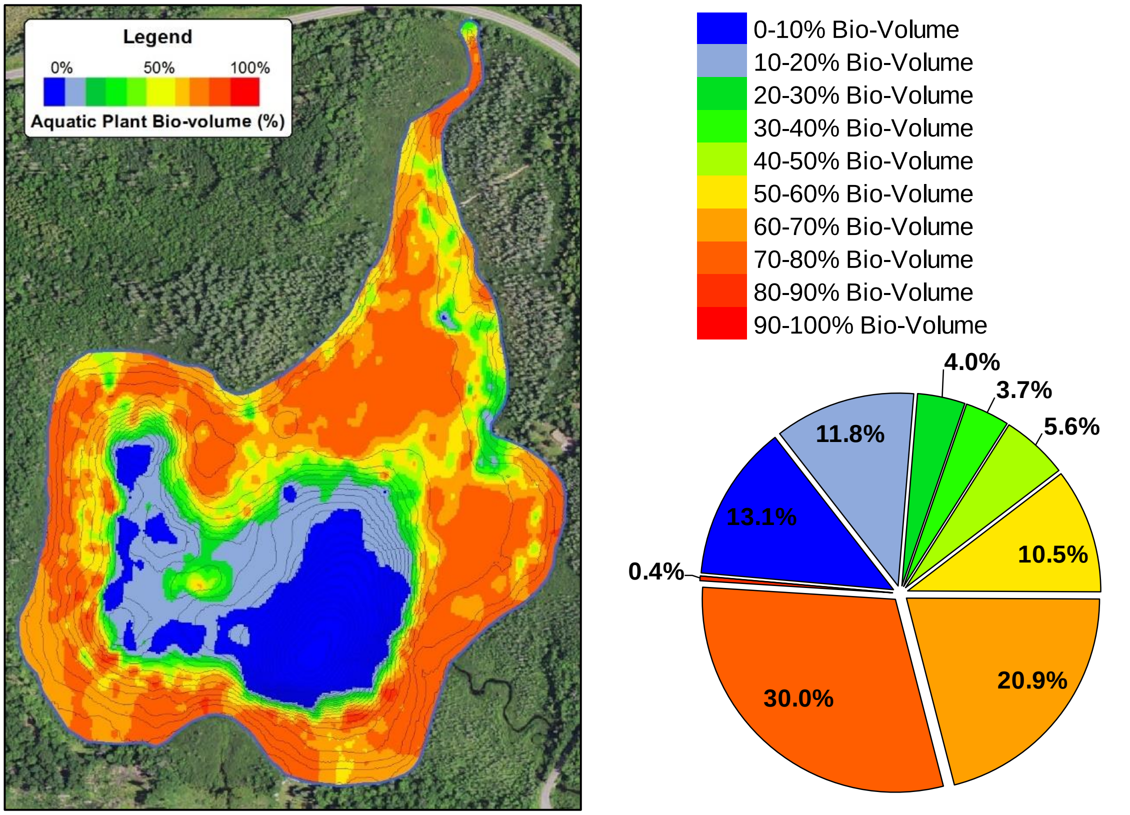


Figure 8.4.4-4. Tamarack Lake 2016 aquatic plant bio-volume. Created using data from August 2016 acoustic survey data. Contour lines represent one-foot increments.

Of the 32 aquatic plant species located in Tamarack Lake in 2016, 22 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.4.4-6). The remaining 10 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 22 species directly sampled with the rake during the point-intercept survey, fern-leaf pondweed, white water lily, and common bladderwort were the three-most frequently encountered aquatic plant species (Figure 8.4.4-6).

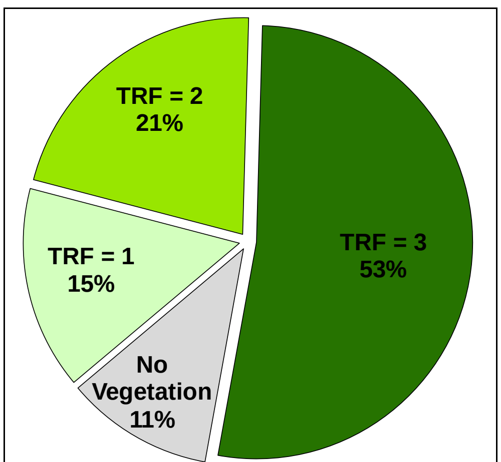


Figure 8.4.4-5. Tamarack Lake 2016 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2016 whole-lake point-intercept survey (N = 145).

Fern-leaf pondweed was the most frequently encountered aquatic plant species in Tamarack Lake in 2016 with a littoral frequency of occurrence of 67% (Figure 8.4.4-6). Fern-leaf pondweed is a common plant in softwater lakes in northern Wisconsin, and is often one of the most abundant. It can be found in shallow to deep water typically over soft sediments. Large beds of fern-leaf pondweed provide excellent structural habitat for aquatic wildlife and help to prevent the suspension of the soft bottom sediments in which they grow. In Tamarack Lake, fern-leaf pondweed was most abundant between 4.0 and 8.0 feet of water.

White water lily was the second-most frequently encountered aquatic plant species in Tamarack Lake during the 2016 point-intercept survey with a littoral frequency of occurrence of 19% (Figure 8.4.4-6). White water lily is a common water lily species that can be found in quiet waters of lakes and rivers throughout Wisconsin. This plant possesses a rhizome which is buried in the sediment and produces large circular leaves which float on the surface. Large, showy, and fragrant white flowers are produced which open in the morning and close by afternoon. In Tamarack Lake, a ring of white water lily around the lake in 2.0-4.0 feet of water was observed (Photo 8.4.4-1 and Map 7). Like other aquatic plants, white water lily provides valuable structural habitat and reduces sediment resuspension and shoreland erosion.

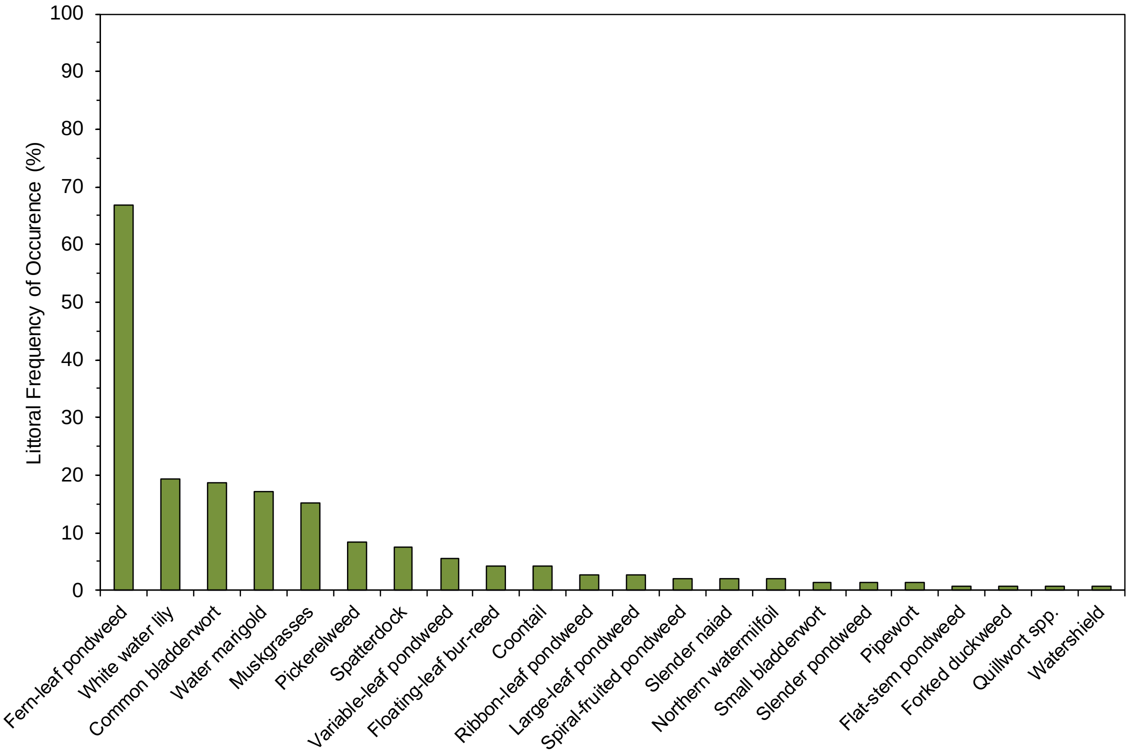


Figure 8.4.4-6. Tamarack Lake 2016 littoral frequency of occurrence of aquatic plant species. Created using data from 2016 whole-lake point-intercept survey.

Common bladderwort was the third-most frequently encountered aquatic plant species in Tamarack Lake during the 2016 point-intercept survey with a littoral frequency of occurrence of 19% (Figure 8.4.4-6). Common bladderwort is one of seven species of bladderwort that occur in Wisconsin and one of two species located in Tamarack Lake. Bladderworts are a genus of carnivorous plants which produce bladder-like traps that are used to capture aquatic invertebrates. Common bladderwort is the most prevalent species in Wisconsin and can be found across a wider range of water quality within areas of quiet water. In summer, common bladderwort produces yellow snapdragon-like flowers on stalks held above the water's surface (Photo 8.4.4-1). In Tamarack Lake, common bladderwort was most abundant between 4.0 and 8.0 feet of water.

Photo 8.4.4-1. Large white water lily (*Nymphaea odorata*) community in Tamarack Lake (left) and flowers of common bladderwort (*Utricularia vulgaris*) from Rainbow Lake (right). Photo credit Onterra, 2016.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.4.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.4.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum* sibiricum) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Tamarack Lake Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.


Photo 8.4.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2016 point-intercept survey on Tamarack Lake and their conservatism values were used to calculate the FQI of Tamarack Lake's aquatic plant community (equation shown below).

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Figure 8.4.4-7 compares the 2016 FQI components of Tamarack Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2016 (22) falls above the median species richness values for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The average conservatism of the 22 native aquatic plant species located in Tamarack Lake in 2016 was 7.3, exceeding the median average conservatism values for lakes within the NLFL ecoregion (6.7) and lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of Tamarack Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

Using Tamarack Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 34.1 (Figure 3.3-4-7). Tamarack Lake's FQI value exceeds the median value for lakes within the NLFL ecoregion (30.8) and the median value for lakes throughout Wisconsin (27.2). Overall, the FQI analysis indicates that the aquatic plant community found in Tamarack Lake is of higher quality than the majority of lakes within the NLFL ecoregion and lakes throughout the state.

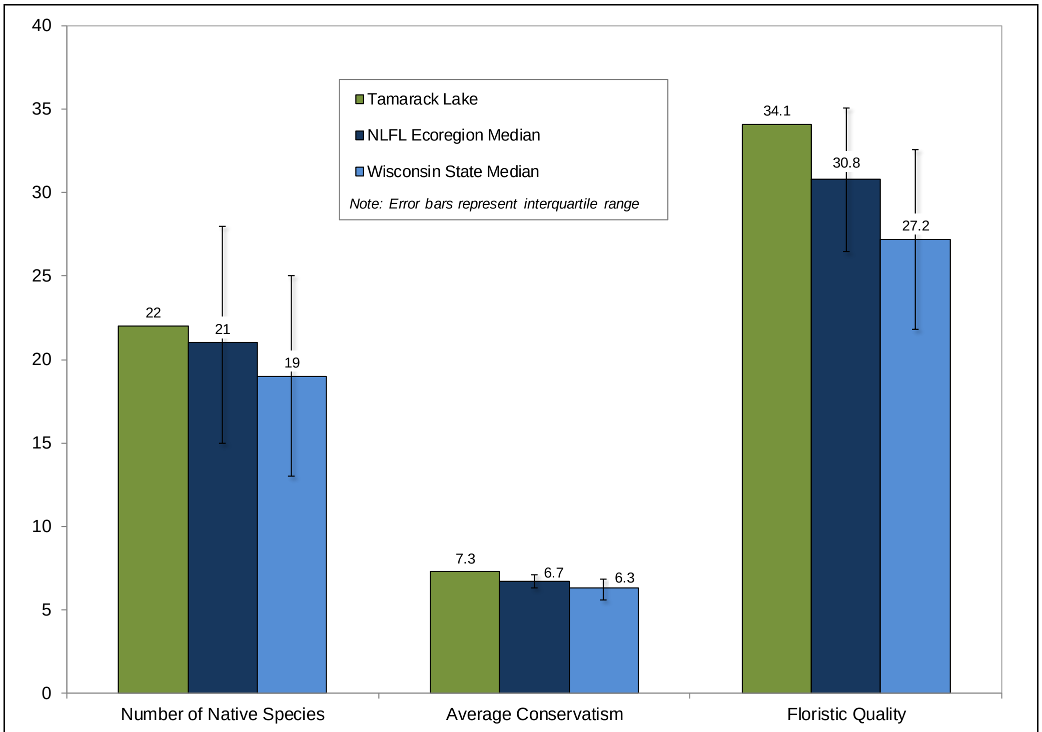


Figure 8.4.4-7. Tamarack Lake Floristic Quality Assessment. Created using data from Onterra 2016 whole-lake point-intercept survey. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Tamarack Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Tamarack Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.4.4-8). Using the data collected from the 2016 point-intercept survey, Tamarack Lake's aquatic plant was found to have low species diversity with a Simpson's Diversity Index value of 0.83. In other words, if two individual aquatic plants were randomly sampled from Tamarack Lake in 2016, there would be an 83% probability that they would be different species. Tamarack Lake's Simpson's Diversity value falls near the lower quartile for lakes in the NLFL ecoregion and below the median for lakes throughout Wisconsin.

One way to visualize Tamarack Lake's lower species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.4.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey. While Tamarack Lake contains a higher number of species, approximately 73% of the plant community is comprised of five species. The remaining 17 species occur in relatively low abundance. Explained another way, if 100 plants were randomly sampled from Tamarack Lake, 36 would be fern-leaf pondweed, 10 would be white water lily, etc. The uneven distribution of aquatic plant species within the community and dominance by a small number of species yields lower species diversity. However, the low species diversity of Tamarack Lake's aquatic plant community is not an indication of degraded conditions. Rather, the combination of the lake's primarily soft substrates in the littoral areas and low-light conditions reduce the number of habitat types available. Fern-leaf pondweed competes against other species well under these conditions which leads to a dominance of this plant within the community.

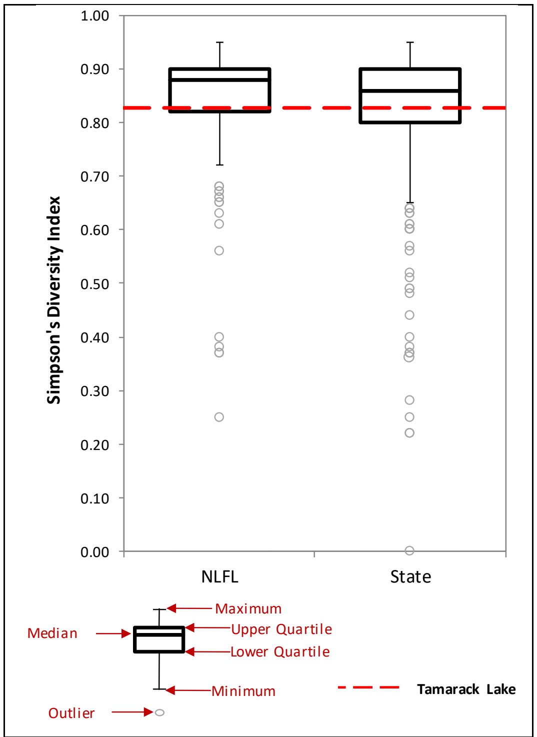


Figure 8.4.4-8. Tamarack Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

In 2016, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Tamarack Lake. This survey revealed Tamarack Lake contains approximately 20 acres of these communities comprised of 10 different aquatic plant species (Tamarack Lake – Map 7 and Table 8.4.4-2). The majority of these communities are comprised of pickerelweed and white water lily. These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Tamarack Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

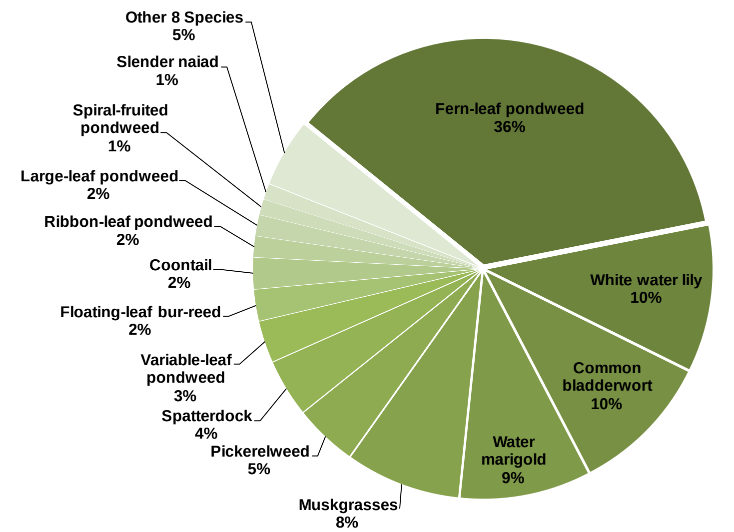


Figure 8.4.4-9. Tamarack Lake 2016 relative frequency of occurrence of aquatic plant species. Created using data from 2016 point-intercept survey.

Table 8.4.4-2. Tamarack Lake 2016 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2016 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	7.8
Floating-leaf	12.3
Mixed Emergent & Floating-leaf	0.0
Total	**20.0**

8.4.5 Aquatic Invasive Species in Tamarack Lake

As of 2016, no aquatic invasive species have been confirmed in Tamarack Lake. However, the non-native Chinese (*Cipanogopaludina chinensis*) and banded (*Viviparus georgianus*) mystery snails and rusty crayfish (*Orconectes rusticus*) have been documented in upstream Birch Lake and it is possible that these species are present in Tamarack Lake. 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).

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact. While it is possible these species are present in Tamarack Lake, their presence has not been officially verified.

8.4.6 Tamarack Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery as those aspects are currently being conducted by the fisheries biologists overseeing the lake. The goal of this section is to provide an overview 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 2017) and personal communications with DNR Fisheries Biologists Steve Gilbert and Hadley Boehm.

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 Birch Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton which are tiny crustaceans that feed upon phytoplankton. 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 piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.4.6-1.

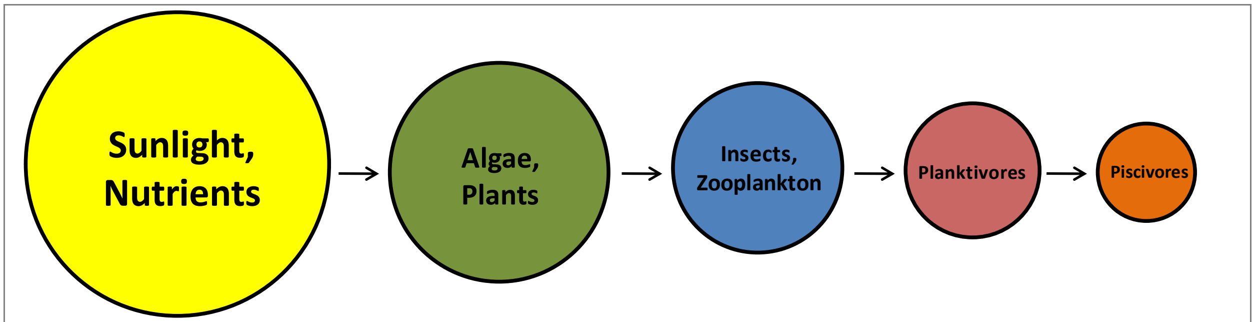


Figure 8.4.6-1 Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Tamarack Lake is a meso-eutrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means Tamarack Lake should be able to support an appropriately sized population of predatory fish (piscovores) when compared to eutrophic or oligotrophic systems. Table 8.4.6-1 shows the popular game fish present in Tamarack Lake.

Table 8.4.6-1. Gamefish present in Tamarack Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
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
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Panfish (*Lepomis*)	11	May - August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other 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 common passive trap used is a fyke net (Photo 8.4.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and 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 and sort the captured fish.

The other commonly used sampling method is electroshocking (Photo 8.4.6-1). 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, *galvanotaxis* stimulates their nervous system and involuntarily causes them to swim toward the electrodes. When the fish are in the vicinity of the electrodes, they undergo *narcosis* (stunned), making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell, fish generally recover within minutes.

Once fish are captured using the appropriate method, data such as count, species, length, weight, sex, tag number, and aging structures may be recorded and the fish released. Fisheries biologists use this data to make recommendations and informed decisions on managing the future of the fishery.


Photo 8.4.6-1. Fyke net positioned in the littoral zone of a Wisconsin lake (right) and an electroshocking boat (left).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photo 8.4.6-2). Stocking of 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. Historical stocking efforts for Tamarack Lake have included muskellunge and are displayed in Table 8.4.6-2.

Photo 8.4.6-2. Fingerling Muskellunge.

Table 8.4.6-2. WDNR stocking data of fish species available for Tamarack Lake (1972-1990).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Muskellunge	Fingerling	100	13.0
1973	Muskellunge	Fingerling	200	13.0
1988	Muskellunge	Fingerling	300	9.0
1990	Muskellunge	Fingerling	300	11.5

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fish biologists can estimate populations and determine trends of captured fish species. The data collected and calculated is then used by fish biologists to determine the best management plan for the lake or chain. One method that is used involves calculating abundance and size structure of the fish populations and comparing to area lakes with the same species.

Tamarack Lake Fish Habitat

Substrate Composition

Just as forest wildlife requires 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 2016, 97% of the substrate sampled in the littoral zone of Tamarack Lake was soft sediments, 2% was rock with the remaining 1% composed of sand substrate.

Coarse Woody Habitat & Fish Sticks Program

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 2006).

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. 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. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 survey documented 18 pieces of coarse woody along the shores of the Tamarack Lake, resulting in a ratio of approximately 11 pieces per mile of shoreline.

Regulations and Management

Current (2016-2017) regulations for Tamarack Lake gamefish species are displayed in Table 8.4.6-3. 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 8.4.6-3. WDNR fishing regulations for Tamarack Lake (2016-2017).

Species	Season	Regulation
Panfish	Open All Year	None, Daily bag limit 25
Largemouth bass and smallmouth bass	June 18, 2016 to March 5, 2017	14", Daily bag limit 5
Northern pike	May 7, 2016 to March 5, 2017	None, Daily bag limit 5
Walleye, sauger, and hybrids	May 7, 2016 to March 5, 2017	Only 1 fish over 14", Daily bag limit 3
Bullheads	Open All Year	None, Unlimited
Rough fish	Open All Year	None, Unlimited

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 8.4.6-2. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

Figure 8.4.6-2. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

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

Tamarack Lake Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.4.6-3). The Town of Winchester falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process.

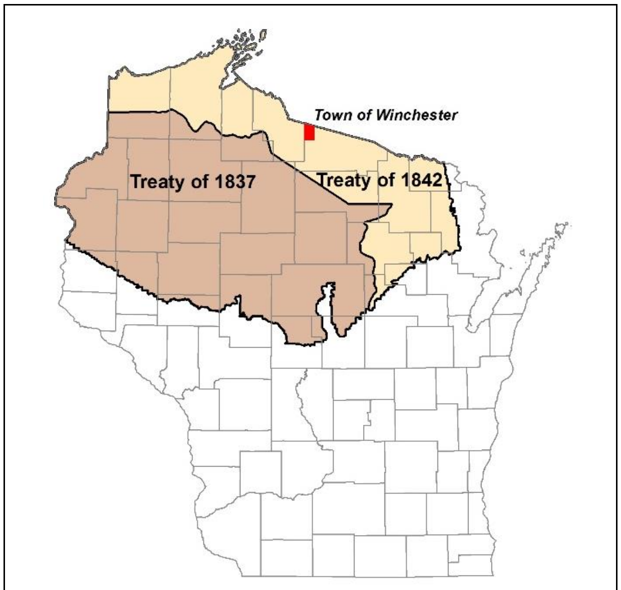


Figure 8.4.6-3. Location of the Town of Winchester within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a *total allowable catch* is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by three or more years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the *safe harvest level*.

Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the *declaration*, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to 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 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake. While within the ceded territory, Tamarack Lake has not experienced a spearfishing harvest.

8.4.7 Tamarack Lake Implementation Plan

The Implementation Plan presented in this section was created through the collaborative efforts of the Birch Lake Association (BLA) and Tamarack Lake riparians Planning Committee, Onterra ecologists, North Lakeland Discovery Center (NLDC), and WDNR staff. It represents the path the BLA and Tamarack Lake riparians will follow in order to meet their lake management goals. Tamarack Lake has few riparian property owners and the BLA has included Tamarack Lake in their meetings, activities, and educational outreach. For this reason, the following Implementation Plan includes management goals and associated actions that both of these lakes will implement. This same Implementation Plan can also be found in the Birch Lake Individual Lake Report (Section 8.3).

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 Birch and Tamarack lake stakeholders as portrayed by the members of the Planning Committees and the numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

Management Action:	Continue monitoring of Birch and Tamarack lakes' water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Glen Wildenberg (current Birch Lake CLMN volunteer) and Martin Plutowski (current Tamarack Lake CLMN volunteer)
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. As discussed in the water quality sections, Birch and Tamarack lakes' water quality is good to excellent in all parameters measured. Continued monitoring will allow for early detection of potential negative trends and may lead to the reason as to why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the BLA have been measuring Secchi disk transparency in Birch Lake annually since 1997 and have been collecting samples for total phosphorus and chlorophyll-*a* annually since 2000. Volunteers from Tamarack Lake have been measuring Secchi disk transparency annually since 2016. Funding for advanced water quality monitoring (addition of total phosphorus and chlorophyll-*a*) has been increasing difficult to acquire, and it was suggested at the planning meetings that the Town of Winchester Lakes Committee may be able to provide funding for the collection of total

phosphorus and chlorophyll-*a* for the town's lakes in the future. Martin Plutowski (or the current Tamarack Lake volunteer) should work with the Town Lakes Committee to determine if funding would be available to conduct total phosphorus and chlorophyll-*a* monitoring on Tamarack Lake in addition to Secchi disk transparency in the future. Emily Heald, the current Water Program Coordinator at the NLDC, has indicated that the NLDC may be able to provide the water quality monitoring volunteers with a Secchi disk and temperature/dissolved oxygen probe for their use. Nearby Trout Lake Research Station may also lend water quality equipment to water quality monitoring volunteers.

The BLA and Tamarack Lake stakeholders realize the importance of continuing this monitoring effort which will supply them with valuable data about their lake. When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Glen Wildenberg and Martin Plutowski appoint/recruit new volunteer(s) as needed. If water quality equipment cannot be provided by WDNR, contact Emily Heald (715.543.2085) at the NLDC to inquire if the NLDC is able to lend equipment.
2. New volunteer(s) contact Sandy Wickman (715.365.8951) as needed.
3. Volunteer(s) reports results to WDNR SWIMS database.

Management Action: Continue monitoring Birch and Tamarack lakes' water levels through NLDC citizen science lake level monitoring program.

Timeframe: Continuation of current effort

Facilitator: Birch Lake: Joe and Dorla Osfar; Tamarack Lake: Martin Plutowski and available/interested Tamarack Lake stakeholders

Description: The NLDC currently administers a citizen-based lake level monitoring program where lake levels are monitored on area lakes. Seasonal and longer-term water level fluctuations are natural in Wisconsin's lakes and are often beneficial for lake health. Continued monitoring of lake levels provides for an understanding of what conditions lead to changes in water levels. Following ice-out in the spring, staff gauges are installed on Birch and Tamarack lakes and referenced to a fixed benchmark. Each week during the open-water season, volunteers record the current lake level. The staff gauges are removed in the fall and water level records are provided to NLDC staff. These lake level data are submitted to the WDNR's Surface Water Integrated

Monitoring System (SWIMS). The collection of lake level monitoring data must be a long-term, multiyear effort to accurately and precisely discern inter- and intra-annual patterns in water level fluctuations.

Action Steps:

1. Current BLA and Tamarack Lake volunteers record water level on staff gauges weekly during the open-water season.
2. Volunteers report water level data to NLDC at the end of each open-water season.
3. NLDC records water level data in WDNR SWIMS database.
4. Joe and Dorla Osfar and Martin Plutowski recruit new volunteers as needed or notify BLA if new water level monitors are needed.

<u>Management Action:</u> Preserve natural and restore highly developed shoreland areas on Birch and Tamarack lakes to improve habitat, reduce erosion, and protect water quality.

Timeframe: Initiate 2018

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: The 2016 Shoreland Condition Assessment found that approximately 70% (4.5 miles) of Birch Lake's immediate shoreland zone contains little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 16% (1.0 miles) contains a higher degree of development categorized as *developed-unnatural* or *urbanized*. On Tamarack Lake, approximately 93% (1.5 miles) of the lake's shoreland was delineated as *natural/undeveloped* while approximately 3% (0.05 miles) was delineated as *developed-unnatural* or *urbanized*. It is important that the owners of properties with little development become educated on the benefits their shoreland is providing to these lakes in terms of maintaining their water quality and habitat, and that these shorelands remain in a natural or semi-natural state. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to these lakes in terms of water quality and contribution to habitat loss.

The BLA board of directors will work with appropriate entities such as the NLDC and Vilas County Land and Water Department to research grant programs and other pertinent information that will aid the BLA and Tamarack Lake riparians in preserving and restoring the shoreland areas of these lakes. The NLDC has several restoration/rain/lakeshore/erosion gardens that can serve as examples and educational pieces for Birch and Tamarack Lake riparians to gather ideas for their properties. In addition, the NLDC can also help riparian property owners with planting ideas. 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. The BLA should contact Catherine Higley (cahigl@co.vilas.wi.us – 715.479.3738), Vilas County's Invasive Species Coordinator, to gather information on how to protect and restore areas of Birch Lake's shoreland.

Action Steps:

1. BLA Board of Directors gathers appropriate information from entities listed above.
2. The BLA provides Birch and Tamarack lake property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural land cover within Birch and Tamarack lakes' watershed beyond the immediate shoreland zone.

Timeframe: Initiate in 2018

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: As is discussed within the Watershed Section (8.3.2), changes in land use beyond the shoreland zone within a lake's watershed can impact water quality. Currently, Birch and Tamarack lakes' watershed is mainly comprised of natural land cover types, forests and wetlands. These natural land cover types export minimal amounts of phosphorus, retain soil, and maintain the good water quality found in these lakes. The BLA and Tamarack Lake stakeholders recognize the importance of maintaining natural land cover within the watershed of these lakes to maintain their water quality for future generations.

As discussed in the previous management action, one way the BLA and Tamarack Lake stakeholders can preserve land within the watershed is through the purchase of land and placement within a land trust. A number of land owners within the watershed have already put their land in a trust. The BLA can also reach out to land owners of property within these lakes' watersheds and provide them with information on the BLA's mission and why preserving their land in a more natural state is beneficial for water quality. In addition, because Birch, Tamarack, and Rainbow lakes share the same watershed, the BLA and Rainbow Lake Association may choose to work together to reach out to property owners throughout the entire watershed of these three lakes to provide them with information on how their land management can lead to the preservation of Birch, Tamarack, and Rainbow lakes.

As of 2017, approximately 40% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by The Forestland Group's Heartwood Forestland Partnership (Birch Lake – Map 8). This land is managed for sustainable logging and is overseen by regional teams working with local forestry consulting firms. The Forestland Group forest management is based on natural regeneration as opposed to planted silvicultural systems, and they were one of three recipients of a Corporate Sustainable Standard Setter Award by the Rainforest Alliance for leadership in the movement toward sustainable certification (TFG website: http://www.forestlandgroup.com/conservation/). The land within the Birch-Tamarack-Rainbow lake watershed is part of the Great Lakes Region Chippewa East Property. Shawn Hagan is the Senior Director for Forestland Operations (906.487.7491) of the Great Lakes Region for The Forestland Group, and the BLA can contact Shawn for more information on how this property within the watershed is managed.

Approximately 3% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by the Wisconsin Department of Natural Resources, while the remaining 57% is comprised of privately-owned parcels. In an effort to preserve natural land cover on these properties, the BLA can include information on the benefits of maintaining these properties in a natural state along with information on the benefits of maintaining a natural shoreline as discussed in the previous management action.

A valuable resource for land owners interested in putting their property in a trust in northern Wisconsin is the Northwoods Land Trust. For other available options, land owners should contact the Vilas County Land and Water Conservation Department. The websites for these groups can be found below:

- The Northwoods Land Trust Website: (www.northwoodslandtrust.org)
- Vilas County Land and Water Conservation Department Website: (http://www.vilasconservation.com/who_we_are.html)

Action Steps:

1. See description above.

Management Goal 2: Increase Navigation Safety on Birch and Tamarack Lakes

Management Action: Consider the placement of waterway markers (non-regulatory danger buoys) to indicate areas in Birch and Tamarack lakes that are hazardous to vessel operation.

Timeframe: Initiate 2018

Facilitator: Birch Lake: BLA Board of Directors; Tamarack Lake: available/interested Tamarack Lake stakeholders

Description: Birch and Tamarack lakes are visited by a number of lake users that recreate on the lake in different ways. Like many lakes, both of these lakes contain some areas that present navigation hazards to lake users. While it is the responsibility of lake users to familiarize themselves with the waterbody and employ safe boating practices, the Birch and Tamarack lake stakeholders would like to deploy non-regulatory danger markers in areas of these lakes that present navigation hazards. Non-regulatory markers are used to mark navigational channels, hazards, and other dangerous areas or to provide general information to the boating public (WDNR PUB-LE-317-2016).

In Birch Lake, these markers would serve to warn lake users of the shallow water and/or rocks present in the area. The acoustic survey conducted in Birch Lake in 2016 identified three areas out from shore which were shallow (< 4 feet in depth) and may present navigation hazards to lake users (Birch Lake – Map 9). Marking these areas will likely also reduce direct impacts (i.e. bottom scarring) from motorboats to valuable native aquatic plant and benthic communities in these areas. Site 1 is a shallow rock bar in the southwest area of the lake approximately 1.0 acre in size. It is proposed that four non-regulatory danger markers be placed around the perimeter of this rock bar as illustrated on Birch Lake – Map 9. Site 2 and 3 are small areas of shallow water of approximately 0.05 acres in size each. It is proposed that a single non-regulatory danger buoy be placed in the center of each of these shallow areas.

Currently, the BLA places three markers in the southwest area of the lake near the small island to indicate the slow, no wake area. Given that these three markers are close to shore, they are readily installed and taken out each year using a small row boat by BLA volunteers. The proposal for adding an additional six markers within the offshore areas previously discussed will make it more logistically challenging for the BLA to get these markers installed and taken out annually. This management action is currently considered as a proposal for marking hazardous areas in Birch Lake, and prior to seeking a permit for these markers the BLA will need to have continued discussions regarding how many additional markers they would like placed in the lake, their location placement, and who and how these markers will be taken in and out of the lake annually.

In Tamarack Lake, one non-regulatory danger marker would be used to identify an area where large rocks are present near the surface and pose hazards to watercraft. It is proposed that one marker be placed at this location to notify lake users of the rocks in these areas (Tamarack Lake – Map 8). As with Birch Lake, Tamarack Lake stakeholders will need to discuss this further to determine sources of funding for the purchase of a marker and who will be responsible for taking this marker in and out of the lake annually.

These non-regulatory danger buoys would be placed in the lakes in spring following ice-out and removed in the fall prior to ice-on. If the BLA and/or Tamarack Lake stakeholder elect to move forward with placing these non-regulatory danger markers in their respective lakes, the initial installation of these markers involves the following requirements as listed in WDNR PUB-LE-317-2016 (http://dnr.wi.gov/files/PDF/pubs/le/LE0317.pdf):

- A WDNR Waterway Marker Application and Permit (Form 8700-58) must be completed.
- The "danger" buoy will be white with an orange diamond. Any information (e.g. "rock") will be printed on this buoy in black. It must by cylindrical in shape, a minimum of 36 inches above the waterline, with a minimum diameter of 7 inches.
- The buoys must be placed by individuals with authorization from the governing entity having jurisdiction over the waters involved.
- The permit must be accompanied by a map or diagram showing the proposed location of the markers (Birch Lake – Map 9 and Tamarack Lake – Map 8). Exact locations must be expressed in GPS coordinates or in specific feet distance from one or more fixed objects whose location is easily identifiable.
- Completed applications and information material should be sent to the WDNR Regional Recreational Safety Warden for Vilas County (Jeremy Cords – contact information below).

Action Steps:

1. The BLA and Tamarack Lake stakeholders have ongoing discussions regarding the addition of non-regulatory waterway markers in their respective lakes as discussed above.
2. If the BLA and/or Tamarack Lake holders elect to move forward with the addition of non-regulatory danger markers in their respective lakes, they would submit WDNR Waterway Marker Application and Permit (Form 8700-58) separately accompanied by Birch Lake – Map 9 and Tamarack Lake – Map 8 to Jeremy Cords (Jeremy.Cords@wi.gov;

920.366.1917), the WDNR Regional Recreational Safety Warden for Vilas County.

3. Following permit approval by the WDNR, the BLA and/or Tamarack Lake stakeholders would purchase non-regulatory danger markers that meet size, shape, and color regulations described for non-regulatory danger markers in WDNR PUB-LE-317-2016 (http://dnr.wi.gov/files/PDF/pubs/le/LE0317.pdf).
4. Individuals with proper authorization will place the markers in the lake following ice-out and will remove the markers prior to ice-on annually.

Management Action: Install signage at Birch and Tamarack lakes' public access location to inform lake users of watercraft regulations on these lakes.

Timeframe: Initiate in 2018

Facilitator: Birch Lake: BLA Board of Directors; Tamarack Lake: interested/available stakeholders

Description: As is discussed in the study results sections, of the 129 stakeholder surveys distributed to Birch Lake riparian property owners in 2016, 50 (39%) were completed. Given the lower response rate, the results of the survey cannot be interpreted as being statistically representative of the population sampled, and at best, the results may indicate possible trends and opinions about the stakeholder perceptions of Birch Lake. However, nearly 50% of respondents indicated that watercraft traffic is currently having a moderate to great negative impact on Birch Lake (Appendix B, Question 2). During the planning meetings, members of the Birch and Tamarack lakes Planning Committees expressed concern about motorboats and personal watercraft operating above slow, no wake speed within the designated setback from the shoreline (100 feet for boats and 200 feet for personal watercraft). The Planning Committee is concerned not only about recreational safety but about the impact to shoreland areas from watercraft operating above slow, no wake too close to shore.

In addition to informing Birch and Tamarack lake riparians on Wisconsin's watercraft regulations and responsible boating practices through their newsletter, a recommendation that no skiing/wakeboarding occur after 7:00 pm, the BLA and Tamarack Lake stakeholders will install signage at the public access point for each lake to provide lake users with a visual representation of the 100- and 200-foot slow, no wake setbacks in an effort to improve recreational safety on these lakes and reduce shoreline erosion/impacts to shoreline habitat. The access point for Tamarack Lake is a carry-in access location on Hwy W that is owned by the Town of Winchester. Members on the Tamarack Lake Planning Committee indicate that they will need to hold additional discussions with Tamarack Lake stakeholders to decide if they would like this type of signage at the carry-in access location.

Onterra will provide the BLA and Tamarack Lake stakeholders with a map similar to Birch Lake – Map 10 and Tamarack Lake – Map 9 displaying these setback areas. The BLA and Tamarack Lake stakeholders will need to provide this map to a sign/graphic design company to create a durable sign for outdoor use at the public access points. In addition, the BLA and Tamarack Lake stakeholders will likely also need to obtain the necessary permission from the Town of Winchester to install new signage at these public access locations.

Action Steps:

1. Onterra provides BLA and Tamarack Lake stakeholders with watercraft regulation maps.
2. Birch Lake and Tamarack Lake stakeholders work with sign/graphic design company to create sign for the public boat landing.
3. BLA and Tamarack Lake stakeholders obtain necessary permission from the Town of Winchester to install sign at the Birch Lake public boat landing.

Management Goal 3: Assure and Enhance the Communication and Outreach of the Birch Lake Association with Birch and Tamarack Lake Stakeholders

Management Action: Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Birch and Tamarack lakes.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The BLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

Currently, the BLA publishes four newsletter issues per year – a hard copy issue once per year which is distributed to all Birch Lake riparian property owners and three electronic issues which are sent to Birch Lake Association members. These newsletters provide members and non-members with association-related information including current projects and updates, meeting times, and educational topics. In addition, the BLA also maintains a website, the Birch/Tamarack Lake Blog (http://birchlake.blogspot.com/), where lake users can find information on Birch and Tamarack lake, meeting times, information on the Town of Winchester lakes, along with a host of lake-related links. During the planning meetings with the Phase II lakes' planning committees, it was suggested that the Rainbow Lake Association (RLA) be included to the Birch/Tamarack lakes blog website after gaining a better understanding on the connectivity between these three lakes. The inclusion of the RLA in the Birch/Tamarack blog will facilitate increased communication between these groups and improve conservation efforts for these three connected lakes.

Eighty-eight percent of Birch Lake stakeholder survey respondents indicated that the BLA keeps them either fairly well informed or highly informed regarding issues with Birch Lake and its management. The BLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Birch Lake and its preservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newsletter, distributed as separate educational materials, or posted on the association's website. The BLA has historically invited lake-related speakers to discuss lake topics at the annual Birch/Tamarack annual meeting on Labor Day weekend and they intend to continue to do so in the future in an effort to educate their membership on responsible lake stewardship. The BLA should also reach out to professionals from the NLDC, WDNR, Vilas County Lakes and Rivers Association, etc. to obtain educational pieces for their newsletter.

Example Educational Topics

- Shoreline restoration and protection
- Effect lawn fertilizers/herbicides have on the lake
- Importance of maintaining course woody habitat
- Fishing rules and regulations
- Tribal spear harvests
- Catch-and-release fishing
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention
- Water quality monitoring updates from Birch and Tamarack lake
- Septic system maintenance
- Water levels
- Littering on the ice and year-round

In addition to publishing a quarterly newsletter, the BLA will also create a mailing to riparian property owners that includes a summary of the 2016 study results along with information on the BLA's role in the management of Birch Lake and the benefits of being a member.

Every other year, the BLA updates and publishes their membership directory. The BLA will also be updating information on their introductory brochure that has been created for distribution to new association members.

Birch Lake Planning Committee members also expressed concern about the need to educate short-term renters on Birch Lake on responsible lake stewardship and watercraft use as these short-term users of the lake often have little vested interest in the lake beyond recreational activities. If the BLA is able to identify rental properties on Birch Lake, the BLA could reach out to these rental property owners to determine if they would be willing to include some type of BLA-created informational packet to their renters. This packet could include items such as the *Town of Winchester Lake User Guide* which provides information on common sense courtesies and watercraft regulations for lake users as well as steps to prevent AIS introductions. The packet could also include the watercraft regulation map for Birch Lake along with other interesting facts or figures about the lake.

The education of Birch Lake property owners who are not members of the BLA was also an issue brought forward by the Birch Lake Planning Committee. They indicated that while the BLA can readily inform its membership, the association has limited influence with non-members. The Town of Winchester Town Lakes Committee is currently having ongoing discussions regarding contracting the NLDC to conduct educational initiatives and monitoring. The Town Lakes Committee has been highly involved the Winchester Lakes Management Planning Project, and following the completing of this project, the committee will be looking to initiate new, smaller projects to help the Winchester lakes. The Town Lakes Committee can also host speakers at public events and publish newspaper and newsletter articles in an effort to maximize outreach to Winchester lakes' users.

Action Steps:

1. See description above.

Management Goal 4: Prevent New Aquatic Invasive Species Introductions to Birch and Tamarack Lake

Management Action: Continue volunteer aquatic invasive species monitoring using the shoreline monitors.

Timeframe: Continuation of current effort.

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: As of this writing, four non-native, invasive species have been documented in Birch Lake: the rusty crayfish, banded mystery snail, Chinese mystery snail, and aquatic forget-me-not. No non-native species have been documented to date in Tamarack Lake. As is discussed in the Other Aquatic Invasive Species in the Town of Winchester Lakes section (section 3.5), in high numbers rusty crayfish have the capacity to reduce aquatic plant abundance while the non-native snails have been shown to displace native snail species. Data on Birch Lake's non-native crayfish and snail populations are not available, so it is not known to what extent these species may be adversely affecting Birch Lake's ecology. The studies completed in 2016 indicate that Birch Lake's native aquatic plant community is very healthy, and the crayfish population may be having limited impacts on the lake's plants. While aquatic forget-me-not was not documented by Onterra along shoreland areas of Birch Lake in 2016, NLDC staff and several BLA volunteers observed this plant in 2017.

The BLA and Tamarack Lake stakeholders understand that it important to prevent future introductions of non-native species such as Eurasian watermilfoil and curly-leaf pondweed. Nearby waterbodies such as Harris Lake and the Manitowish Chain of Lakes contain populations of curly-leaf pondweed, while Presque Isle Lake contains a population of Eurasian watermilfoil. In lakes without Eurasian watermilfoil and curly-leaf pondweed, early detection of these can often lead to successful control, and in instances with small infestations, possibly even eradication. Currently, Birch and Tamarack lakes volunteers have received aquatic invasive species identification and monitoring training and perform shoreline surveys in which volunteers are responsible for periodically monitoring specific areas of the lake. This methodology allows the entire lake to be monitored for the presence of non-native species. In addition to volunteer monitoring, NLDC staff completes AIS surveys on Birch and Tamarack lakes two times per year.

Action Steps:

1. Birch and Tamarack lakes volunteers updated their identification and monitoring skills by attending training sessions provided by the NLDC (877.543.2085).
2. Trained volunteers recruit and train additional association members.

3. Complete monitoring surveys following protocols.

Management Action: Install aquatic invasive species (AIS) signage at Tamarack/Rainbow lakes public carry-in access location.

Timeframe: Initiate 2018

Facilitator: Interested/available Tamarack Lake stakeholders

Description: Tamarack Lake contains a carry-in public access owned by the Town of Winchester located on the northern side of the lake where County Hwy W crosses Rainbow Creek. At present, this public access location does not contain an AIS awareness sign to inform lake users on AIS prevention. The WDNR is currently offering these signs, posts, and hardware free of charge. Tamarack Lake Planning Committee members indicated they would have to have continued discussion with Tamarack Lake stakeholders to determine if they would like AIS signage posted at this carry-in access point. Tamarack Lake stakeholders should also work with the Rainbow Lake Association (RLA) as Rainbow Lake can also be accessed by this carry-in location. To request an AIS boat landing sign, Tamarack Lake stakeholders and the RLA should contact Tim Campbell (timothy.campbell@wisconsin.gov – 608.26.3531), WDNR AIS Education Specialist, to request a sign for the Tamarack/Rainbow lakes carry-in access.

Action Steps:

1. Please see above description.

Management Action: Initiate aquatic invasive species rapid response plan upon discovery of new infestation.

Timeframe: Initiate upon invasive species discovery.

Facilitator: Birch Lake: BLA Board of Directors (suggested); Tamarack Lake: interested/available stakeholders

Description: In the event that an aquatic invasive species such as Eurasian watermilfoil is located by the trained volunteers in Birch or Tamarack lake, the areas would be marked using GPS and the BLA or Tamarack Lake stakeholders should contact resource managers (NLDC) immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase and the results would be used to develop potential control strategies.

Action Steps:

1. BLA and/or Tamarack Lake stakeholders contact NLDC (877.543.2085) upon discovery of new invasive species in Birch or Tamarack lake.

Management Action: Continue Clean Boats Clean Waters watercraft inspections at Birch Lake's public access location.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors (suggested)

Description: The BLA has been periodically conducting watercraft inspections using volunteers at the public boat landing since 2007 through the Clean Boats Clean Waters (CBCW) program. In-kind time for watercraft inspections at Birch Lake is being provided through the WDNR grants as part of the four-year lake management planning project (2015-2018). However, the BLA would like to continue watercraft inspections beyond 2018. The intent of the boat inspections would not only be to prevent additional exotic species from entering the lake through the public access point, but also to prevent the infestation of other waterways with exotic species that originated in Birch Lake. The goal would be to monitor the during the busiest times (e.g. holiday weekends) in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on our lakes and educating people about how they are the primary vector of their spread.

The BLA would like to continue watercraft inspections using volunteers. Often, it is difficult for lake groups to recruit and maintain a volunteer base to oversee CBCW inspections throughout the summer months. Recruitment outside of the BLA may be necessary in order to have sufficient coverage of the Birch Lake public access. Education efforts outside of the lake community help to not only raise awareness about the threat of AIS, but also potentially recruit new volunteers to participate in activities such as CBCW.

Members of the BLA, as well as other volunteers, will need to be trained on CBCW protocols in order to participate in public boat landing inspections. Fully understanding the importance of CBCW inspections, paid watercraft inspectors may be sought to ensure monitoring occurs at the public boat landing. These paid inspectors may be purchased alone or in conjunction with volunteers through the BLA or in the community.

Action Steps:

1. Members of the BLA periodically attend CBCW training sessions through the WDNR to update their skills to current standards.
2. Training of additional volunteers completed by those previously trained.
3. Begin inspections during high-use weekends.
4. Report results to WDNR and BLA.
5. Promote enlistment and training of new volunteers to keep program fresh.

Management Goal 5: Enhance the fishery of Birch and Tamarack Lakes

Management Action: Continue work with WDNR fisheries managers to enhance the fishery of Birch and Tamarack lakes.

Timeframe: Continuation of current effort

Facilitator: BLA Board of Directors and interested/available Tamarack Lake stakeholders

Description: In the 2016 stakeholder survey, fishing was ranked second behind relaxing/entertaining by respondents when asked to rank their top three activities that are important reasons for owning or renting their property on or near Birch Lake (Appendix B, Question 17). Respondents indicated that walleye, muskellunge, and smallmouth bass were the top three most sought-after fish by anglers in Birch Lake, and 79% of respondents rated the current fishing on Birch Lake as either fair or good (Appendix B, Questions 11 and 12). Approximately 44% of respondents indicated the quality of fishing has gotten somewhat worse since they began fishing on Birch Lake, while 39% indicated the quality of fishing has remained the same (Appendix B, Question 13).

Birch Lake is currently listed as an Area of Special Natural Resource Interest (ASNRI) for harboring naturally reproducing populations of both walleye and muskellunge, while Tamarack Lake has a ASNRI designation for a naturally reproducing muskellunge population. The BLA and Tamarack Lake stakeholders understand that a multitude of factors such as changes in habitat, water levels, and fishing pressure affect fish communities, and the BLA and Tamarack Lake stakeholders would like to take an active role in maintaining a healthy fishery to ensure Birch and Tamarack lakes remain high-quality fishing lakes for future generations.

Both Birch and Tamarack lake are currently overseen by WDNR fisheries biologist Hadley Boehm (715.356.5211). In an effort to remain informed on studies pertaining to fisheries in these lakes, the BLA Board of Directors and interested/available Tamarack Lake stakeholders should contact Hadley at least once per year (perhaps during the winter months when field work is not occurring) for a brief summary of activities. In addition, the BLA can discuss management options for maintaining and enhancing the lakes' fishery, which may include changes in angling regulations and/or habitat enhancements.

Action Steps:

See description above.

Please note that study methods and explanations of analyses for Rainbow Lake can be found within the Town of Winchester Town-wide Management Plan document.

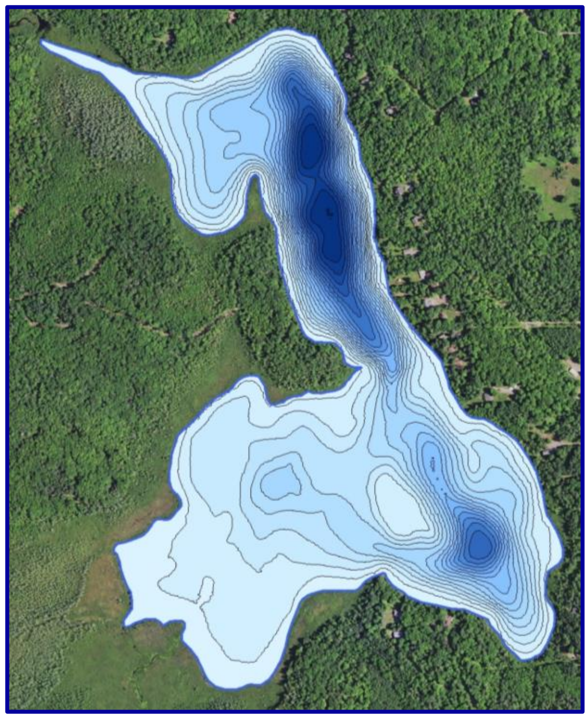
8.5 Rainbow Lake

An Introduction to Rainbow Lake

Rainbow Lake, Vilas County, is a 148-acre deep lowland, brown-water, meso-eutrophic drainage lake with a maximum depth of 39 feet and a mean depth of 9 feet (Rainbow Lake – Map 1). Its surficial watershed encompasses approximately 6,737 acres within the Flambeau River Watershed and is comprised mainly of intact forests and wetlands. Rainbow Lake is fed by upstream Tamarack Lake through Rainbow Creek from the south, and water leaves Rainbow Lake through Rainbow Creek to the north and flows into downstream North Turtle Lake. In 2016, 45 native aquatic plant species were located within the lake, of which fern-leaf pondweed (*Potamogeton robbinsii*) was the most common. Non-native aquatic plant species were not located in Rainbow Lake in 2016, and no other non-native species have been documented within the lake.

Lake at a Glance - Rainbow Lake

Morphology	
LakeType	Deep Lowland Drainage
Surface Area (Acres)	148
Max Depth (feet)	39
Mean Depth (feet)	9
Perimeter (Miles)	3.5
Shoreline Complexity	4.0
Watershed Area (Acres)	6,737
Watershed to Lake Area Ratio	43:1
Water Quality	
Trophic State	Meso-eutrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	24.4
Avg Summer Chl-α (µg/L)	10.3
Avg Summer Secchi Depth (ft)	6.6
Summer pH	7.5
Alkalinity (mg/L as $CaCO_3$)	30.1
Vegetation	
Number of Native Species	45
NHI-Listed Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Species	None
Average Conservatism	7.2
Floristic Quality	40.7
Simpson's Diversity (1-D)	0.93



Descriptions of these parameters can be found within the town-wide portion of themanagement plan

8.5.1 Rainbow Lake Water Quality

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

In 2016, a stakeholder survey was sent to 33 Rainbow Lake riparian property owners. Fourteen (42%) of these 33 surveys were completed and returned. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Rainbow Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B. When asked about Rainbow Lake's current water quality 100% of the respondents indicated the water quality is *excellent* or *good* (Figure 8.5.1-1). When asked how water quality has changed in Rainbow Lake since they first visited the lake, 92% of respondents indicated water quality has *remained the same* and 8% indicated they were *unsure* (Figure 8.5.1-1).

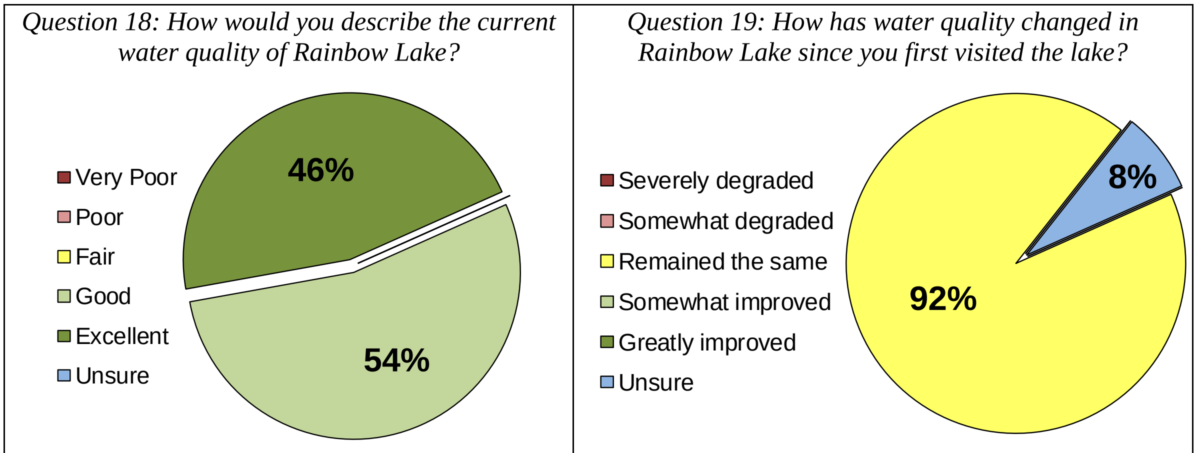


Figure 8.5.1-1. Rainbow Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 14 (42%) respondents of 33 surveys distributed.

The total phosphorus data collected from Rainbow Lake in 2016 represent the first time this parameter has been measured from the lake. The average summer total phosphorus concentration measured in Rainbow Lake in 2016 was 24.4 µg/L which falls into the *good* category for deep lowland drainage lakes in Wisconsin (Figure 8.5.1-2). This average summer total phosphorus concentration is relatively similar to the median concentration for other deep lowland drainage lakes in Wisconsin (23.0 µg/L) and for all lake types within the NLF ecoregion (21.0 µg/L). As is discussed further within the Rainbow Lake Watershed Assessment Section (Section 8.5.2), the total phosphorus concentrations measured in Rainbow Lake align with predicted values generated based upon the lake's watershed size and land cover composition. While a determination of how phosphorus concentrations have changed over time cannot be made given the lack of historical data, given the minimal human development within the watershed it is likely that phosphorus concentrations have not changed significantly in Rainbow Lake since European settlement.

One historical chlorophyll-*a* concentration measurement is available from Rainbow Lake from August of 1984 with a concentration of 6.0 µg/L. In 2016, chlorophyll-*a* concentrations in Rainbow Lake ranged from 0.92 µg/L in late-October to 19.2 µg/L in late-July. The average summer chlorophyll-*a* concentration in 2016 was 11.8 µg/L, falling on the line between *good* and *fair* for Wisconsin's deep lowland drainage lakes (Figure 8.5.1-2). Rainbow Lake's 2016 summer chlorophyll-*a* concentration is higher than the median concentration for other deep lowland drainage lakes in Wisconsin (7.0 µg/L) and the median concentration for all lakes within the NLF ecoregion (5.6 µg/L).

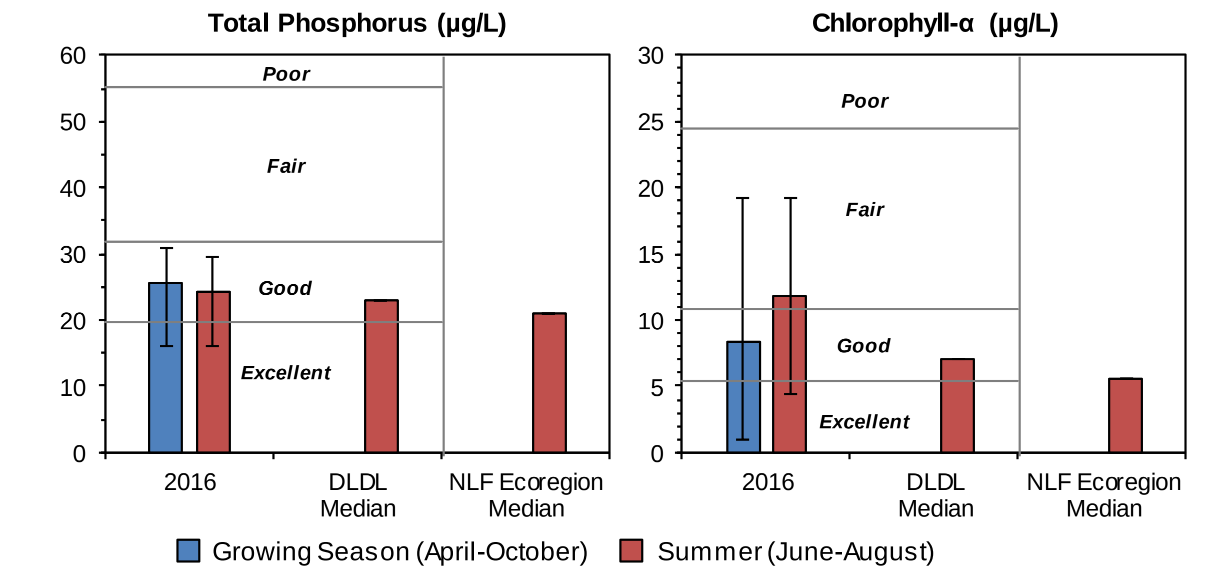


Figure 8.5.1-2. Rainbow Lake 2016 average growing season and summer total phosphorus and chlorophyll-α concentrations compared to median values for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Secchi disk transparency data from Birch Lake are available annually from 2005-2016 with the exception of 2008 (Figure 8.5.1-3). These data indicate that water clarity in Rainbow Lake can be variable from year to year, but the weighted summer average Secchi disk depth is 6.6 feet, falling into the *good* category for Wisconsin's deep lowland drainage lakes. Rainbow Lake's average summer Secchi disk depth falls lightly below the median values for deep lowland drainage lakes in Wisconsin and for all lake types within the NLF ecoregion. Water clarity in Rainbow Lake is lower than expected based upon the low chlorophyll-*a* concentrations, and is an indication that a factor other than phytoplankton is influencing water clarity.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in Rainbow Lake in 2016 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Rainbow Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Rainbow Lake in 2016 averaged 70 SU (standard units), indicating the lake's water is *tea-colored*. The high concentrations of dissolved organic acids in the lake reduce the water's clarity. It is important to note that the tea-colored water in Rainbow Lake is natural, and is not an indication of degraded conditions.

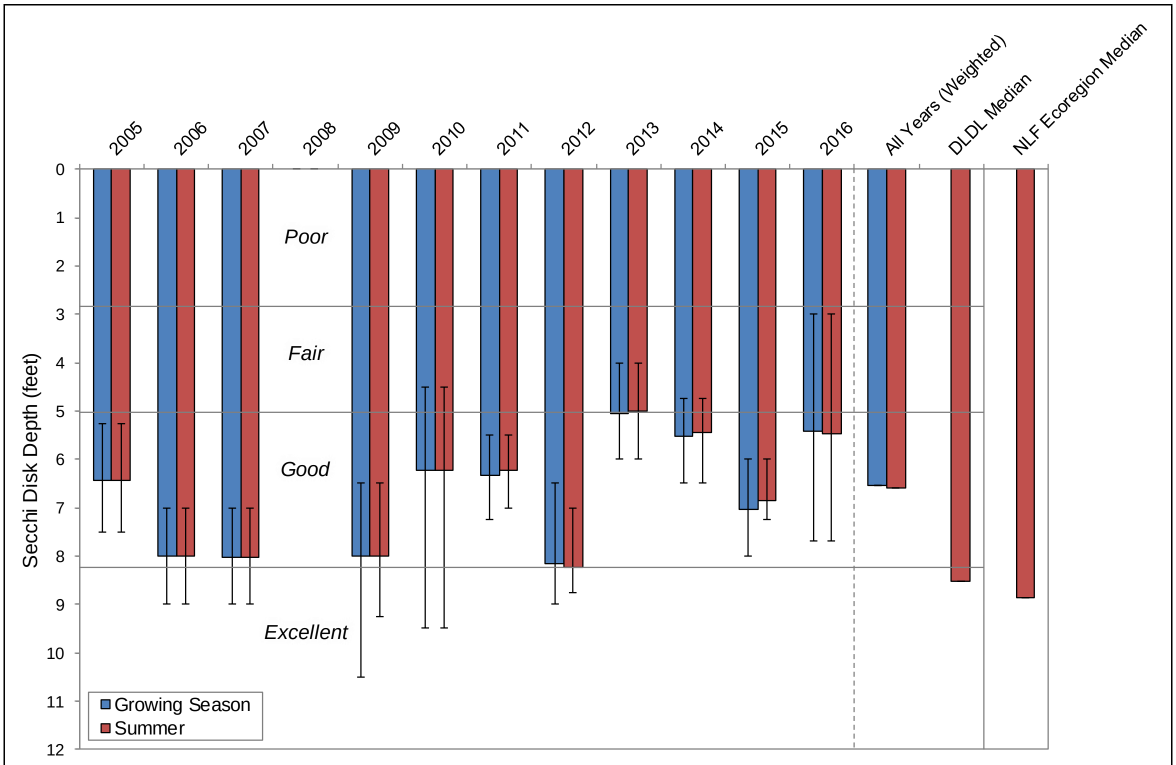


Figure 8.3.1-3. Rainbow Lake average annual Secchi disk depths and median Secchi disk depths for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

The Secchi disk transparency data indicate that water clarity since 2013 has been lower when compared to previous measurements going back to 2005. The average growing season Secchi disk depth from 2005-2012 was 7.3 feet compared to an average of 5.8 feet from 2013-2016. When water clarity declines, typically lake managers first look to see if chlorophyll-*a* concentrations have increased. Unfortunately, neither chlorophyll-*a* nor total phosphorus concentrations are available over this time period. However, Harris, Hiawatha, and Birch lakes have all shown a similar a pattern of lower water clarity over this most recent period despite no measured increase in total phosphorus or chlorophyll-*a*. It is believed the recent decline in water clarity in these lakes and Rainbow Lake is the result of an increase in annual precipitation.

Precipitation data obtained from nearby Hurley, WI indicate that annual precipitation has been above average each year since 2013 (Figure 8.5.1-4). This increase in precipitation likely flushed a greater amount of dissolved organic compounds from coniferous forests and wetlands in Rainbow Lake's watershed into the lake, resulting in reduced water clarity. Given the large areas of coniferous wetlands in Rainbow Lake's watershed, it is to be expected that larger amounts of these dissolved compounds will be delivered to the lake during years with higher precipitation.

To determine if internal nutrient loading (discussed in town-wide section of management plan) is a significant source of phosphorus in Rainbow Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on five occasions from Rainbow Lake in 2016 and once in 2017 (Figure 8.3.1-6). Near-bottom total phosphorus concentrations increased over the course of the growing season from 52 µg/L in May to 226 µg/L in August. As is discussed in the Dissolved Oxygen subsection, Rainbow Lake maintained stratification over the course of the summer and an anoxic hypolimnion. This allowed phosphorus to be released from bottom sediments into the overlying water within the hypolimnion.

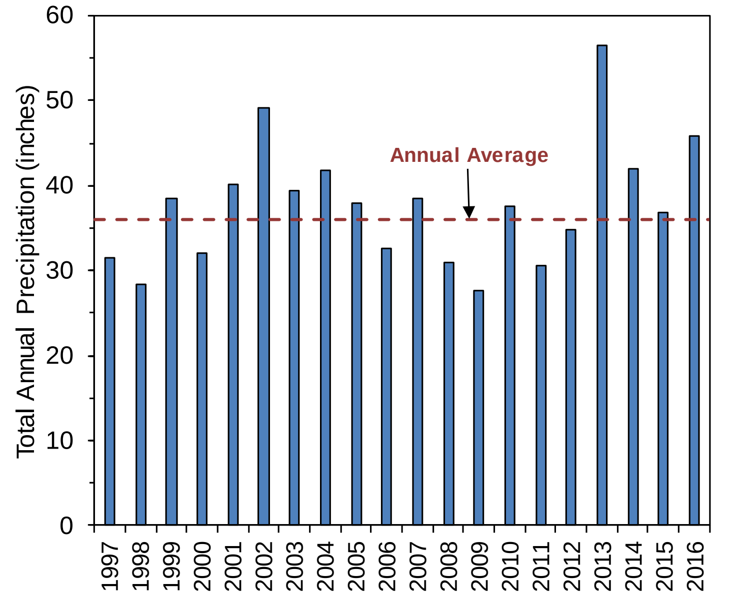


Figure 8.5.1-5. Total annual precipitation measured in Hurley, WI. Data obtained from Midwestern Regional Climate Center (2016).

While the near-bottom total phosphorus concentrations measured in Rainbow Lake in 2016 indicate the internal release of phosphorus from bottom sediments is occurring during summer stratification, near-surface total phosphorus concentrations indicate the majority of this phosphorus remains within the hypolimnion and is not being mobilized to surface waters. Following fall mixing in October, there was a small increase in near-surface total phosphorus concentrations likely due to near-bottom phosphorus being mixed throughout the water column. While internal phosphorus loading occurs in Rainbow Lake, the lake's morphology prevents this phosphorus from being mixed to the surface during the growing season and it does not appear to be effecting phosphorus concentrations at the surface.

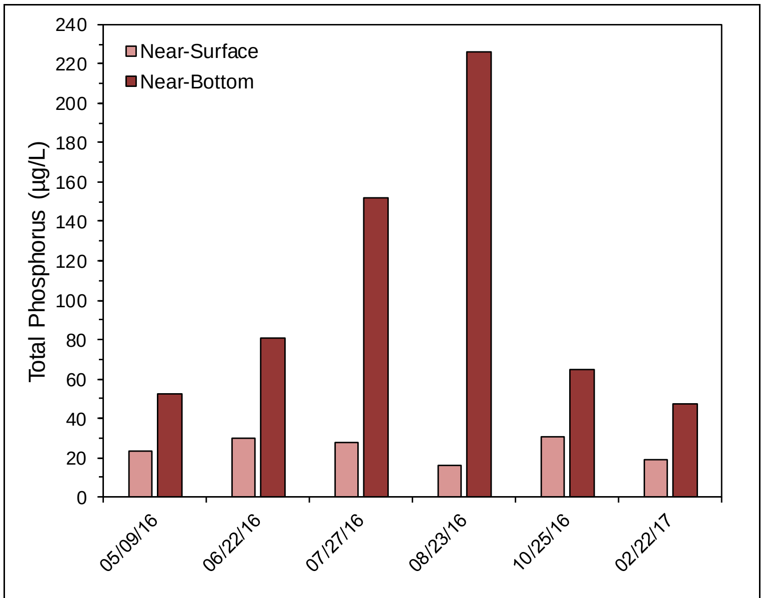


Figure 8.5.1-6. Rainbow Lake near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations measured in 2016.

Rainbow Lake Trophic State

Figure 8.5.1-7 contains the Trophic State Index (TSI) values for Rainbow Lake calculated from the data collected in 2016 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency 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 for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Rainbow Lake indicate the lake is at present in a meso-eutrophic state. Rainbow Lake's productivity is similar to the productivity of other deep lowland drainage lakes throughout Wisconsin and slightly higher when compared to the productivity of all lake types within the NLF ecoregion.

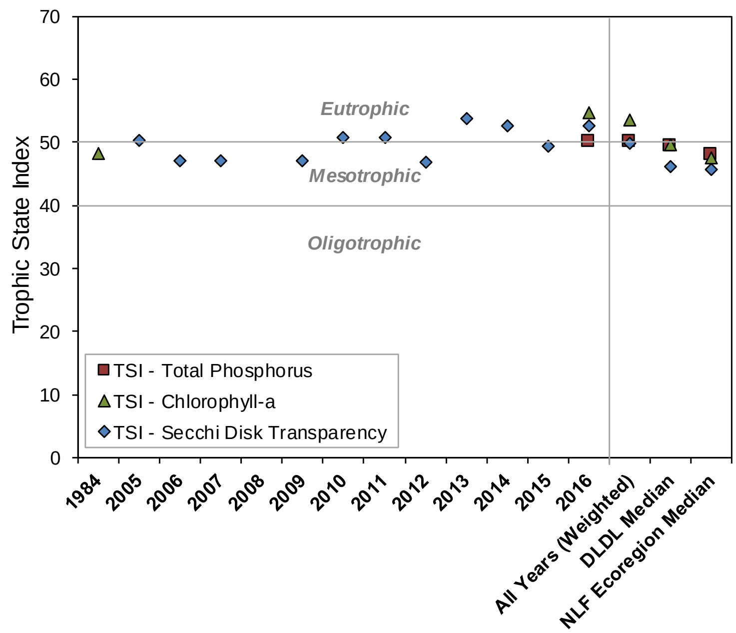


Figure 8.5.1-7. Rainbow Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Rainbow Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling event conducted by Onterra ecologists. These data are displayed in Figure 8.5.1-8. The temperature and dissolved oxygen data collected in 2016 indicate that the lake remained stratified throughout the summer and develops anoxia from 15.0 feet and deeper by mid-summer. By October, surface temperatures had cooled and the lake had mixed as indicated by relatively uniform temperature and dissolved oxygen throughout the water column. Dissolved oxygen collected under the ice in February 2017 indicated sufficient oxygen throughout most of the water column for aquatic life, indicating winter fish kills are likely not an issue for Rainbow Lake.

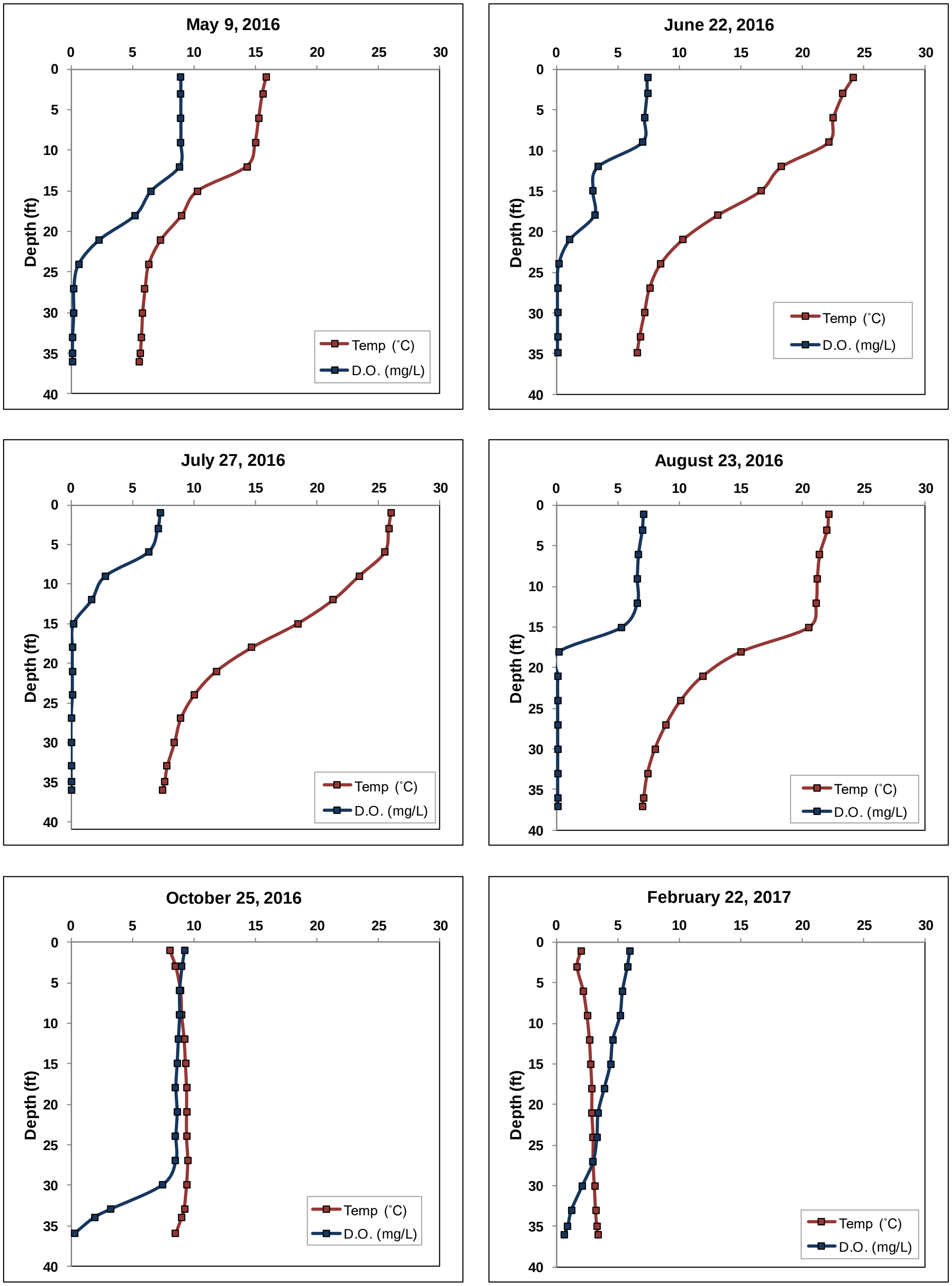


Figure 8.5.1-8. Rainbow Lake 2016/17 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Rainbow Lake

The previous section is centered on parameters relating to Rainbow Lake's trophic state. 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 Rainbow Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. Rainbow Lake's mid-summer surface water pH was measured at 7.5 in 2016. This value indicates Rainbow Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Rainbow Lake's average alkalinity measured in 2016 was 30.1 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while Rainbow Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from Rainbow Lake in 2016 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Rainbow Lake's pH falls within this range. Rainbow Lake's calcium concentration in 2016 was 9.3 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Rainbow Lake in 2016 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2016 surveys.

8.5.2 Rainbow Lake Watershed Assessment

Rainbow Lake's surficial watershed encompasses approximately 6,737 acres (Figure 8.5.2-1 and Rainbow Lake – Map 2) yielding a watershed to lake area ratio of 43:1. For modeling, the watershed was divided between the Tamarack Lake subwatershed and the Rainbow Lake direct watershed. Rainbow Lake's direct watershed is comprised of land cover types including forests (50%), wetlands (32%), pasture/grass (9%), the lake's surface itself (9%), and rural residential areas (<1%) (Figure 8.5.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Rainbow Lake's residence time is approximately 0.18 years, or the water within the lake is completely replaced approximately 5.5 times per year.

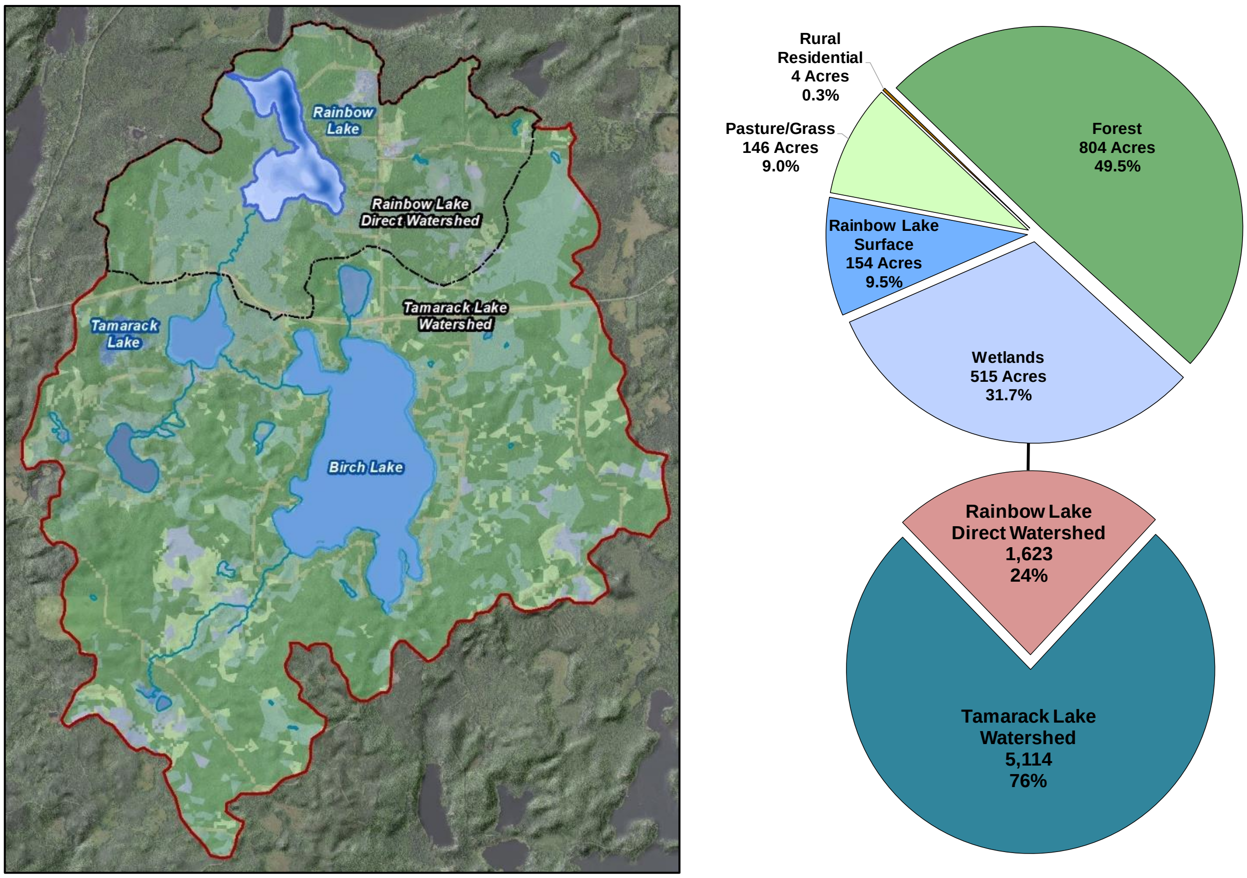


Figure 8.5.2-1. Rainbow Lake watershed boundary (red line) and proportion of land cover types. Rainbow Lake direct watershed is indicated by black dashed line. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types within Rainbow Lake's direct watershed and phosphorus data from upstream Tamarack Lake, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Rainbow Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Rainbow Lake riparian property owners in 2016 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that a approximately 610 pounds of phosphorus are delivered to Rainbow Lake from its watershed on an annual basis (Figure 8.5.2-2).

Of the estimated 610 pounds of phosphorus being delivered to Rainbow Lake on an annual basis, approximately 415 pounds (68%) originates from the Tamarack Lake subwatershed while the remaining 195 pounds originates from the lake's direct watershed (Figure 8.5.2-2). Within Rainbow Lake's direct watershed, forests account for 64 pounds (10%), wetlands account for 46 pounds (8%), atmospheric deposition onto the lake surface accounts for 42 pounds (7%), pasture/grasslands account for 40 pounds (6%), and riparian septic systems were estimated to account for 4 pounds (1%) (Figure 8.5.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 23 µg/L. The 2016 measured growing season total phosphorus concentration in Rainbow Lake was very similar to the predicted at 25.5 µg/L. This indicates that the lake's watershed was modeled accurately and that there are no significant sources of unaccounted phosphorus entering the lake.

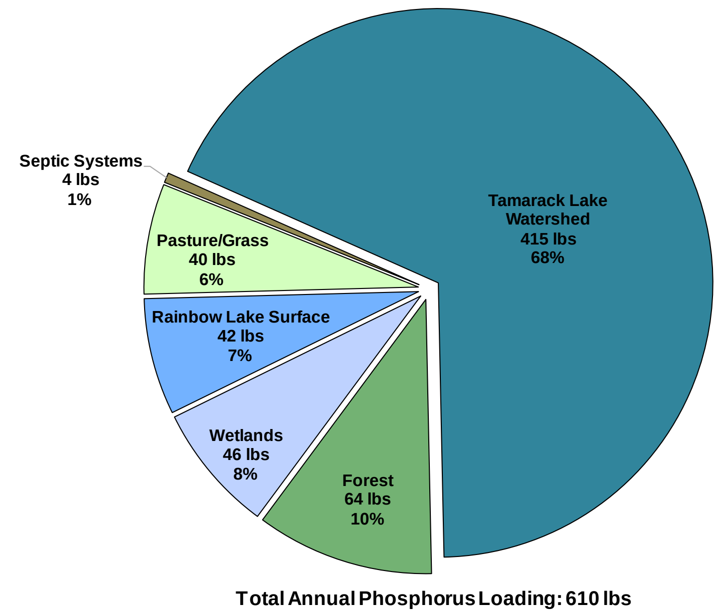


Figure 8.5.2-2. Rainbow Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Rainbow Lake Water Levels

Lake water levels can fluctuate naturally over varied timescales due to changes in precipitation and/or changes in human land use. Natural seasonal and long-term changes in water levels in lakes are beneficial as they generally create more diverse plant and animal communities. Water level fluctuations in drainage lakes, like Rainbow Lake, tend to be more moderate when compared to seepage lakes which lack input from streams or rivers and are largely tied to the level of the groundwater aquifer. Even during drier periods, rivers and streams still provide a source of water to drainage lakes. However, drainage lakes may show increases in water levels relatively quickly following large rain events.

Beginning in 2010, the NLDC and Rainbow Lake volunteers began monitoring Rainbow Lake's water levels annually during the open water season (Figure 8.5.2-3). Over the course of this monitoring, Rainbow Lake's water levels fluctuated a maximum of approximately 20 inches, with a minimum water level recorded in 2012 and a maximum water level recorded in 2014. The average intra-annual water level variation from 2010-2017 was 9.7 inches. Water levels in 2016 were approximately 1.0 inches above the 2010-2017 average while water levels in 2017 were 0.7 inches below average. The data collected from Rainbow Lake indicate that water levels tend to fluctuate both intra- and interannually with changes in precipitation levels. Ongoing collection of water level data at Rainbow Lake will allow for a better understanding of longer-term changes in water levels.

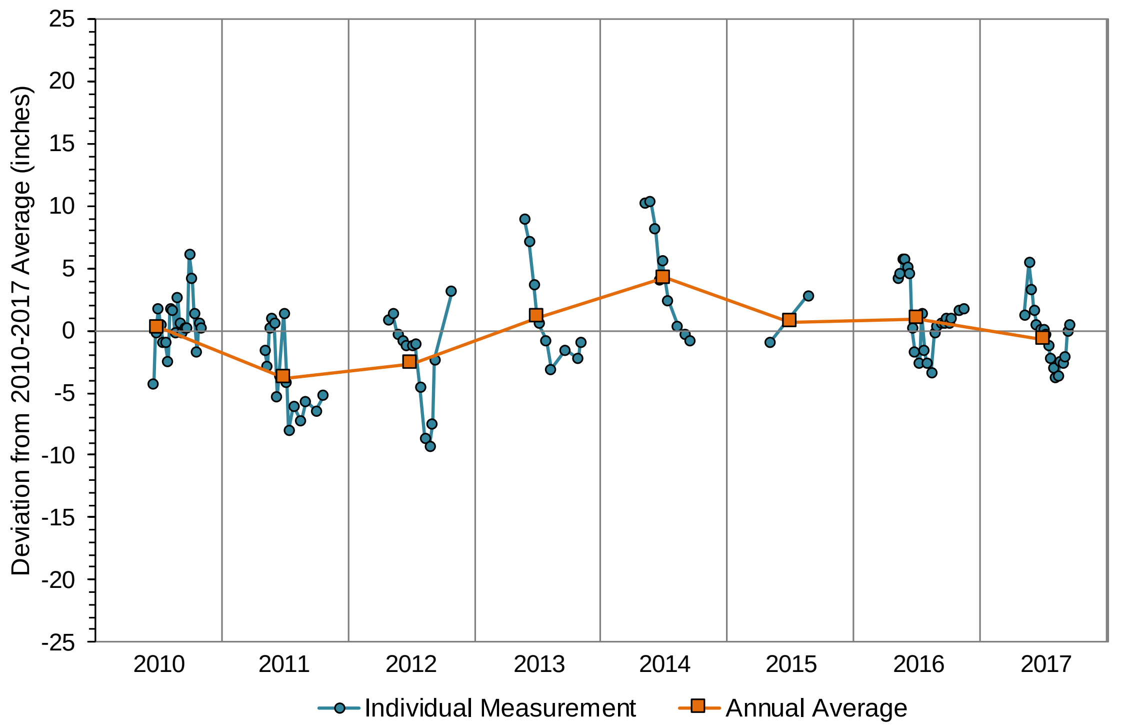


Figure 8.5.2-3. Rainbow Lake 2010-2017 water levels. Created using data provided by NLDC.

8.5.3 Rainbow Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the late-summer of 2016, the immediate shoreland of Rainbow Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

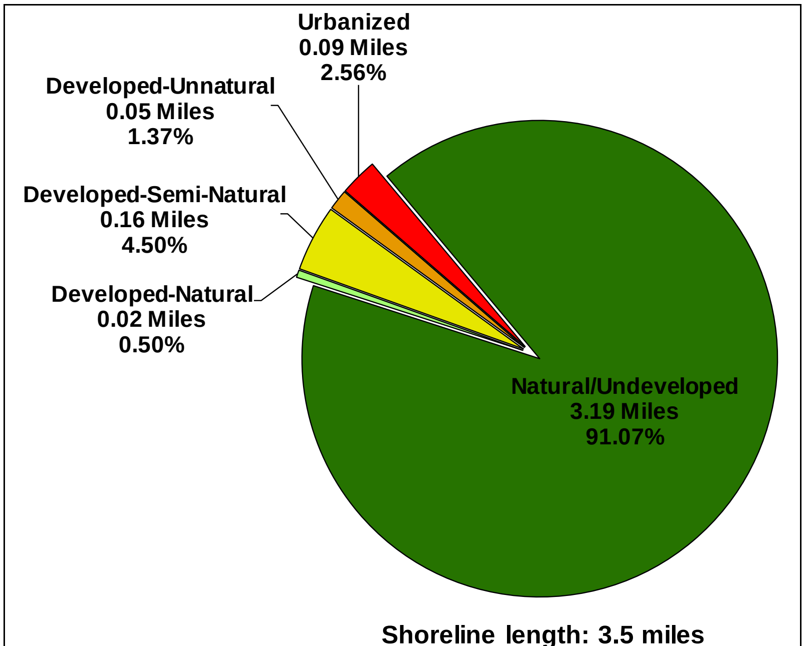


Figure 8.5.3-1. Rainbow Lake shoreland categories and total lengths. Based upon a late-summer 2016 survey. Locations of these categorized shorelands can be found on Rainbow Lake - Map 3.

The 2016 survey revealed that Rainbow Lake has stretches of shoreland that fit all five shoreland assessment categories (Figure 8.5.3-1). In total, 3.22 miles (91.5%) of the 3.5-mile shoreland zone were categorized as natural/undeveloped or developed-natural or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.15 miles (3.5%) of the shoreland was categorized as developed-unnatural or urbanized, shoreland areas which provide little benefit to and may actually adversely impact the lake. If restoration of Rainbow Lake's shoreland is to occur, primary focus should be placed on these highly developed shoreland areas. Rainbow Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Rainbow Lake in 2016. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on Rainbow Lake, a total of 55 pieces were observed along 3.5 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 16:1 (Figure 8.5.3-2). Onterra ecologists have been completing these surveys on Wisconsin's lakes for five years, and Rainbow Lake falls in the 29th percentile for the number of coarse woody habitat pieces per shoreline mile of 75 lakes studied. While the majority of the shoreland zone around Rainbow Lake is natural, the lower number of coarse woody habitat pieces is due to non-forested wetlands which surround a large portion of the lake and lack larger trees. Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in these lakes. The locations of these coarse woody habitat pieces are displayed on Rainbow Lake – Map 4.

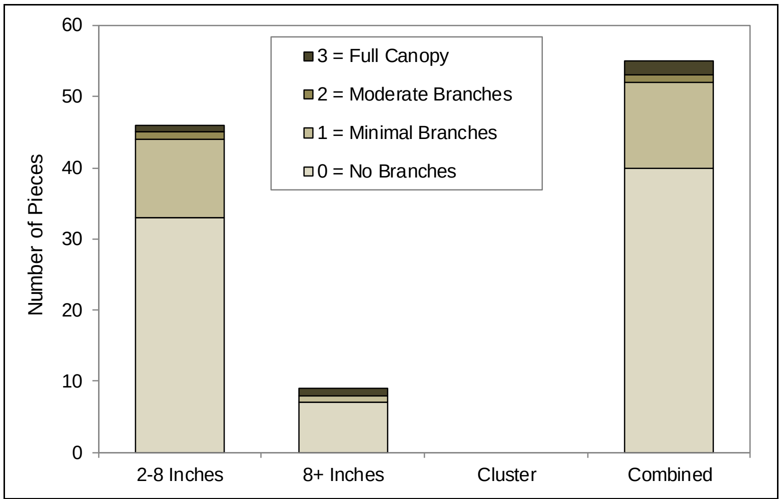


Figure 8.5.3-2. Rainbow Lake coarse woody habitat survey results. Based upon a late-summer 2016 survey. Locations of Rainbow Lake coarse woody habitat can be found on Rainbow Lake – Map 4.

8.5.4 Rainbow Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Rainbow Lake on June 28, 2016. 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. Fortunately, no curly-leaf pondweed was located in Rainbow Lake in 2016, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. Rainbow Lake users should familiarize themselves with curly-leaf pondweed and its identification as nearby Harris Lake contains a population of curly-leaf pondweed that was discovered in 2008.

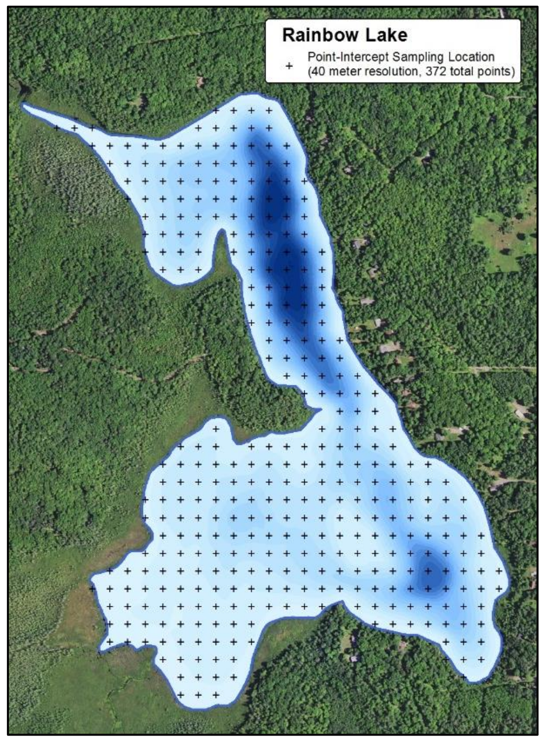


Figure 8.5.4-1. Rainbow Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Rainbow Lake by Onterra ecologists on July 20, 2016 (Figure 8.5.4-1). During these surveys, a total of 45 aquatic plant species were located, none of which are considered to be non-native, invasive species (Table 8.5.4-1). The species list also contains the 30 species recorded from Rainbow Lake during a survey completed by the WDNR in 2009. Most of the species located in 2009 were relocated in 2016 along with other species which were not recorded in 2009.

Lakes in Wisconsin vary in their morphometry, water chemistry, and substrate composition, and all of these factors influence aquatic plant community composition. In early August of 2016, Onterra ecologists completed an acoustic survey on Rainbow Lake (bathymetric results on Rainbow Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Rainbow Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2016 acoustic survey showed that substrate hardness varies widely in shallow areas of Rainbow Lake with both the hardest and softest substrates in the lake occurring within 1.0-6.0 feet of water (Figure 8.5.4-2). The softer substrates occurred near the mouth of Rainbow Creek and in areas of adjacent wetlands while shallower areas within eastern and northern portions of the lake had the hardest substrates. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2016 aquatic plant bio-volume data are displayed in Figure 8.5.4-3 and Rainbow Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2016 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 8 feet. However, the majority of aquatic plant growth occurs within 3.0-5.0 feet of water. The 2016 acoustic survey indicated approximately 49% of Rainbow Lake's area contains aquatic vegetation, while the remaining 51% of the lake is too deep and light-limited to support aquatic plant growth.

As mentioned, aquatic plants were recorded growing to a maximum depth of 8 feet in 2016. Of the 172 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 88% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2016 indicates that 22% of the 172 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 46% had a TRF rating of 2, and 20% had a TRF rating of 3 (Figure 8.5.4-5). These data indicate that aquatic plant density in Rainbow Lake is relatively high throughout most areas where plants occur.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Of the 45 aquatic plant species located in Rainbow Lake in 2016, 32 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.5.4-6). The remaining 13 plants were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 32 species directly sampled with the rake during the point-intercept survey, fern-leaf pondweed, common bladderwort, and muskgrasses were the three-most frequently encountered aquatic plant species (Figure 8.5.4-6).

Table 8.5.4-1. List of aquatic plant species located in Rainbow Lake during Onterra 2016 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2009 (WDNR)	2016 (Onterra)
Emergent	*Carex lacustris*	Lake sedge	6		I
	Carex lasiocarpa	Narrow-leaved woolly sedge	9		I
	Carex stricta	Common tussock sedge	7		I
	Carex utriculata	Common yellow lake sedge	7		I
	Dulichium arundinaceum	Three-way sedge	9		I
	Eleocharis palustris	Creeping spikerush	6		X
	Iris versicolor	Northern blue flag	5		I
	Phragmites australis subsp. *americanus*	Common reed	5		I
	Pontederia cordata	Pickerelweed	9	X	X
	Sagittaria sp.	Arrowhead sp.	N/A	X	
	Schoenoplectus acutus	Hardstem bulrush	5	X	X
	Typha latifolia	Broad-leaved cattail	1	X	I
FL	*Brasenia schreberi*	Watershield	7	X	X
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X	X
FL/E	*Sparganium* sp. (sterile)	Sterile Bur-reed sp.	N/A		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	
	Ceratophyllum echinatum	Spiny hornwort	10		X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Elodea nuttallii	Slender waterweed	7		X
	Eriocaulon aquaticum	Pipewort	9	X	
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes spp.	Quillwort spp.	8	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	I
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X
	Potamogeton natans	Floating-leaf pondweed	5	X	X
	Potamogeton obtusifolius	Blunt-leaved pondweed	9		I
	Potamogeton praelongus	White-stem pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7		X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10		X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Utricularia gibba	Creeping bladderwort	9		I
	Utricularia intermedia	Flat-leaf bladderwort	9		X
	Utricularia minor	Small bladderwort	10		X
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	
	Juncus pelocarpus	Brown-fruited rush	8	X	
	Schoenoplectus subterminalis	Water bulrush	9		X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern by Wisconsin Natural Heritage Inventory*

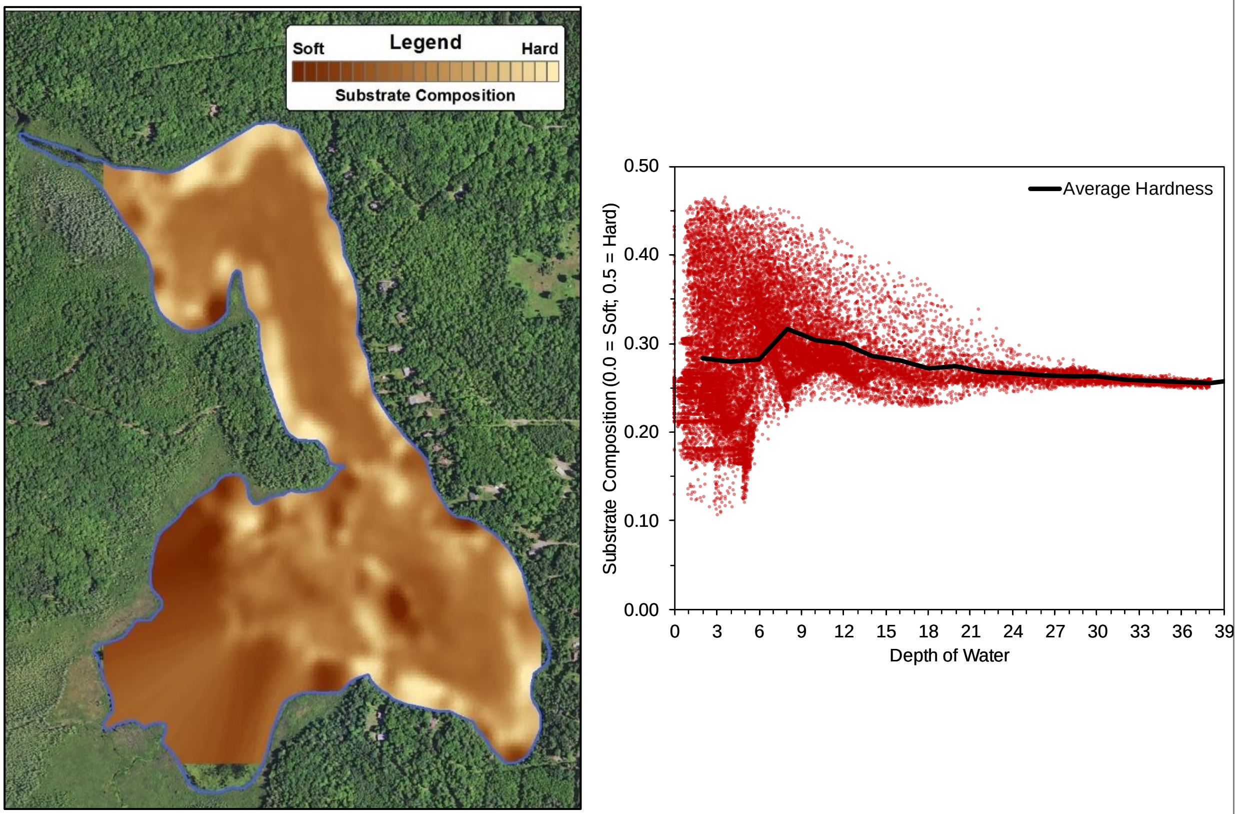


Figure 8.5.4-2. Rainbow Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Individual data points are displayed in red. Creating using data from August 2016 acoustic survey.

Fern-leaf pondweed was the most frequently encountered aquatic plant species in Rainbow Lake in 2016 with a littoral frequency of occurrence of 51% (Figure 8.5.4-6). Fern-leaf pondweed is a common plant in softwater lakes in northern Wisconsin, and is often one of the most abundant. It can be found in shallow to deep water typically over soft sediments. Large beds of fern-leaf pondweed provide excellent structural habitat for aquatic wildlife and help to prevent the suspension of the soft bottom sediments in which they grow. In Rainbow Lake, fern-leaf pondweed was most abundant between 3.0 and 5.0 feet of water.

Common bladderwort was the second-most frequently encountered aquatic plant species in Rainbow Lake during the 2016 point-intercept survey with a littoral frequency of occurrence of 22% (Figure 8.5.4-6). Common bladderwort is one of seven species of bladderwort that occur in Wisconsin and one of four species located in Rainbow Lake. Bladderworts are a genus of carnivorous plants which produce bladder-like traps that are used to capture aquatic invertebrates. Common bladderwort is the most prevalent species in Wisconsin and can be found across a wider range of water quality within areas of quiet water. In summer, common bladderwort produces yellow snapdragon-like flowers on stalks held above the water's surface (Photo 8.5.4-1). In Rainbow Lake, common bladderwort was most abundant between 2.0 and 4.0 feet of water.

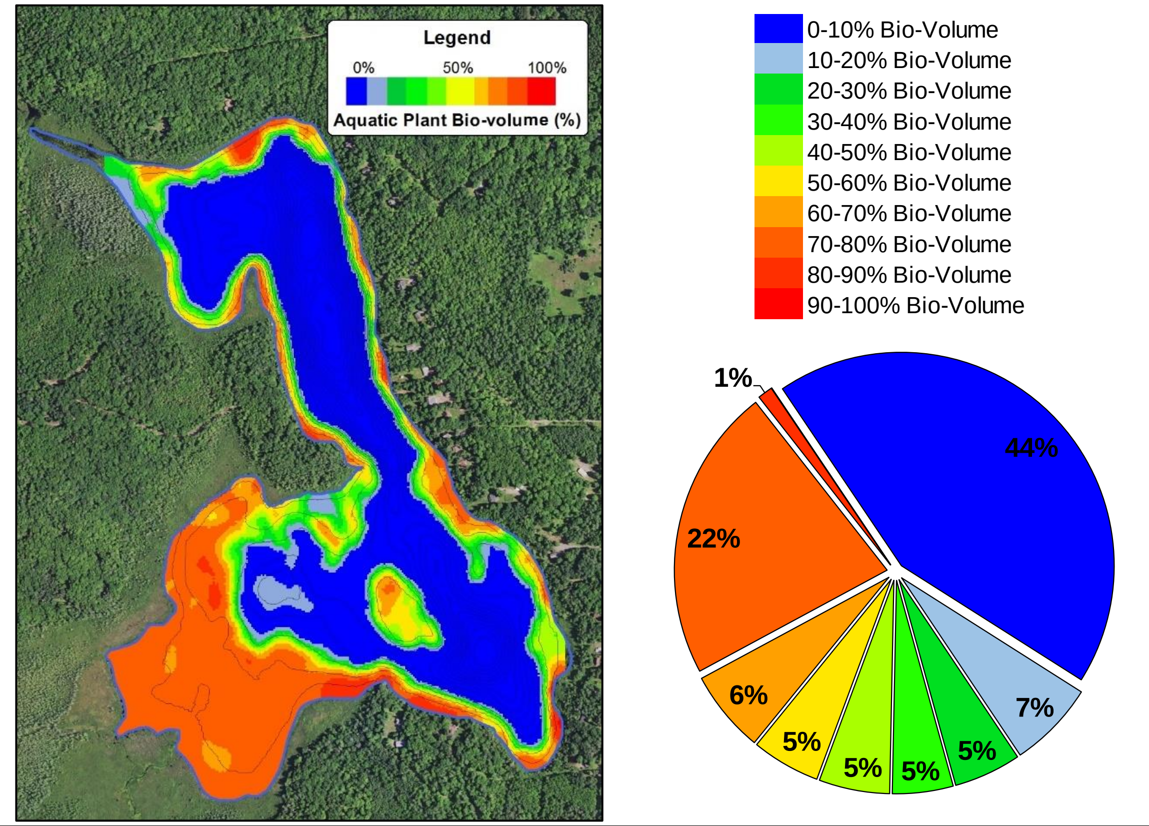


Figure 8.5.4-4. Rainbow Lake 2016 aquatic plant bio-volume. Created using data from August 2016 acoustic survey data. Contour lines represent one-foot increments.

Muskgrasses were the third-most frequently encountered aquatic plant in Rainbow Lake in 2016 with a littoral frequency of occurrence of 18% (Figure 8.5-4-6). Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin. Muskgrasses tend to be most prevalent in hardwater lakes rich in calcium, but some species can also be found in softwater lakes like Rainbow Lake. In Rainbow Lake, muskgrasses were located in shallow water mainly from 2.0-4.0 feet over areas of sandy substrate.

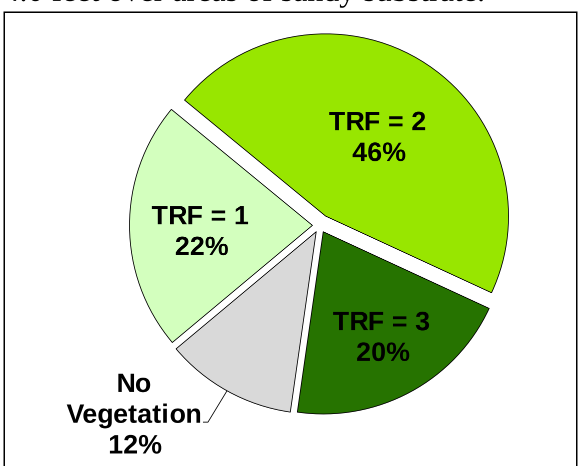


Figure 8.5.4-5. Rainbow Lake 2016 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2016 whole-lake point-intercept survey (N = 172).

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.5.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

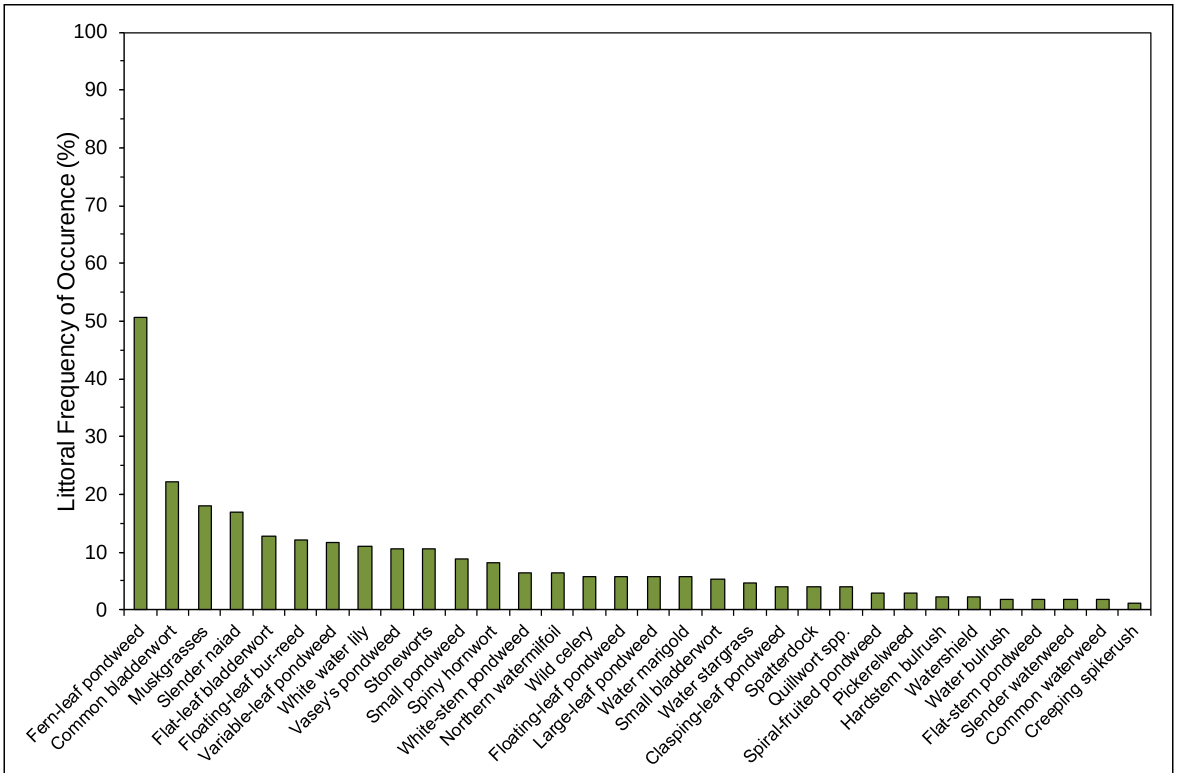


Figure 8.5.4-6. Rainbow Lake 2016 littoral frequency of occurrence of aquatic plant species. Created using data from 2016 whole-lake point-intercept survey.

Photo 8.5.4-1. Flowers of common bladderwort (*Utricularia vulgaris*) from Rainbow Lake. Photo credit Onterra, 2016.

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.5.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum* sibiricum) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

Photo 8.5.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Rainbow Lake Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2016 point-intercept survey on Rainbow Lake and their conservatism values were used to calculate the FQI of Rainbow Lake's aquatic plant community (equation shown below).

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

Figure 8.5.4-7 compares the 2016 FQI components of Rainbow Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2016 (32) falls above the upper quartile for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The average conservatism of the 32 native aquatic plant species located in Rainbow Lake in 2016 was 7.2, exceeding the median average conservatism values for lakes within the NLFL ecoregion (6.7) and lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of Rainbow Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

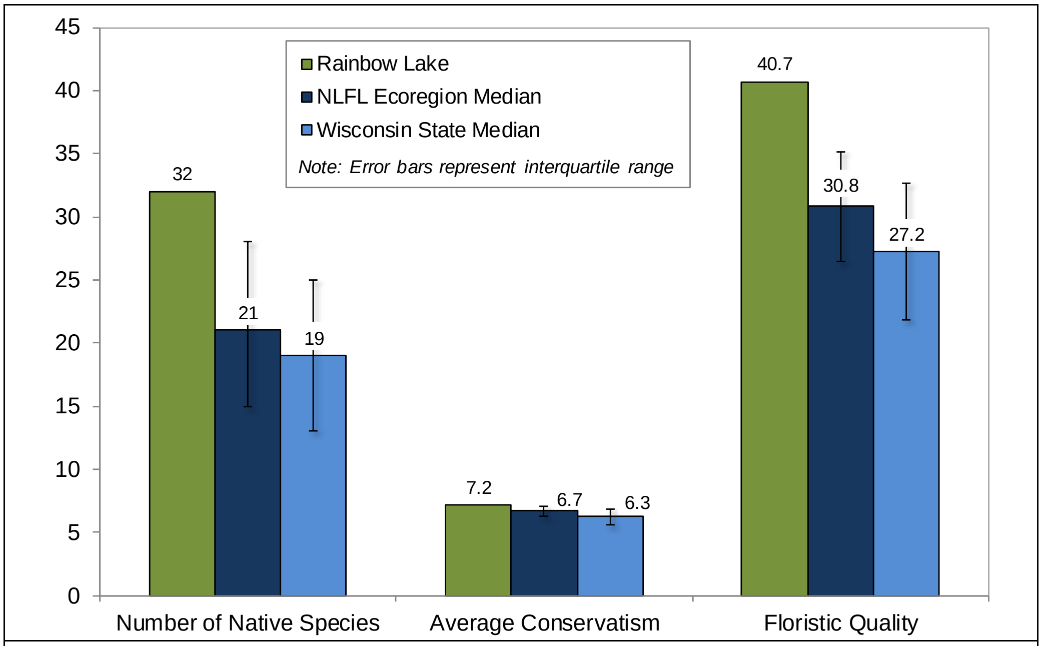


Figure 8.5.4-7. Rainbow Lake Floristic Quality Assessment. Created using data from Onterra 2016 whole-lake point-intercept survey. Analysis follows Nichols (1999).

Using Rainbow Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 40.7 (Figure 3.3-4-7). Rainbow Lake's FQI value exceeds the upper quartile for lakes within the NLFL ecoregion (30.8) and the median value for lakes throughout Wisconsin (27.2). Overall, the FQI analysis indicates that the aquatic plant community found in Rainbow Lake is of higher quality than the majority of lakes within the NLFL ecoregion and lakes throughout the state.

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Rainbow Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Rainbow Lake's diversity value ranks.

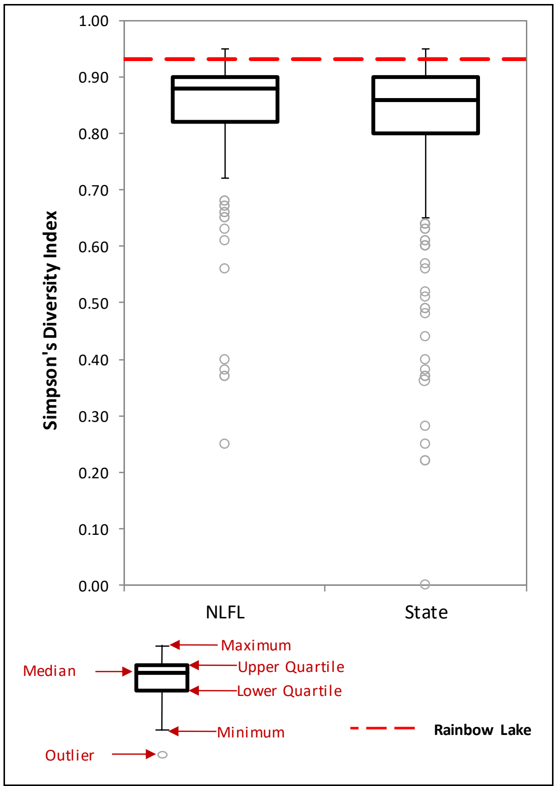


Figure 8.5.4-8. Rainbow Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

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Lake Management Planning

Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.5.4-8). Using the data collected from the 2016 point-intercept survey, Rainbow Lake's aquatic plant was found to have high species diversity with a Simpson's Diversity Index value of 0.93. In other words, if two individual aquatic plants were randomly sampled from Rainbow Lake in 2016, there would be a 93% probability that they would be different species. Rainbow Lake's Simpson's Diversity value exceeds the upper quartiles for lakes in the NLFL ecoregion and lakes throughout Wisconsin.

One way to visualize Rainbow Lake's high species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2016 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. 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 fern-leaf pondweed was found at 51% of the littoral sampling locations in Rainbow Lake in 2016, its relative frequency of occurrence was 19%. Explained another way, if 100 plants were randomly sampled from Rainbow Lake in 2016, 19 of them would be muskgrasses. Rainbow Lake contains a wide array of habitat types in terms of substrate composition and sheltered versus open water. The variety of habitat types in Rainbow Lake allows the lake to support a higher number of species and also increases diversity.

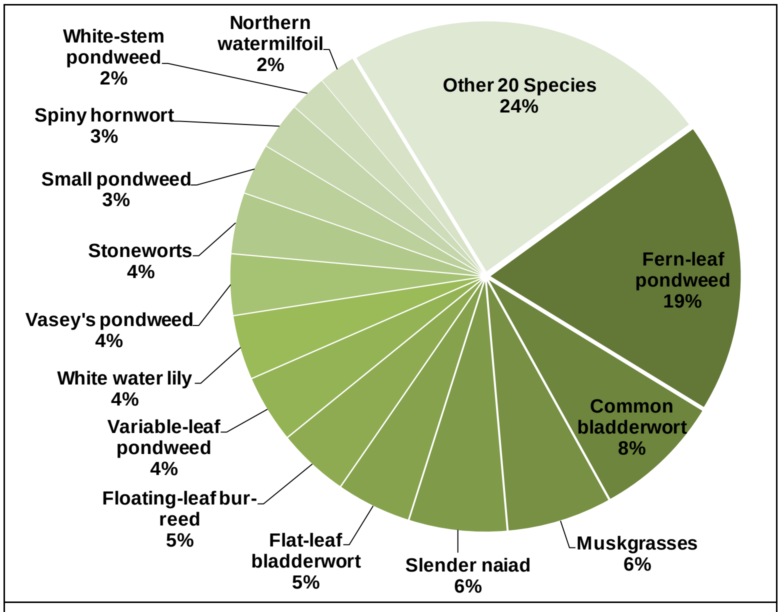


Figure 8.5.4-9. Rainbow Lake 2016 relative frequency of occurrence of aquatic plant species. Created using data from 2016 point-intercept survey.

In 2016, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Rainbow Lake. This survey revealed Rainbow Lake contains approximately 47 acres of these communities comprised of 16 different aquatic plant species (Rainbow Lake – Map 7 and Table 8.5.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Rainbow Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.5.4-2. Rainbow Lake 2016 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2016 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	3.0
Floating-leaf	22.5
Mixed Emergent & Floating-leaf	21.6
Total	**47.1**

8.5.5 Aquatic Invasive Species in Rainbow Lake

As of 2016, no aquatic invasive species have been confirmed in Rainbow Lake. However, the non-native Chinese (*Cipanogopaludina chinensis*) and banded (*Viviparus georgianus*) mystery snails and rusty crayfish (*Orconectes rusticus*) have been documented in upstream Birch Lake and it is possible that these species are present in Rainbow Lake. 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).

Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact. While it is possible these species are present in Rainbow Lake, their presence has not been officially verified.

8.5.6 Rainbow Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery as those aspects are currently being conducted by the fisheries biologists overseeing the lake. The goal of this section is to provide an overview 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 2017) and personal communications with DNR Fisheries Biologists Steve Gilbert and Hadley Boehm.

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 Birch Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton which are tiny crustaceans that feed upon phytoplankton. 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 piscovorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 8.5.6-1.

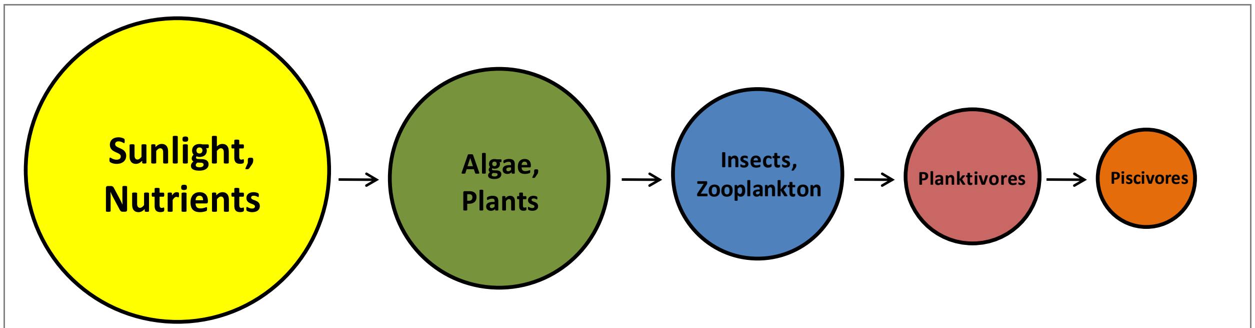


Figure 8.5.6-1 Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Rainbow Lake is a meso-eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Rainbow Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 8.5.6-1 shows the popular game fish present in Rainbow Lake.

Table 8.5.6-1. Gamefish present in Rainbow Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
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
Panfish (*Lepomis*)	11	May - August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish

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 common passive trap used is a fyke net (Photo 8.5.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net and 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 and sort the captured fish.

The other commonly used sampling method is electroshocking (Photo 8.5.6-1). 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, *galvanotaxis* stimulates their nervous system and involuntarily causes them to swim toward the electrodes. When the fish are in the vicinity of the electrodes, they undergo *narcosis* (stunned), making them easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking does not kill the fish and after being placed in the livewell, fish generally recover within minutes.

Once fish are captured using the appropriate method, data such as count, species, length, weight, sex, tag number, and aging structures may be recorded and the fish released. Fisheries biologists use this data to make recommendations and informed decisions on managing the future of the fishery.

Photo 8.5.6-1. Fyke net positioned in the littoral zone of a Wisconsin lake (right) and an electroshocking boat (left).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photo 8.4.6-3). Stocking of 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. Historical stocking efforts for Rainbow Lake have included muskellunge and are displayed in Table 8.5.6-2.

Photo 8.5.6-3. Fingerling Muskellunge.

Table 8.5.6-2. WDNR stocking data of fish species available for Rainbow Lake (1972-1990).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Muskellunge	Fingerling	300	11
1974	Muskellunge	Fingerling	300	11

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fish biologists can estimate populations and determine trends of captured fish species. The data collected and calculated is then used by fish biologists to determine the best management plan for the lake or chain. One method that is used involves calculating abundance and size structure of the fish populations and comparing to area lakes with the same species.

Rainbow Lake Fish Habitat

Substrate Composition

Just as forest wildlife requires 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 2016, 77% of the substrate sampled in the littoral zone of Rainbow Lake was soft sediments and 23% was composed of sand substrate.

Coarse Woody Habitat & Fish Sticks Program

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 2006).

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. 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. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. A fall 2016 survey documented 55 pieces of coarse woody along the shores of the Rainbow Lake, resulting in a ratio of approximately 16 pieces per mile of shoreline.

Regulations and Management

Current (2016-2017) regulations for Rainbow Lake gamefish species are displayed in Table 8.5.6-3. 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 8.5.6-3. WDNR fishing regulations for Rainbow Lake (2016-2017).

Species	Season	Regulation
Panfish	Open All Year	None, Daily bag limit 25
Largemouth bass and smallmouth bass	June 18, 2016 to March 5, 2017	14", Daily bag limit 5
Northern pike	May 7, 2016 to March 5, 2017	None, Daily bag limit 5
Walleye, sauger, and hybrids	May 7, 2016 to March 5, 2017	Only 1 fish over 14", Daily bag limit 3
Bullheads	Open All Year	None, Unlimited
Rough fish	Open All Year	None, Unlimited

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 8.5.6-2. 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 than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 8.5.6-2. 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/)

Rainbow Lake Tribal Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.4.6-3). The Town of Winchester falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process.

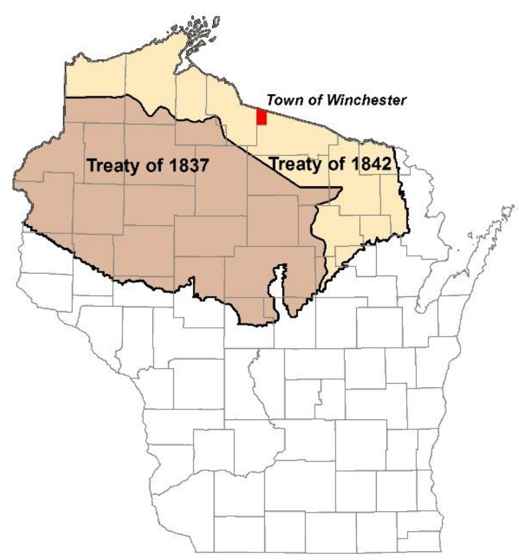


Figure 8.5.6-3. Location of the Town of Winchester within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

This highly structured procedure begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a *total allowable catch* is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% (walleye) or 27% (muskellunge) of the lake's known or modeled population, but may vary on an individual lake basis due to other circumstances. In lakes where population estimates are out of date by three or more years, a standard percentage is used. The total allowable catch number may be reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the *safe harvest level*.

Often, the biologists overseeing a lake cannot make adjustments due to the regimented nature of this process, so the total allowable catch often equals the safe harvest level. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent. This result is called the *declaration*, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal declaration and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007).

Spearers are able to 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 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met or the season ends.

In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake. While within the ceded territory, Rainbow Lake has not experienced a spearfishing harvest. A declaration for walleye harvest has been listed for Rainbow Lake in recent years, however no spearing efforts have been undertaken likely due to limited access.

8.5.7 Rainbow Lake Implementation Plan

The Implementation Plan presented in this section was created through the collaborative efforts of the Rainbow Lake Association (RLA) Planning Committee, Onterra ecologists, and North Lakeland Discovery Center (NLDC) and WDNR staff. It represents the path the RLA 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 Rainbow Lake stakeholders as portrayed by the members of the Planning Committee and the numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain current water quality conditions

Management Action:	Continue monitoring of Rainbow Lake's water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Ron Menozzi (current CLMN volunteer)
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. As discussed in the Water Quality Section, Rainbow Lake's water quality was good to excellent in all parameters measured. Continued monitoring can lead to early detection of potential negative trends and may lead to the reason to why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the RLA have been measuring Secchi disk transparency in Rainbow Lake annually since 2005. The RLA realizes the importance of continuing this effort which will supply them with valuable data about their lake. Funding from the WDNR for advanced water quality monitoring (addition of total phosphorus and chlorophyll-*a*) has been increasingly difficult to acquire. It was suggested at the planning meetings that the Town of Winchester Town Lakes Committee may be able to provide funding to lakes within the township to process samples for total phosphorus and chlorophyll-*a*. The RLA should work with members of the Town Lakes Committee to determine if funding will be available to collect total phosphorus and chlorophyll-*a* data in addition to Secchi disk transparency on Rainbow Lake in the future. Emily Heald, the current Water Program Coordinator at the NLDC, has indicated that the NLDC may be able to provide the water quality monitoring volunteers with a temperature/dissolved oxygen probe for their use. Nearby Trout Lake

Research Station may also lend water quality equipment to water quality monitoring volunteers.

Ron Menozzi is currently the CLMN volunteer collecting Secchi disk transparency data from Rainbow Lake, and the RLA Board of Directors will appoint a water quality monitor at each annual meeting as needed. When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Ron Menozzi and RLA Board of Directors appoints/recruits new volunteer(s) as needed at annual meeting.
2. New volunteer(s) contact Sandy Wickman (715.365.8951) as needed.
3. Volunteer(s) reports results to WDNR SWIMS database and to RLA members during annual meeting.

Management Action: Continue monitoring Rainbow Lake's water levels through NLDC citizen science lake level monitoring program.

Timeframe: Continuation of current effort

Facilitator: Nancy and Jeff Johnson

Description: The NLDC currently administers a citizen-based lake level monitoring program which is supported by a WDNR grant where lake levels are monitored on area lakes. Seasonal and longer-term water level fluctuations are natural in Wisconsin's lakes and are often beneficial for lake health. Continued monitoring of lake levels provides for an understanding of what conditions lead to changes in water levels. Following ice-out in the spring, a staff gauge is installed on Rainbow Lake and referenced to a fixed benchmark. Each week during the open-water season, volunteers record the current lake level. The staff gauges are removed in the fall and water level records are provided to NLDC staff. These lake level data are submitted to the WDNR's Surface Water Integrated Monitoring System (SWIMS).

1. Current Rainbow Lake volunteers record water level on staff gauges weekly during the open-water season.
2. Volunteers report water level data to NLDC at the end of each open-water season.
3. NLDC records water level data in WDNR SWIMS database.
4. Nancy and Jeff Johnson recruit new volunteers as needed or notify RLA if new water level monitors are needed.

Management Action:	Preserve natural and restore highly developed shoreland areas on Rainbow Lake to improve habitat, reduce erosion, and protect water quality.
Timeframe:	Initiate 2018
Facilitator:	RLA Board of Directors (suggested)
Description:	The 2016 Shoreland Condition Assessment found that approximately 92% (3.2 miles) of Rainbow Lake's immediate shoreland zone contains little to no development, delineated as either *natural/undeveloped* or *developed-natural*, while approximately 4% (0.1 miles) contains a higher degree of development categorized as *developed-unnatural* or *urbanized*. It is important that the owners of properties with little development become educated on the benefits their shoreland is providing to Rainbow Lake in terms of maintaining the lake's water quality and habitat, and that these shorelands remain in a natural or semi-natural state. It is equally important that the owners of properties with developed shorelands become educated on the lack of benefits and possible harm their shoreland has to Rainbow Lake's water quality and contribution to habitat loss. The RLA board of directors will work with appropriate entities such as the NLDC and Vilas County Land and Water Department to research grant programs and other pertinent information that will aid the RLA in preserving and restoring Rainbow Lake's shoreland. The NLDC has several restoration/rain/lakeshore/erosion gardens that can serve as examples and educational pieces for Birch and Tamarack Lake riparians to gather ideas for their properties. In addition, the NLDC can also help riparian property owners with planting ideas. 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. The RLA should contact Catherine Higley (cahigl@co.vilas.wi.us – 715.479.3738), Vilas County's Invasive Species Coordinator, to gather information on how to protect and restore areas of rainbow Lake's shoreland.
Action Steps:	
1.	RLA Board of Directors gathers appropriate information from entities listed above.
2.	The RLA provides Rainbow Lake property owners with the necessary informational resources to protect or restore their shoreland should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Water Department office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action:	Preserve natural land cover within Rainbow Lake's watershed beyond the immediate shoreland zone.

Timeframe: Initiate in 2018

Facilitator: RLA Board of Directors (suggested)

Description: As is discussed within the Watershed Section (8.5.2), changes in land use beyond the shoreland zone within a lake's watershed can impact water quality. Currently, Rainbow Lake's watershed is mainly comprised of natural land cover types, forests and wetlands. These natural land cover types export minimal amounts of phosphorus, retain soil, and maintain the good water quality found in these lakes. The RLA recognizes the importance of maintaining natural land cover within the watershed to maintain their water quality for future generations.

As is discussed in the previous management action, one way the RLA can preserve land within the watershed is through the purchase of land and placement within a land trust. A number of land owners within the watershed have already put their land in a trust. The RLA can also reach out to land owners of property within these lakes' watersheds and provide them with information on the RLA's mission and why preserving their land in a more natural state is beneficial for water quality. In addition, because Birch, Tamarack, and Rainbow lakes share the same watershed, the RLA and Birch Lake Association may choose to work together to reach out to property owners throughout the entire watershed of these three lakes to provide them with information on how their land management can lead to the preservation of Birch, Tamarack, and Rainbow lakes.

As of 2017, approximately 40% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by The Forestland Group's Heartwood Forestland Partnership (Rainbow Lake – Map 8). This land is managed for sustainable logging and is overseen by regional teams working with local forestry consulting firms. The Forestland Group forest management is based on natural regeneration as opposed to planted silvicultural systems, and they were one of three recipients of a Corporate Sustainable Standard Setter Award by the Rainforest Alliance for leadership in the movement toward sustainable certification (TFG website: http://www.forestlandgroup.com/conservation/). The land within the Birch-Tamarack-Rainbow lake watershed is part of the Great Lakes Region Chippewa East Property. Shawn Hagan is the Senior Director for Forestland Operations (906.487.7491) of the Great Lakes Region for The Forestland Group, and the RLA can contact Shawn for more information on how this property within the watershed is managed.

Approximately 3% of the land within the Birch-Tamarack-Rainbow lake watershed is owned by the Wisconsin Department of Natural Resources, while the remaining 57% is comprised of privately-owned parcels. In an effort to preserve natural land cover on these properties, the RLA can include information on the benefits of maintaining these properties in a natural state along with information on the benefits of maintaining a natural shoreline as discussed in the previous management action.

Action Steps:

1. See description above.

Management Goal 2: Increase Navigation Safety on Rainbow Lake

Management Action: Install signage at public carry-in access location on Rainbow Creek to inform lake users of watercraft regulations on Rainbow Lake.

Timeframe: Initiate in 2018

Facilitator: RLA Board of Directors (suggested)

Description: Rainbow Lake does not possess a public boat launch on the lake and watercraft traffic was not listed as a top concern by respondents to the 2016 stakeholder survey. However, members of the Rainbow Lake Planning Committee felt it would be important to inform lake users of watercraft regulation areas on Rainbow Lake by placing signage at the public carry-in access point located where County Highway W crosses Rainbow Creek. This signage will provide lake users with a visual representation of the 100- and 200-foot slow, no wake setbacks in an effort to improve recreational safety on Rainbow Lake and reduce shoreline erosion/impacts to shoreline habitat.

Onterra will provide the RLA with a map similar to Rainbow Lake – Map 9 displaying these setback areas. The RLA will need to provide this map to a sign/graphic design company to create a durable sign for outdoor use at the public access points. In addition, the RLA will likely also need to obtain the necessary permission from the Town of Winchester to install new signage at this public access location.

Because the public access point on Rainbow Creek allows access to both Rainbow and Tamarack lakes, the RLA should work with Tamarack Lake stakeholders to develop signage that informs lake users of watercraft regulations on both of these lakes. Onterra will also be providing a watercraft regulation map for Tamarack Lake.

Action Steps:

1. Onterra provides RLA with Rainbow Lake watercraft regulation map similar to Rainbow Lake – Map 9.
2. Rainbow Lake works with sign/graphic design company to create sign for the public boat landing.
3. RLA obtains necessary permission from the Town of Winchester to install sign at the Birch Lake public boat landing.

Management Goal 3: Assure and Enhance the Communication and Outreach of the Rainbow Lake Association with Rainbow Lake Stakeholders

Management Action: Promote stakeholder involvement, inform stakeholders on various lake issues, as well as the quality of life on Rainbow Lake.

Timeframe: Continuation of current effort

Facilitator: RLA Board of Directors (suggested)

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. The RLA will continue its effort to promote lake preservation and enhancement through a variety of educational efforts.

The RLA has published a newsletter for its membership in the past and would like to get this effort going again. Currently, the RLA does not have an individual or committee to head up the publishing and distribution of the newsletter. At the planning committee meetings, the RLA Planning Committee indicated that they will seek an RLA member to lead the redevelopment and distribution of an association newsletter. The RLA currently communicates with its membership via email, and the distribution of an electronic newsletter would be an excellent mode of communication and education for the RLA to its membership.

The RLA would also like to initiate the development of an association website and/or blog. The Birch Lake Association (BLA) currently maintains the Birch Lake Blog, a website where Birch Lake stakeholders can find information about the lake, meeting times, and an assortment of lake-related links. It was suggested during the planning meetings that the BLA could incorporate Rainbow Lake into their blog website seeing as the lakes are connected to each other. The development of a website/blog which incorporates information and lake-related issues from Birch, Tamarack, and Rainbow lakes would be an excellent avenue for interested stakeholders to gain information not only on how their actions impact their lake but lakes downstream as well. The RLA should reach out to the BLA in regards to joining the Birch Lake Blog.

The RLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Rainbow Lake and its preservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings can be found below. These topics can be included within the association's newly developed newsletter, distributed as separate educational materials, or posted on the association's future website. The RLA can also invite speakers to discuss lake-related topics or hold workshops for their members at their annual meetings. The RLA should also reach out to professionals from the NLDC, WDNR, Vilas County Lakes and Rivers Association, etc. to obtain educational pieces for their newsletter.

Example Educational Topics

- Shoreline restoration and protection
- Effect lawn fertilizers/herbicides have on the lake
- Importance of maintaining course woody habitat
- Fishing rules and regulations
- Catch-and-release fishing
- Boating regulations and safety
- Pier regulations and responsible placement to minimize habitat disturbance
- Importance of maintaining a healthy native aquatic plant community
- Respect to and maintaining a safe distance from wildlife (e.g. loons) within the lake
- Aquatic invasive species (AIS) prevention
- Water quality monitoring updates from Rainbow Lake
- Septic system maintenance
- Water levels
- Littering on the ice and year-round

Action Steps:

1. See description above.

Management Goal 4: Prevent New Aquatic Invasive Species Introductions to Rainbow Lake

Management Action: Continue RLA volunteer aquatic invasive species monitoring using the shoreline monitors.

Timeframe: Continuation of current effort.

Facilitator: RLA Board of Directors (suggested)

Description: As of this writing, no aquatic invasive species have been documented in Rainbow Lake. The RLA understands that it important to prevent future introductions of non-native species such as Eurasian watermilfoil and curly-leaf pondweed. Nearby waterbodies such as Harris Lake and the Manitowish Chain of Lakes contain populations of curly-leaf pondweed, while Presque Isle Lake contains a population of Eurasian watermilfoil. In lakes without Eurasian watermilfoil and curly-leaf pondweed, early detection of these can often lead to successful control, and in instances with small infestations, possible even eradication. Currently, RLA volunteers have received aquatic invasive species identification and monitoring training and perform shoreline surveys in which volunteers are responsible for periodically monitoring specific areas of the lake. This methodology allows the entire lake to be monitored for the presence of non-native species. In addition to RLA volunteer monitoring, NLDC staff completes AIS surveys on Rainbow Lake two times per year.

Action Steps:

1. RLA volunteers updated their identification and monitoring skills by attending training sessions provided by the NLDC (877.543.2085).
2. Trained volunteers recruit and train additional association members.
3. Complete monitoring surveys following protocols.

Management Action: Initiate aquatic invasive species rapid response plan upon discovery of new infestation.

Timeframe: Initiate upon invasive species discovery.

Facilitator: RLA Board of Directors (suggested)

Description: In the event that an aquatic invasive species such as Eurasian watermilfoil is located by the trained volunteers, the areas would be marked using GPS and the RLA should contact resource managers (NLDC) immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase and the results would be used to develop potential control strategies.

Action Steps:

1. RLA contact NLDC (877.543.2085) upon discovery of new invasive species in Birch Lake.

Management Action:	Install aquatic invasive species (AIS) signage at Tamarack/Rainbow lakes public carry-in access location.
Timeframe:	Initiate 2018
Facilitator:	RLA Board of Directors
Description:	Rainbow Lake contains a carry-in public access located on the northern side of the lake where County Highway W crosses Rainbow Creek. At present, this public access location does not contain an AIS awareness sign to inform lake users on AIS prevention. The WDNR is currently offering these signs, posts, and hardware free of charge. To request an AIS boat landing sign, the RLA should contact Tim Campbell (timothy.campbell@wisconsin.gov – 608.26.3531), WDNR AIS Education Specialist, to request a sign for the Rainbow Lake carry-in access. Lake users can also access Tamarack Lake from this launch site, and the RLA should work with Martin Plutowski from Tamarack Lake to coordinate obtaining this AIS signage.
Action Steps:	
1.	Please see above description.

Management Goal 5: Enhance the fishery of Rainbow Lake

Management Action:	Continue work with WDNR fisheries managers to enhance the fishery of Rainbow Lake.
Timeframe:	Continuation of current effort
Facilitator:	RLA Board of Directors (suggested)
Description:	In the 2016 stakeholder survey, fishing was ranked third behind relaxing/entertaining and nature viewing by respondents when asked to rank their top three activities that are important reasons for owning or renting their property on or near Rainbow Lake (Appendix B, Question 17). Respondents indicated that bluegill, crappie, northern pike, and muskellunge were the most sought-after fish by anglers in Rainbow Lake, and 67% of respondents rated the current fishing on Rainbow Lake as either good or excellent (Appendix B, Questions 11 and 12). Approximately 42% of respondents indicated the quality of fishing has gotten somewhat worse since they began fishing on Rainbow Lake, while 42% indicated the quality of fishing has remained the same (Appendix B, Question 13). Rainbow Lake is currently listed as an Area of Special Natural Resource Interest (ASNRI) for harboring naturally reproducing populations of both walleye and muskellunge. The RLA and understands that a multitude of factors such as changes in habitat, water levels, and fishing pressure affect fish communities, and the RLA would like to take an active role in maintaining a healthy fishery to ensure Rainbow Lake remains a high-quality fishing lake for future generations.

Rainbow Lake is currently overseen by WDNR fisheries biologist Hadley Boehm (715.356.5211). In an effort to remain informed on studies pertaining to fisheries in these lakes, the RLA Board of Directors should contact Hadley at least once per year (perhaps during the winter months when field work is not occurring) for a brief summary of activities. In addition, the RLA can discuss management options for maintaining and enhancing the lakes' fishery, which may include changes in angling regulations and/or habitat enhancements.

Action Steps:

See description above.

Please note that study methods and explanations of analyses for Rock Lake can be found within the Town of Winchester Town-wide Management Plan document.

8.6 Rock Lake

An Introduction to Rock Lake

Rock Lake, Vilas County, is a 126-acre shallow lowland, brown-water, eutrophic drainage lake with a maximum depth of 20 feet and a mean depth of 9 feet (Rock Lake – Map 1). Its surficial watershed encompasses approximately 3,624 acres across portions of Vilas County, WI and Gogebic County, MI. Rock Lake is fed by upstream No Mans Lake via No Mans Creek, and the lake drains into downstream North Turtle Lake. In 2017, 42 native aquatic plant species were located within the lake, of which fern-leaf pondweed (*Potamogeton robbinsii*) was the most common. The non-native, invasive wetland plant pale-yellow iris (*Iris pseudacorus*) was located in numerous locations along Rock Lake's shoreline in 2017. To date, no other non-native species have been documented in Rock Lake.

Lake at a Glance - Rock Lake

Morphometry	
LakeType	Shallow Lowland Drainage
Surface Area (Acres)	126
Max Depth (feet)	20
Mean Depth (feet)	9
Perimeter (Miles)	3.9
Shoreline Complexity	6.0
Watershed Area (Acres)	3,624
Watershed to Lake Area Ratio	28:1
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	26
Avg Summer Chl-α (µg/L)	12
Avg Summer Secchi Depth (ft)	5.7
Summer pH	7.6
Alkalinity (mg/L as $CaCO_3$)	31
Vegetation	
Number of Native Species	42
NHI-Listed Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Species	Pale-yellow Iris (*Iris pseudacorus*)
Average Conservatism	6.9
Floristic Quality	35.6
Simpson's Diversity (1-D)	0.92

Descriptions of these parameters can be found within the town-wide portion of the management plan

8.6.1 Rock Lake Water Quality

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

In 2017, a stakeholder survey was sent to 52 Rock Lake riparian property owners. Nineteen (37%) of these 52 surveys were completed and returned. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of Rock Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B. When asked about Rock Lake's current water quality, 58% of the respondents indicated the water quality is *good* or *excellent*, 32% indicated the water quality is *fair*, 5% indicated the water quality is *poor*, and 5% were unsure (Figure 8.6.1-1). When asked how water quality has changed in Rock Lake since they first visited the lake, 63% of respondents indicated water quality has *remained the same*, 27% indicated the water quality has *somewhat degraded*, 5% indicated it has *severely degraded*, and 5% were unsure (Figure 8.6.1-1).

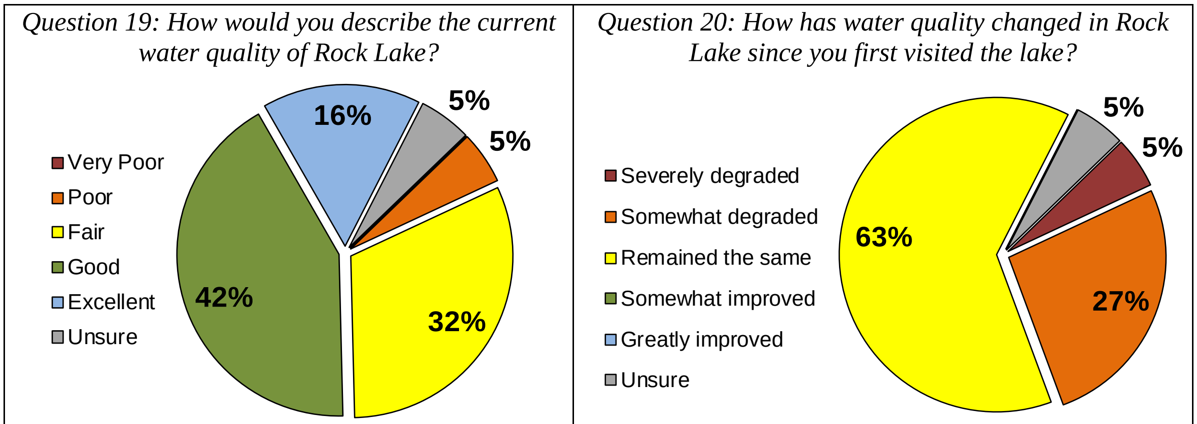


Figure 8.6.1-1. Rock Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 19 (37%) respondents of 52 surveys distributed.

Near-surface total phosphorus data for Rock Lake are available from 1985, 2005-2009, and 2017 (Figure 8.6.1-2). Average summer total phosphorus concentrations have been relatively stable over the time period for which data are available, and the weighted average summer concertation of 26 µg/L falls within the *excellent* category for shallow lowland drainage lakes in Wisconsin. The average summer phosphorus concentration in 2017 was slightly above average at 30 µg/L, likely due to increased runoff from above-average precipitation. Precipitation data obtained from nearby Manitowish Waters indicates precipitation in 2017 was four inches above average. Rock Lake's phosphorus concentrations are lower than the median concentration for shallow lowland drainage lakes in Wisconsin (33 µg/L) but above the median for all lake types within the Northern Lakes and Forests (NLF) ecoregion (21 µg/L). The available data indicate phosphorus concentrations have been relatively stable in Rock Lake since 2005.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Rock Lake from 1984, 2005-2009, and 2017 (Figure 8.6.1-3). Like total phosphorus concentrations, average summer chlorophyll-*a* concentrations are relatively stable, ranging from *excellent* to *good* for shallow lowland drainage lakes in Wisconsin. Overall, the weighted average summer chlorophyll-*a* concentration is 12 µg/L, falling into the *good* category for Wisconsin's shallow lowland drainage lakes. Rock Lake's average summer chlorophyll-*a* concentration is slightly higher than the median value for shallow lowland drainage lakes (9.4 µg/L) and higher than the median value for all lake types within the NLF ecoregion (5.6 µg/L). The available data indicate that annual chlorophyll-*a* concentrations in Rock Lake have been relatively stable since 2005, and algal production has not increased.

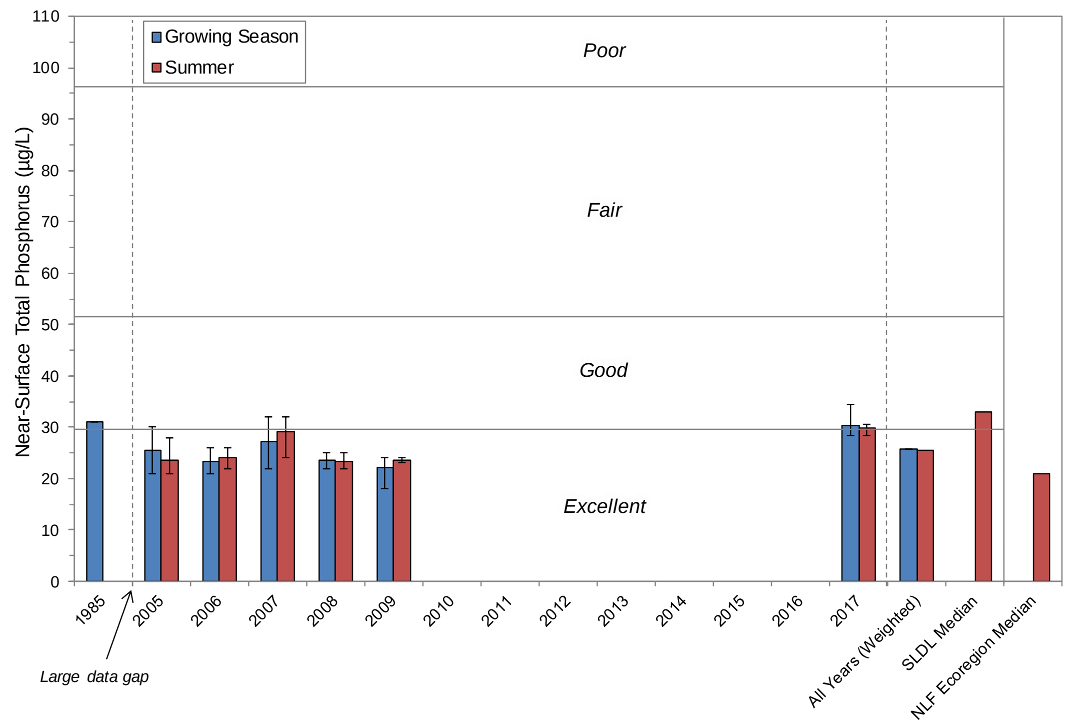


Figure 8.6.1-2. Rock Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Secchi disk transparency data from Rock Lake are available from 1984, 1985, 1991-2002, 2005, 2007-2010, 2012-2015, and 2017 (Figure 8.6.1-4). These data indicate that water clarity is relatively variable in Rock Lake from year to year, ranging from 4.3 feet in 1991 to 7.3 feet in 1994. The weighted summer average Secchi disk depth is 5.7 feet, falling into the *excellent* category for shallow lowland drainage lakes in Wisconsin. Rock Lake's average summer Secchi disk depth is comparable to the median value for shallow lowland drainage lakes (5.6 feet) but lower than the median value for all lake types within the NLF ecoregion (8.9 feet). Trends analysis of Rock Lake's Secchi disk data indicates no significant trends (positive or negative) in water clarity are occurring over time.

annually from 2005-2016 with the exception of 2008 (Figure 8.6.1-3). These data indicate that water clarity in Rock Lake can be variable from year to year, but the weighted summer average Secchi disk depth is 6.6 feet, falling into the *good* category for Wisconsin's deep lowland drainage lakes. Rock Lake's average summer Secchi disk depth falls lightly below the median values for deep lowland drainage lakes in Wisconsin and for all lake types within the NLF ecoregion. Water clarity in Rock Lake is somewhat lower than expected based upon chlorophyll-*a* concentrations, indicating that another factor in addition to phytoplankton is influencing water clarity.

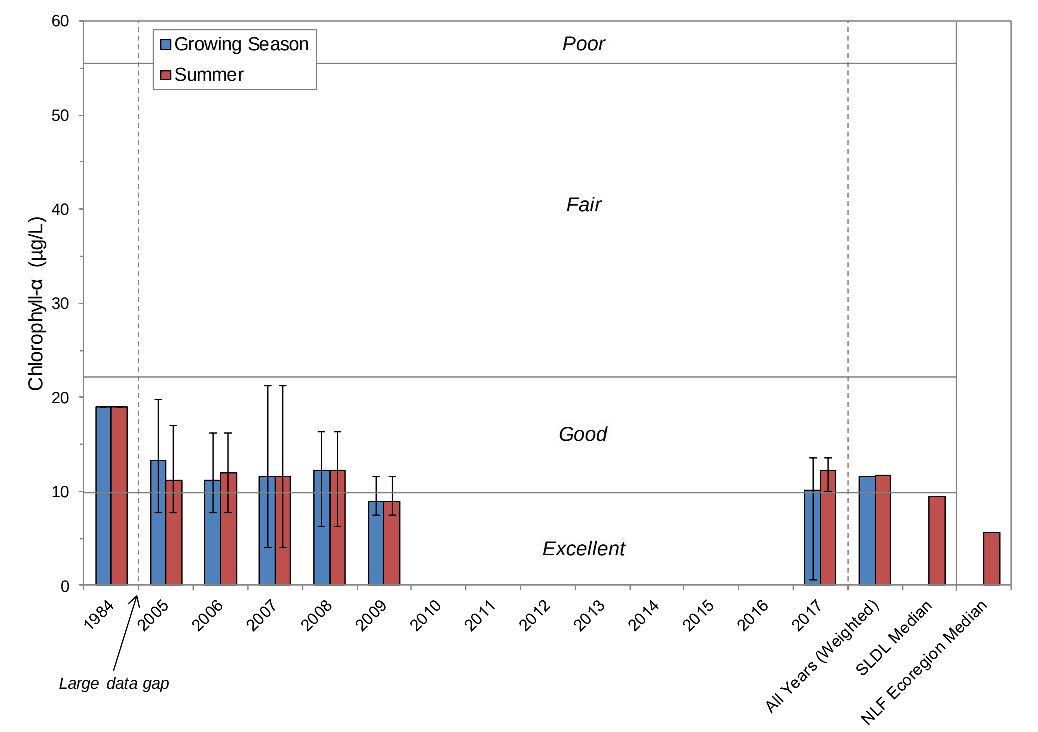


Figure 8.6.1-3. Rock Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in Rock Lake in 2017 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in Rock Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Rock Lake in 2017 averaged 65 SU (standard units), indicating the lake's water is *tea-colored*. The high concentrations of dissolved organic acids in the lake reduce the water's clarity. It is important to note that the tea-colored water in Rock Lake is natural, and is not an indication of degraded conditions.

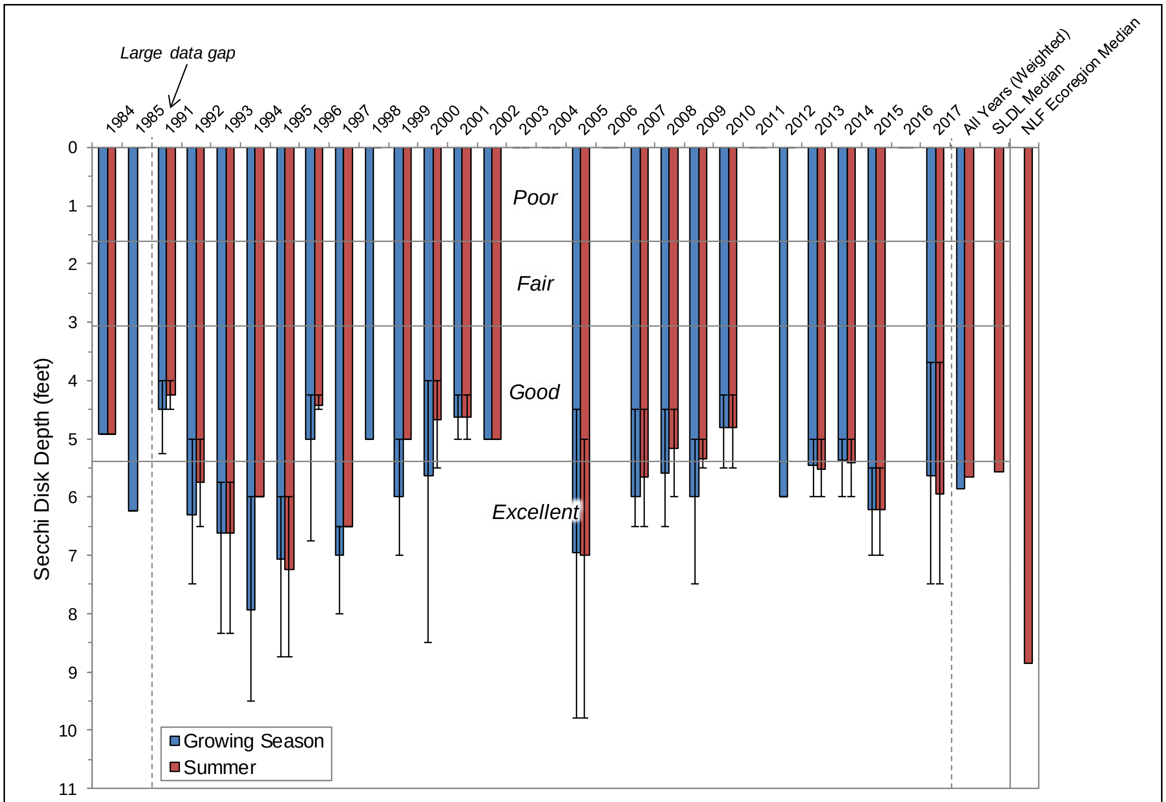


Figure 8.6.1-4. Rock Lake average annual Secchi disk depths and median Secchi disk depths for state-wide shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

To determine if internal nutrient loading (discussed in town-wide section of management plan) is a significant source of phosphorus in Rock Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on three occasions from Rock Lake in 2017 and once in 2018 (Figure 8.6.1-5). Near-bottom total phosphorus concentrations were similar to those measured at the surface on all sampling locations and were not elevated. This indicates that the release of phosphorus from bottom sediments in Rock Lake is not a significant source of phosphorus to the lake. Given that Rock Lake is a shallow lake, it does not stratify for long periods in the summer allowing anoxia to develop in bottom waters.

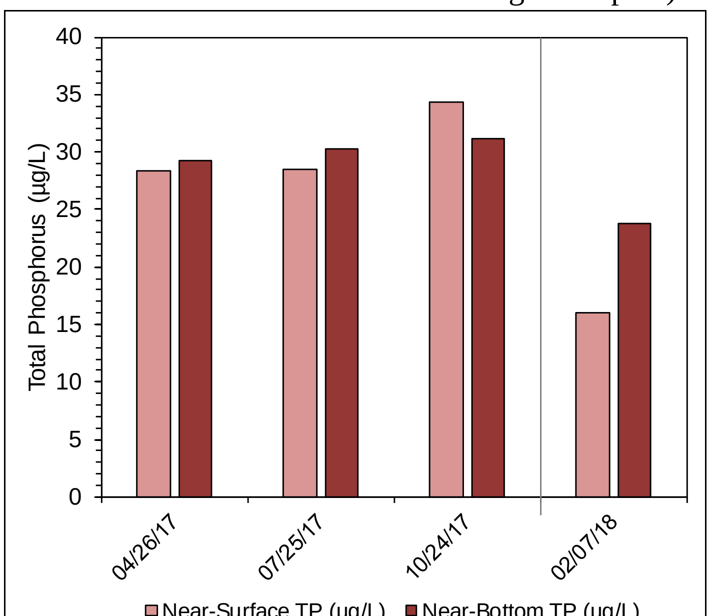


Figure 8.6.1-5. Rock Lake near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations measured in 2017 and 2018.

Rock Lake Trophic State

Figure 8.6.1-6 contains the Trophic State Index (TSI) values for Rock Lake calculated from the data collected in 2017 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency 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 for these three parameters are to one another indicates a higher degree of correlation. The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Rock Lake indicate the lake is at present in a lower eutrophic state. Rock Lake's productivity is similar to the productivity of other shallow lowland drainage lakes throughout Wisconsin and higher when compared to the productivity of all lake types within the NLF ecoregion. It should be noted that Rock Lake was likely naturally eutrophic prior to Euro-American settlement, and its eutrophic status is not believed to be the result of human activity.

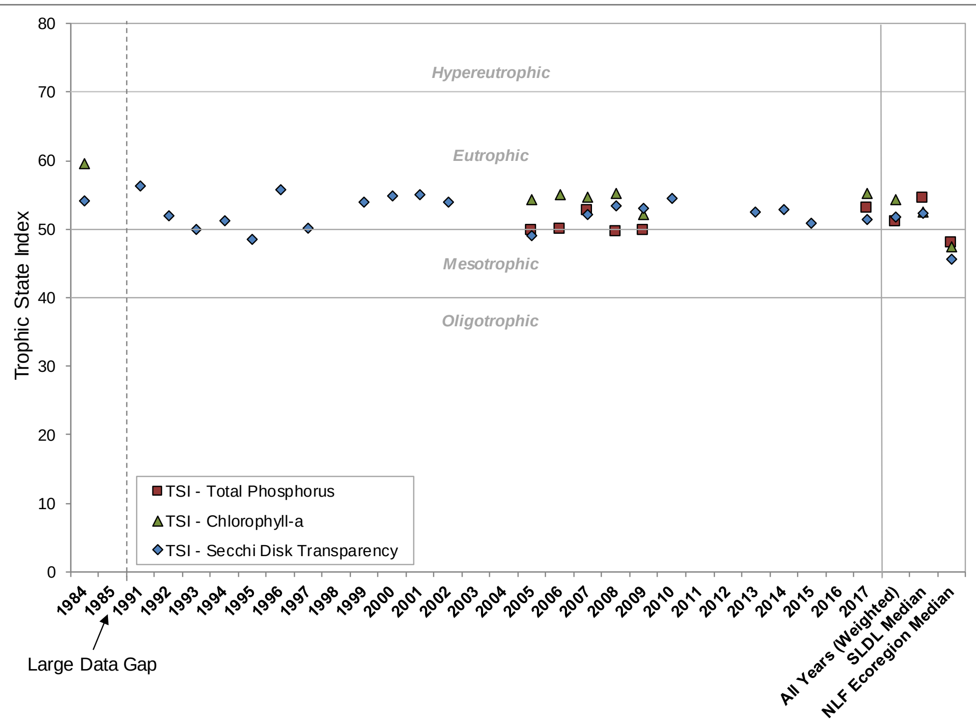


Figure 8.6.1-6. Rock Lake, statewide shallow lowland drainage lakes (SLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Rock Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling events conducted by Onterra ecologists. These data are displayed in Figure 8.6.1-7. The temperature and dissolved oxygen data collected in 2017 indicate that Rock Lake did not develop strong, thermal stratification during the summer. The lake's shallow nature facilitates wind-driven mixing of the water column and the lake does not experience strong stratification. The loss of oxygen leading to fish kills can occur in shallow, productive lakes in winter. Heavy snow over ice reduces light penetration, leading to a reduction in oxygen production through photosynthesis by plants and algae. In productive lakes, the decomposition of organic matter rapidly depletes available oxygen. With the ice preventing atmospheric diffusion of oxygen into the water, low or no oxygen conditions can develop leading to fish stress or mortality.

Dissolved oxygen concentrations measured under the ice in Rock Lake in 2018 were relatively low, ranging from 3.8 – 4.2 mg/L. While fish are able to survive at these lower levels of dissolved oxygen, these concentrations are approaching levels that can lead to fish stress and mortality. Given Rock Lake is a shallow, productive lake, these lower dissolved oxygen concentrations in winter are not unexpected. However, because Rock Lake possesses an inflowing tributary and is connected to downstream North Turtle Lake, fish are likely able to find sufficient oxygen levels in these areas in winter.

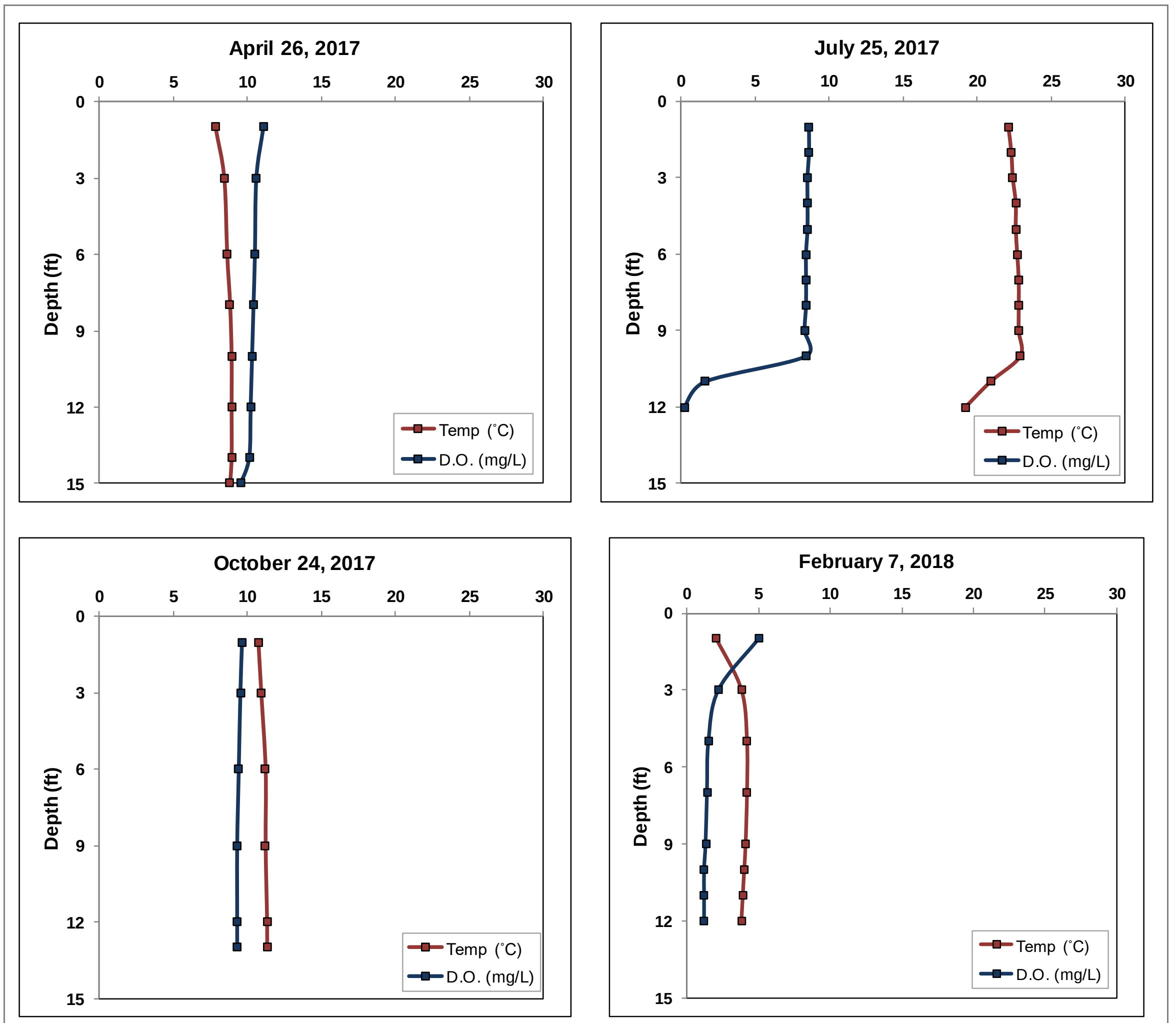


Figure 8.6.1-7. Rock Lake 2017/18 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from Rock Lake

The previous section is centered on parameters relating to Rock Lake's trophic state. 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 Rock Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. Rock Lake's mid-summer surface water pH was measured at 7.6 in 2017. This value indicates Rock Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Rock Lake's average alkalinity measured in 2017 was 30.7 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while Rock Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from Rock Lake in 2017 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and Rock Lake's pH falls within this range. Rock Lake's calcium concentration in 2017 was 8.8 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in Rock Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys.

Rock Lake was placed on the 303(d) list of impaired waterbodies for contaminated fish tissue by mercury in 1998. While mercury is found naturally in the environment due to volcanic eruptions and weathering of rocks, the majority of the mercury found in Wisconsin's waterbodies is the result of coal-fired power plants and the release of mercury into the atmosphere. Mercury is deposited into lakes, rivers, and streams through precipitation and the deposition of dust particles where it converted into its mobile and harmful form, methylmercury. Methylmercury becomes stored in bodies of aquatic animals, and concentrations tend to be highest in those species at the top of the food chain. In humans, mercury affects the nervous system and is of special concern for unborn children, infants, and children. For advice on eating fish from Rock Lake, please see the Rock Lake Fisheries Data Integration Section (Section 8.6.6).

8.6.2 Rock Lake Watershed Assessment

Rock Lake's surficial watershed encompasses approximately 3,624 acres (Figure 8.6.2-1 and Rock Lake – Map 2) yielding a watershed to lake area ratio of 28:1. Rock Lake's direct watershed is comprised of land cover types including forests (42%), wetlands (48%), open water (14%), rural open space (6%), pasture/grass (1%), and rural residential areas (<1%) (Figure 8.6.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Rock Lake's residence time is approximately 0.26 years, or the water within the lake is completely replaced approximately 3.8 times per year.

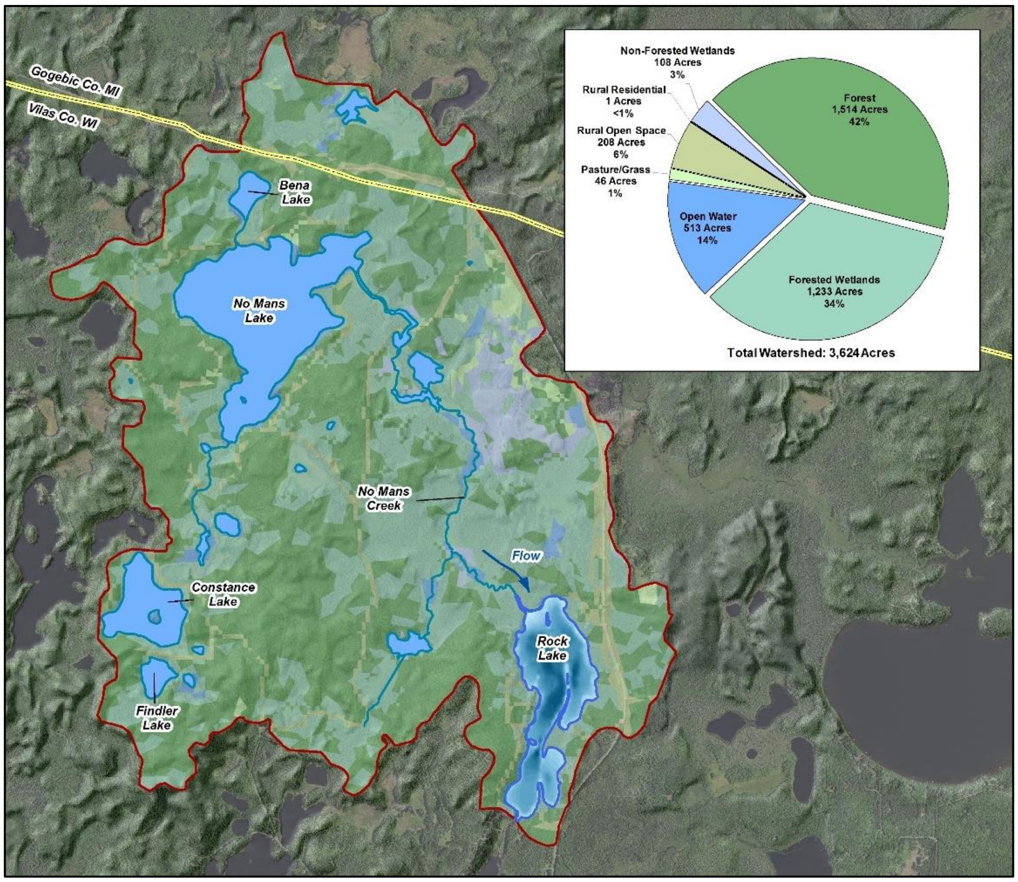


Figure 8.6.2-1. Rock Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

While total phosphorus data from upstream lakes are typically used for more accurate modeling, no phosphorus data are available from No Mans Lake. Using the land cover types within Rock Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Rock Lake from its watershed. In addition, data obtained from a stakeholder survey sent to Rock Lake riparian property owners in 2017 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that approximately 381 pounds of phosphorus are delivered to Rock Lake from its watershed on an annual basis (Figure 8.6.2-2).

Of the estimated 381 pounds of phosphorus being delivered to Rock Lake on an annual basis, approximately 154 lbs (40%) originate from wetlands, 121 lbs (32%) originate from forests, 68 lb (18%) originate from rural/open space and pasture/grass, 33 lbs (9%) originate from direct atmospheric deposition onto the lake's surface, and 4 lbs (1%) originate from riparian septic systems (Figure 8.6.2-2).

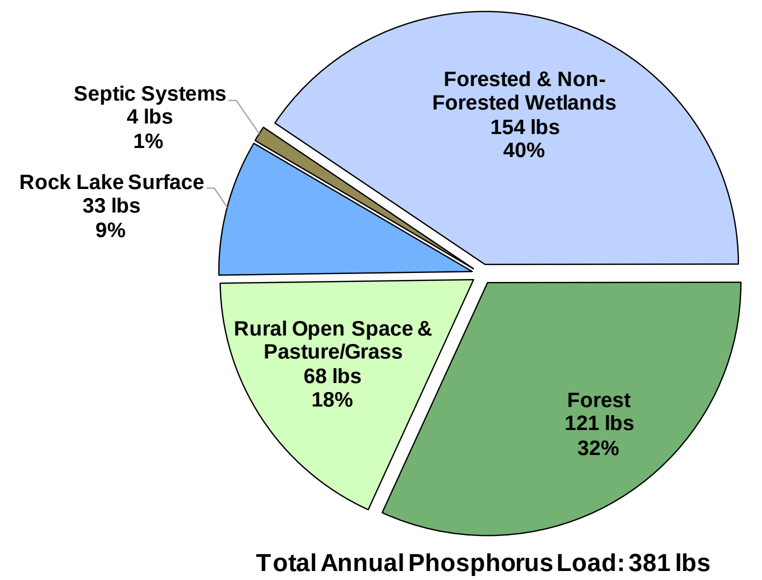


Figure 8.6.2-2. Rock Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 24 µg/L in Rock Lake. This predicted in-lake phosphorus concentration is nearly identical to the measured growing season phosphorus concentration of 25 µg/L. The similarity between predicted and measured concentrations is an indication that the watershed was modeled accurately and there are no significant sources of unaccounted phosphorus entering the lake.

8.6.3 Rock Lake Shoreland Condition

Shoreland Development

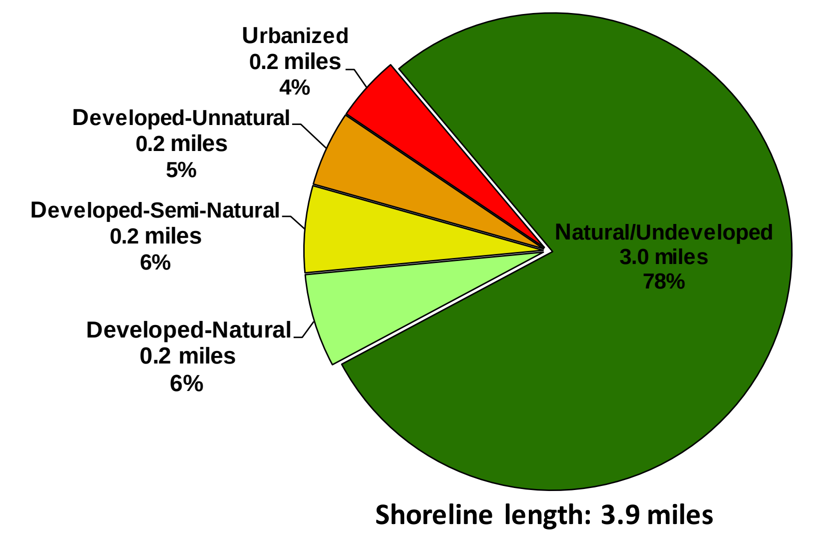


Figure 8.6.3-1. Rock Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on Rock Lake - Map 3.

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the fall of 2017, the immediate shoreland of Rock Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

The 2017 survey revealed that Rock Lake has stretches of shoreland that fit all five shoreland assessment categories (Figure 8.6.3-1). In total, 3.2 miles (84%) of the 3.9-mile shoreland zone were categorized as natural/undeveloped or developed-natural or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.4 miles (9%) of the shoreland was categorized as developed-unnatural or urbanized, shoreland areas which provide little benefit to and may actually adversely impact the lake. If restoration of Rock Lake's shoreland is to occur, primary focus should be placed on these highly developed shoreland areas. Rock Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on Rock Lake in 2017. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on Rock Lake, a total of 198 pieces were observed along 3.9 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 51:1 (Figure 8.6.3-2). Onterra ecologists have completed these surveys on 98 Wisconsin lakes since 2012, and Rock Lake falls in the 88th percentile for the number of coarse woody habitat pieces per shoreline mile.

Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in Rock Lake. The locations of these coarse woody habitat pieces are displayed on Rock Lake – Map 4.

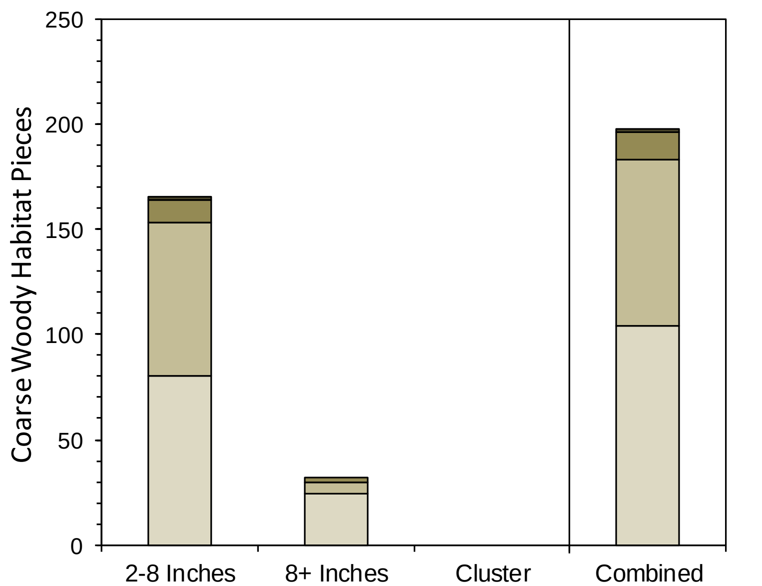


Figure 8.6.3-2. Rock Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of Rock Lake coarse woody habitat can be found on Rock Lake – Map 4.

8.6.4 Rock Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on Rock Lake on June 30, 2017. 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. Fortunately, no curly-leaf pondweed was located in Rock Lake in 2017, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. However, pale-yellow iris, a non-native wetland plant, was located in numerous locations along Rock Lake's shoreline in 2017. Because of its ecological significance, pale-yellow iris in Rock Lake is discussed further in the subsequent Non-Native Aquatic Plants subsection.

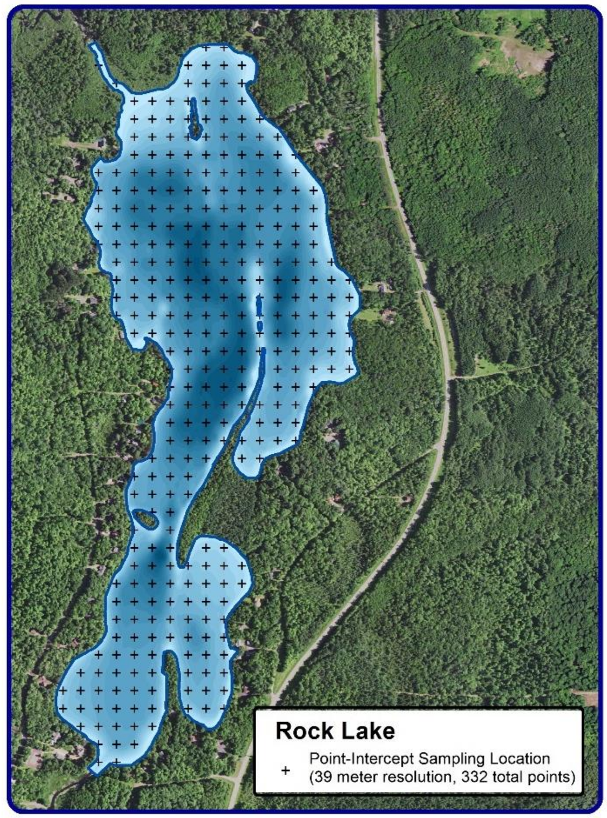


Figure 8.6.4-1. Rock Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on Rock Lake by Onterra ecologists on July 18 and 19, 2017 (Figure 8.6.4-1). During these surveys, a total of 43 aquatic plant species were located, one of which is considered to be a non-native, invasive species: pale-yellow iris (Table 8.6.4-1).

Lakes in Wisconsin vary in their morphometry, water chemistry, substrate composition, and management, all factors which influence aquatic plant community composition. In late September of 2017, Onterra ecologists completed an acoustic survey on Rock Lake (bathymetric results on Rock Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to Rock Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2017 acoustic survey showed that substrate hardness varies widely in shallow areas of Rock Lake with both the hardest and softest substrates in the lake occurring within 1.0-6.0 feet of water (Figure 8.6.4-2). The softer substrates occurred near the mouth of No Mans Creek on the north side of the lake and in the northern area the bay in the southeastern part of the lake. However, most of the shallower areas around the lake contained rock or sand. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.6.4-1. List of aquatic plant species located in Rock Lake during Onterra 2017 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Acorus americanus*	Sweetflag	7	I
	Carex utriculata	Common yellow lake sedge	7	I
	Decodon verticillatus	Water-willow	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Iris pseudacorus	Pale-yellow iris	Exotic	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Sparganium americanum	Eastern bur-reed	8	I
	Sparganium eurycarpum	Common bur-reed	5	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submersed	*Bidens beckii*	Water marigold	8	X
	Callitriche palustris	Common water starwort	8	I
	Ceratophyllum demersum	Coontail	3	X
	Ceratophyllum echinatum	Spiny hornwort	10	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Elodea nuttallii	Slender waterweed	7	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort spp.	8	X
	Lobelia dortmanna	Water lobelia	10	X
	Myriophyllum farwellii	Farwell's watermilfoil	9	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton berchtoldii	Slender pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	I
	Potamogeton foliosus	Leafy pondweed	6	I
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X

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

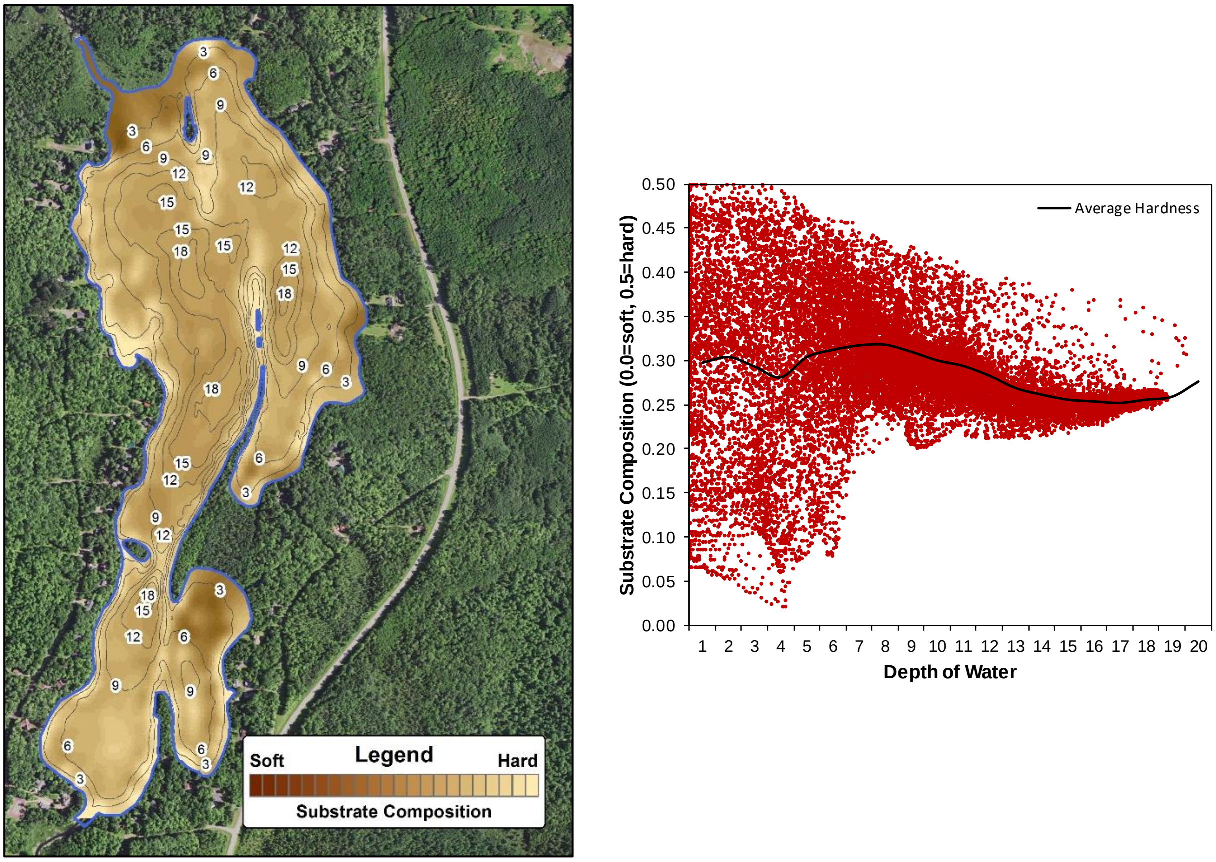


Figure 8.6.4-2. Rock Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Individual data points are displayed in red. Creating using data from September 2017 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2017 aquatic plant bio-volume data are displayed in Figure 8.6.4-3 and Rock Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2017 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 8 feet. However, the majority of aquatic plant growth occurs within 1.0-4.0 feet of water. The 2017 acoustic survey indicated approximately 18% of Rock Lake's area is occupied by aquatic vegetation, while the remaining 82% of the lake is too deep and light-limited to support aquatic plant growth.

As mentioned, aquatic plants were recorded growing to a maximum depth of 8 feet in 2017. Of the 146 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 39% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2017 indicates that 22% of the 146 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 11% had a TRF rating of 2, and 6% had a TRF rating of 3 (Figure 8.6.4-5). These data indicate that aquatic plant occurrence and density in Rock Lake is relatively low.

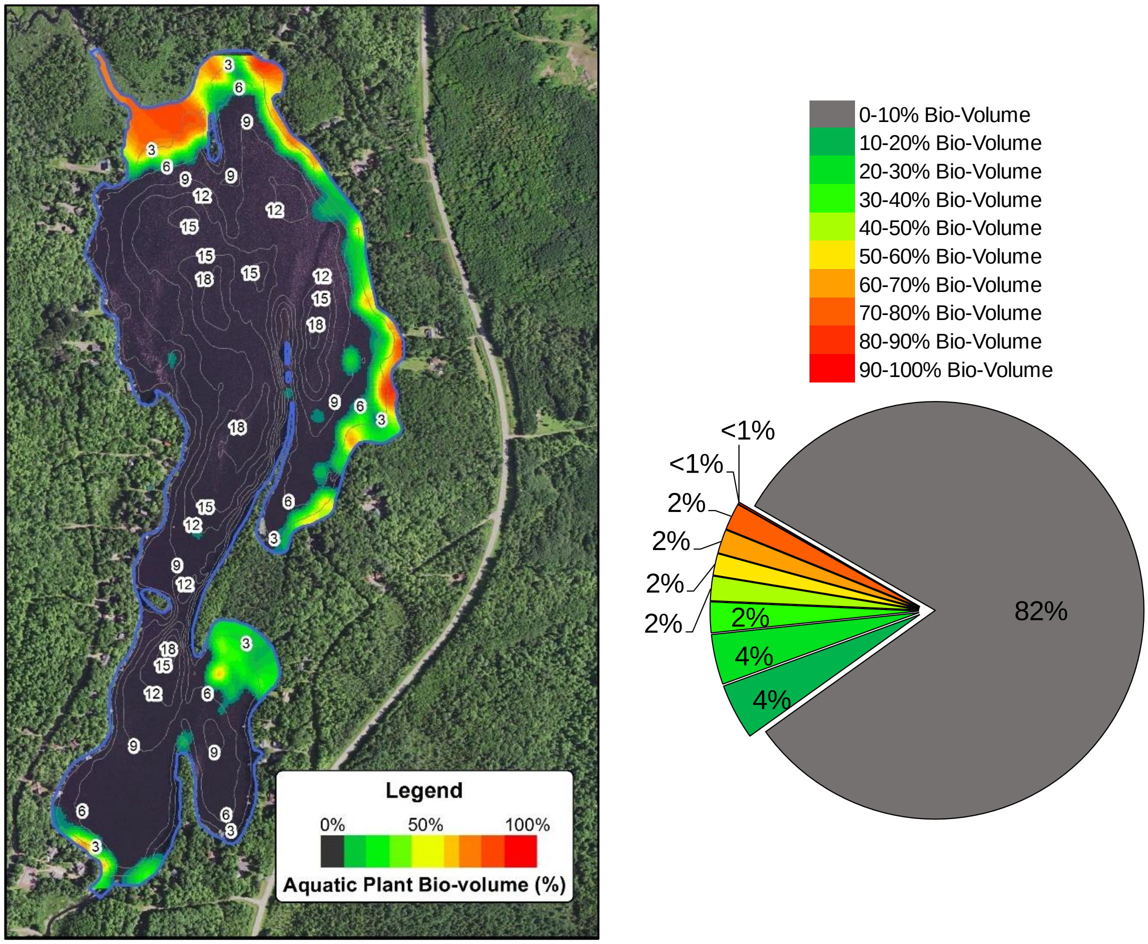


Figure 8.6.4-4. Rock Lake 2017 aquatic plant bio-volume. Created using data from September 2017 acoustic survey data.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Of the 43 aquatic plant species located in Rock Lake in 2017, 27 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.6.4-6). The remaining 16 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 27 species directly sampled with the rake during the point-intercept survey, fern-leaf pondweed, wild celery, and stoneworts were the three-most frequently encountered aquatic plant species (Figure 8.6.4-6).

Fern-leaf pondweed was the most frequently encountered aquatic plant species in Rock Lake in 2017 with a littoral frequency of occurrence of 18% (Figure 8.6.4-6). Fern-leaf pondweed is a common plant in softwater lakes in northern Wisconsin, and is often one of the most abundant. It can be found in shallow to deep water typically over soft sediments. Large beds of fern-leaf pondweed provide excellent structural habitat for aquatic wildlife and help to prevent the suspension of the soft bottom sediments in which they grow. In Rock Lake, fern-leaf pondweed was most abundant between 2.0 and 5.0 feet of water.

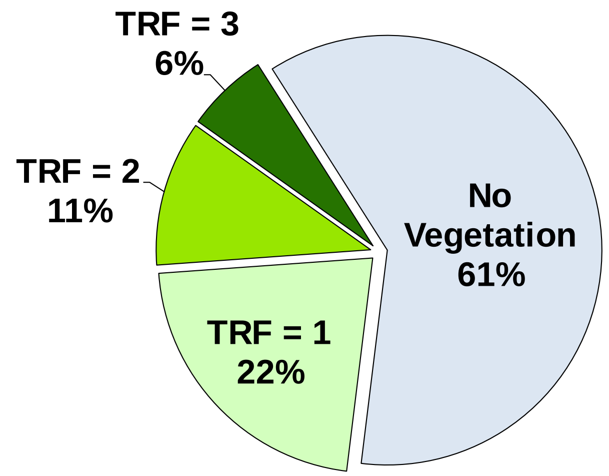


Figure 8.6.4-5. Rock Lake 2017 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2017 whole-lake point-intercept survey (N = 146).

Wild celery, also known as tape or eelgrass, was the second-most frequently encountered aquatic plant species in Rock Lake in 2017 with a littoral frequency of occurrence of 16% (Figure 8.3.4-6). Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. Rock Lake's areas of sand/cobble and low light conditions as a result of its stained water favor for abundance of wild celery. In 2017, wild celery was most abundant over hard substrates in water 2.0-4.0 feet deep.

Stoneworts, a genus of macroalgae, were the third-most frequently encountered aquatic plant in Rock Lake in 2017 with a littoral frequency of occurrence of 9% (Figure 8.3.4-6). Stoneworts can grow relatively large and form dense beds along the lake bottom, supplying oxygen to deeper waters and providing structural habitat for micro- and macroinvertebrates and fish. Little is known about the life histories and distribution of stonewort species in Wisconsin; however, it is known that stoneworts require high quality water and are indicators of good environmental health. Stoneworts were most abundant between 5.0 and 7.0 feet of water in Rock Lake.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.6.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.6.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum* sibiricum) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

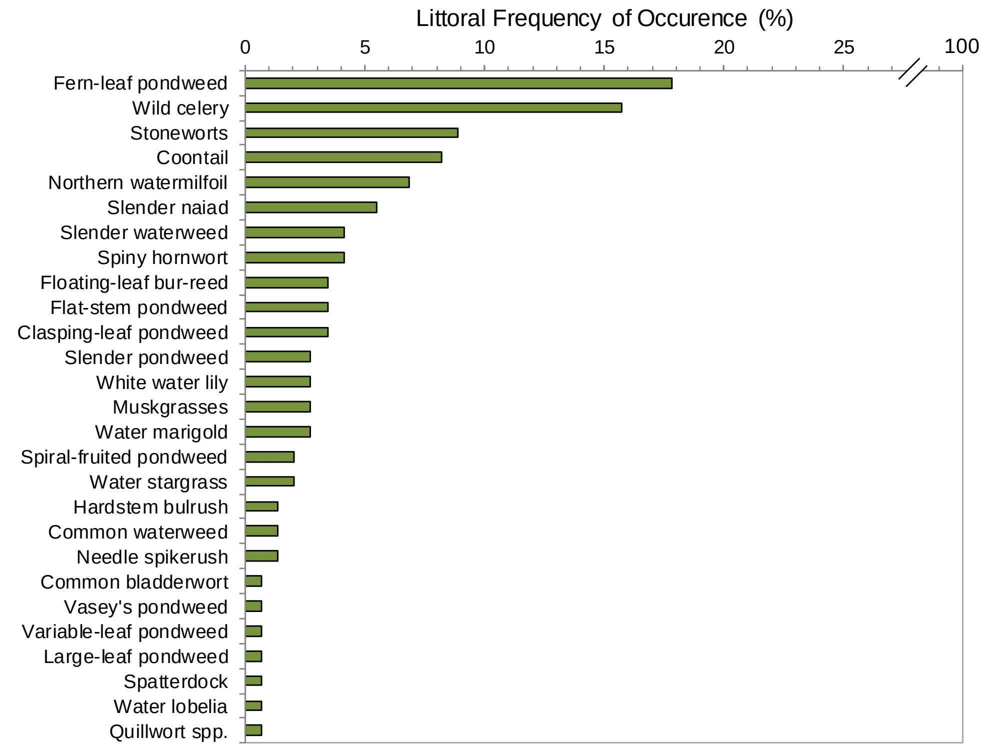


Figure 8.6.4-6. Rock Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data from 2017 whole-lake point-intercept survey.

Photo 8.6.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like Rock Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2017 point-intercept survey on Rock Lake and their conservatism values were used to calculate the FQI of Rock Lake's aquatic plant community (equation shown below).

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

Figure 8.6.4-7 compares the 2017 FQI components of Rock Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2017 (27) falls above the median value for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The average conservatism of the 27 native aquatic plant species located in Rock Lake in 2017 was 6.9, exceeding the median average conservatism values for lakes within the NLFL ecoregion (6.7) and lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of Rock Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

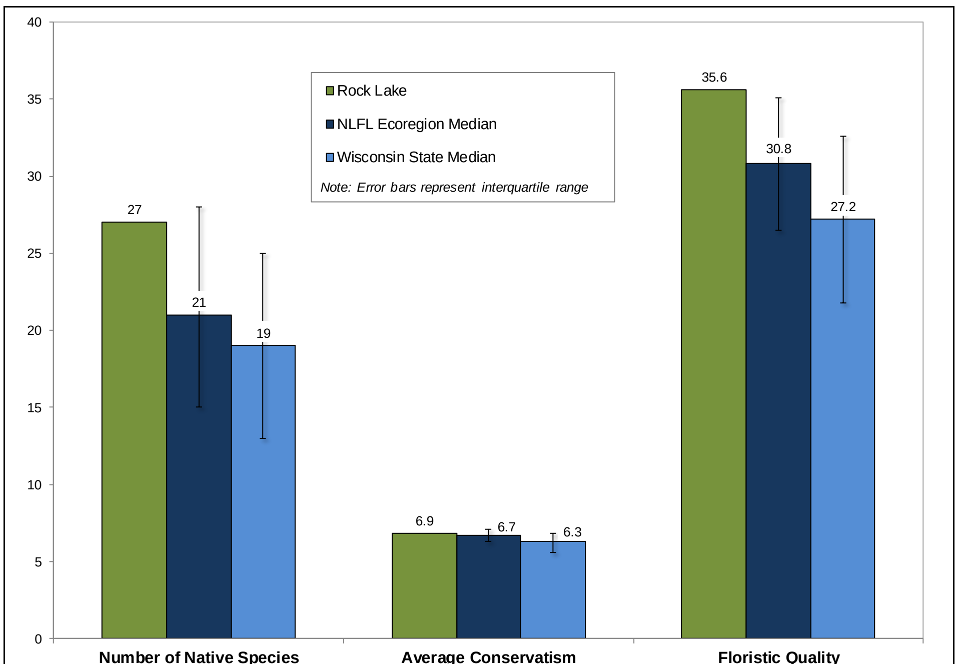


Figure 8.6.4-7. Rock Lake Floristic Quality Assessment. Created using data from Onterra 2017 whole-lake point-intercept survey. Analysis follows Nichols (1999).

Using Rock Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 35.6 (Figure 8.6.4-7). Rock Lake's FQI value exceeds the median values for lakes within the NLFL ecoregion (30.8) and the state (27.2). Overall, the FQI analysis indicates that the aquatic plant community found in Rock Lake is of higher quality than the majority of lakes within the NLFL ecoregion and lakes throughout the state.

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because Rock Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Rock Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.6.4-8). Using the data collected from the 2017 point-intercept survey, Rock Lake's aquatic plant was found to have high species diversity with a Simpson's Diversity Index value of 0.92. In other words, if two individual aquatic plants were randomly sampled from Rock Lake in 2017, there would be a 92% probability that they would be different species. Rock Lake's Simpson's Diversity value exceeds the upper quartiles for lakes in the NLFL ecoregion and lakes throughout Wisconsin.

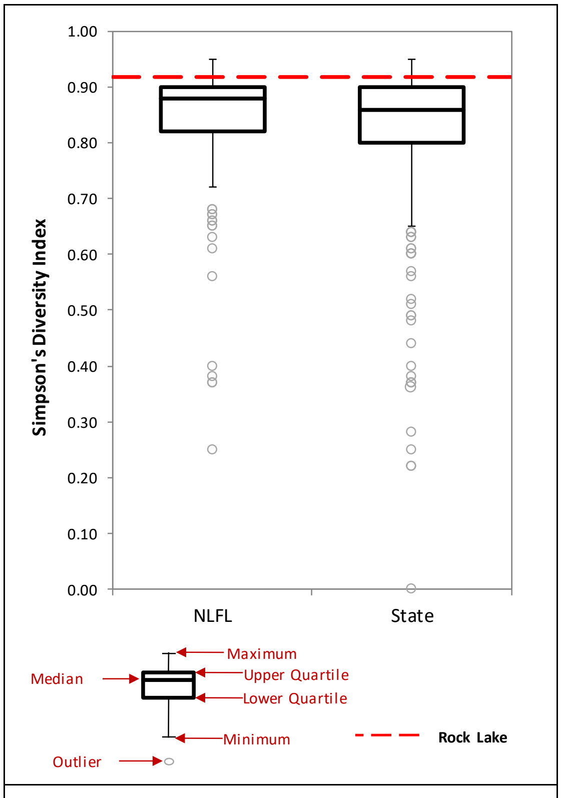


Figure 8.6.4-8. Rock Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

One way to visualize Rock Lake's high species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. 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 fern-leaf pondweed was found at 18% of the littoral sampling locations in Rock Lake in 2017, its relative frequency of occurrence was 17%. Explained another way, if 100 plants were randomly sampled from Rock Lake in 2017, 17 of them would be fern-leaf pondweed. Rock Lake contains a wide array of habitat types in terms of substrate composition and sheltered versus open water. The variety of habitat types in Rock Lake allows the lake to support a higher number of species and also increases diversity.

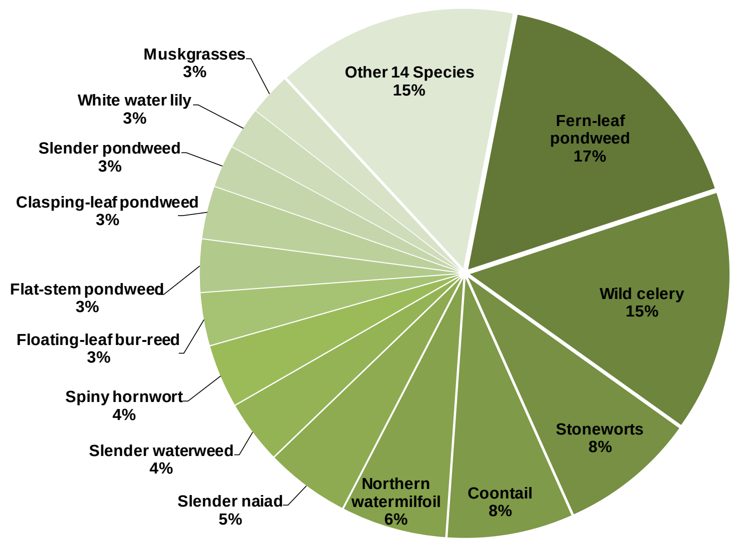


Figure 8.6.4-9. Rock Lake 2017 relative frequency of occurrence of aquatic plant species. Created using data from 2017 point-intercept survey.

In 2017, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in Rock Lake. This survey revealed Rock Lake contains approximately 11 acres of these communities comprised of 16 plant species (Rock Lake – Map 7 and Table 8.6.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Rock Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.6.4-2. Rock Lake 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2017 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	3.8
Floating-leaf	4.7
Mixed Emergent & Floating-leaf	2.4
Total	**11.0**

Non-native Aquatic Plants in Rock Lake

Pale-Yellow Iris

Pale yellow iris (*Iris pseudacorus*; Photo 8.6.4-4 and Rock Lake – Map 8) 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 was located growing along the shorelines of Rock Lake by NLDC and Onterra staff in 2017 (Rock Lake – Map 7). There are a number of control strategies that can be used to control pale-yellow iris. A strategy for managing pale-yellow iris on Rock Lake is discussed within the Turtle Chain Implementation Plan.

Photo 8.6.4-4. Pale-yellow iris (*Iris pseudacorus*), a non-native, invasive wetland plant found along the shorelines of Rock Lake in 2017. Photo credit Onterra.

8.6.5 Aquatic Invasive Species in Rock Lake

As of 2017, the only non-native species documented in Rock Lake is pale-yellow iris (*Iris pseudacorus;* discussed in previous section). However, the non-native rusty crayfish (*Orconectes rusticus*) has been documented in downstream North Turtle Lake, and it is likely that rusty crayfish are present in Rock Lake. Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact. While it is possible these species are present in Rock Lake, their presence has not been officially verified.

8.6.6 Rock Lake 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 Rock Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2017 & GLIFWC 2017).

Rock Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in Rock Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae, 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 8.6.6-1.

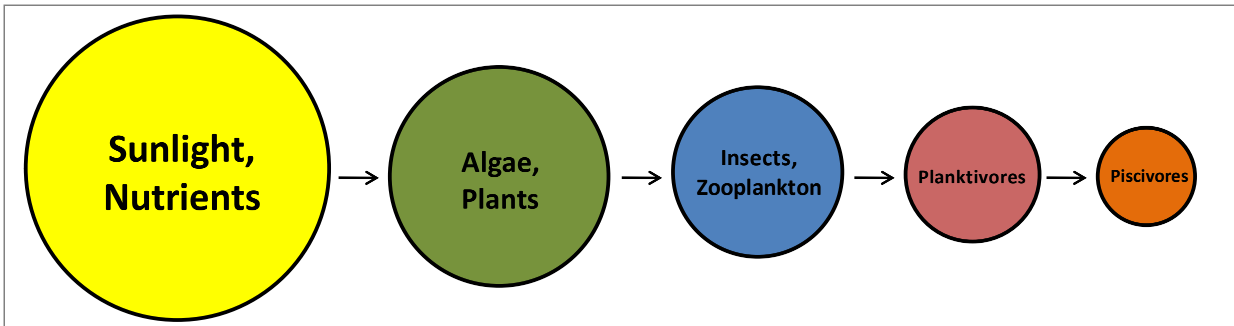


Figure 8.7.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section (Section 8.6.1), Rock Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means Rock Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 8.6.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past surveys of Rock Lake include common shiner (*Luxilus cornutus*), golden shiner (*Notemigonus crysoleucas*), greater redhorse (*Moxostoma valenciennesi*), and white sucker (*Catostomus commersonii*).

Table 8.6.6-1. Gamefish present in Rock Lake 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
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, 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 8.6.6-1). 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 electroshocking (Photograph 8.6.6-1). This is often done 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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 these data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 8.6.6-1. 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 fry, fingerling, or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 8.6.6-2). Stocking of 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. Rock Lake was stocked from 1972 to 1974 with walleye (Table 8.6.6-2).

Photograph 8.6.6-2. Fingerling Walleye. Photo courtesy of WDNR.

Table 8.6.6-2. Stocking data available for walleye in Rock Lake (1972-1974).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Walleye	Unspecified	Fingerling	3,000	3
1974	Walleye	Unspecified	Fingerling	3,000	3

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second-most important reason for owning property on or near Rock Lake (Question #17). Figure 8.6.6-2 displays the fish that Rock Lake stakeholders enjoy catching the most, with walleye and crappie being the most popular. Approximately 76% of these same respondents believed that the quality of fishing on the lake was either fair or poor (Figure 8.6.6-3). Approximately 70% of respondents who fish Rock Lake believe the quality of fishing has been somewhat or much worse since they started fishing the lake (Figure 8.6.6-3).

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. Creel surveys were completed on Rock, South Turtle and North Turtle Lakes during the 1991-92 and 2010-11 fishing seasons (Table 8.6.6-5).

Total angler effort was somewhat higher in 1991-92 (20.5 hours/acre) compared to the 2010-11 season (18.1 hours/acre). Anglers directed the largest amount of effort towards walleye and muskellunge during both the 2010-11 and 1991-92 seasons (Table 8.6.6-5).

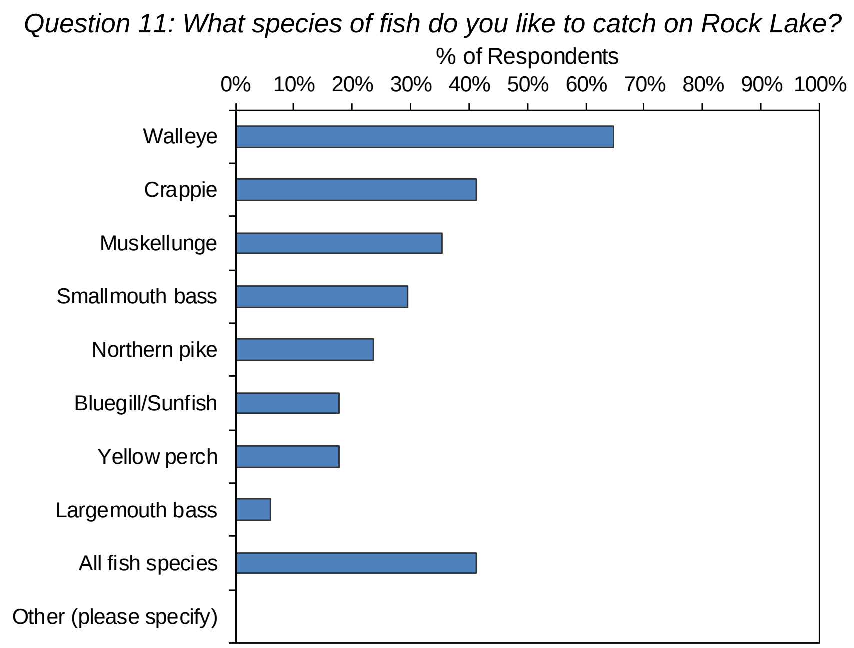


Figure 8.6.6-2. Stakeholder survey response Question 11. Created based on data from 19 respondents of 52 surveys sent (37%).

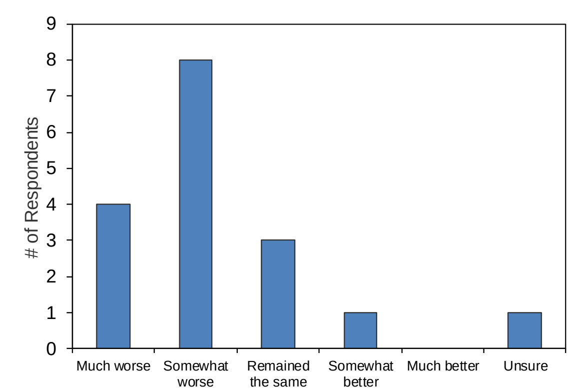


Figure 8.6.6-3. Stakeholder survey responses to questions 12 and 13. Created based on data from 19 respondents of 52 surveys sent (37%).

Table 8.6.6-5. Creel Survey data for 1991-92 and 2010-11 fishing seasons.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Largemouth Bass	1991	20.5	0	0	0	0	0		
	2010	18.1	0.9	30	0.1	0	0	11.3	
Muskellunge	1991	20.5	6.7	84	0.2	0	0	45.5	
	2010	18.1	6	95	0.3	0	0	31.7	
Northern Pike	1991	20.5	0.6	62	0.2	11	0	36.2	
	2010	18.1	0.5	51	0.1	5	0	5.6	
Smallmouth Bass	1991	20.5	0.7	179	0.5	33	0.1	5.7	32.2
	2010	18.1	1.9	484	1.3	19	0.1	1.9	67.1
Walleye	1991	20.5	11.3	4457	12.1	117	0.3	0.9	37.5
	2010	18.1	10.2	2501	6.8	1249	3.4	1.5	3

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above 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 are analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present in Rock Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on Rock Lake (Figure 8.6.6-2). A 2010 WDNR fisheries survey conducted on Rock Lake showed a low density of walleye (WDNR 2010).

Panfish

Panfish (crappie) are the most sought-after panfish in Rock Lake according the stakeholder survey. The WDNR 2010 fisheries survey found abundant populations of yellow perch with moderate numbers of black crappie and bluegill (WDNR 2010).

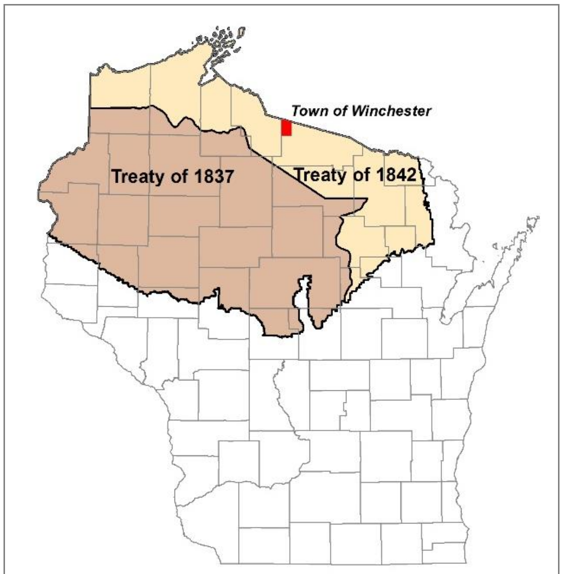


Figure 8.6.6-4. Location of Town of Winchester within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Rock Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.6.6-4). Rock Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory.

While within the ceded territory, Rock Lake has not experienced a spearfishing harvest. A small quota for walleye harvest has been listed for the Rock Lake in recent years; however, no spearing efforts have been undertaken.

Rock Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, evade 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 have substrates largely comprised of sand and rock 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 do 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 over soft sediments as well. According to the point-intercept survey conducted by Onterra in 2017, 78% of the substrate sampled in the littoral zone of Rock Lake were soft sediments, 16% was composed of rock, and 6% were composed of sand sediments.

Woody Habitat

As discussed in the Shoreland Condition section (Section 8.6.3), 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 over 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 2006). A fall 2017 survey completed on Rock Lake documented 198 pieces of coarse woody along the shores of Rock Lake, resulting in a ratio of approximately 51 pieces per mile of shoreline. When compared to the other 98 lakes Onterra has completed coarse woody habitat surveys on since 2012, Rock Lake falls in the 88th percentile for the number of course woody habitat pieces per shoreline mile.

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. 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 8.6.6-3). 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 other partner contributions.

Photograph 8.6.6-3. Examples of fish sticks (left) and half-log habitat structures (right). (Photos by WDNR).

Fish cribs are a fish habitat structure that are placed on the lakebed. Installing fish cribs may 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. Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 8.6.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 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 are spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline and are mainly installed to enhance 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 indicated the addition of rock substrate did not significantly improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structures in a lake does not require 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. The Town of Winchester should 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 Rock Lake.

Regulations

Regulations for Rock Lake gamefish species as of April 2018 are displayed in Table 8.6.6-4. 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 8.6.6-4. WDNR fishing regulations for Rock Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	None but only 1 fish over 14" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 3 hooks, baits, or lures maximum per boat.

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.

As discussed in the Rock Lake Water Quality section (Section 8.6.1), Rock Lake was placed on the 303(d) list of impaired waterbodies for contaminated fish tissue by mercury in 1998. General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.6.6-5. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

Figure 8.6.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

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

Please note that study methods and explanations of analyses for North Turtle Lake can be found within the Town of Winchester Town-wide Management Plan document.

8.7 North Turtle Lake

An Introduction to North Turtle Lake

North Turtle Lake, Vilas County, is a 368-acre deep lowland (two-story), brown-water, mesotrophic drainage lake with a maximum depth of 51 feet and a mean depth of 21 feet (North Turtle Lake – Map 1). Its surficial watershed encompasses approximately 12,901 acres across portions of Vilas County, WI and Gogebic County, MI. Primary tributaries flowing into North Turtle Lake include Rock Creek from the north and Rainbow Creek from the northeast. North Turtle Lake drains into the northern portion of South Turtle Lake and the Turtle River. In 2017, 35 native aquatic plant species were located within the lake, of which wild celery (*Vallisneria americana*) was the most common. The non-native, invasive wetland plant pale-yellow iris (*Iris pseudacorus*) was located in a few locations along North Turtle Lake's shoreline in 2017. To date, rusty crayfish (*Orconectes rusticus*) have been the only other non-native species documented in North Turtle Lake.

Lake at a Glance - North Turtle Lake

Morphometry	
LakeType	Deep Lowland Drainage (Two-Story)
Surface Area (Acres)	368
Max Depth (feet)	51
Mean Depth (feet)	21
Perimeter (Miles)	5.6
Shoreline Complexity	4.4
Watershed Area (Acres)	12,901
Watershed to Lake Area Ratio	34:1
Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	16
Avg Summer Chl-α (µg/L)	5
Avg Summer Secchi Depth (ft)	8.4
Summer pH	7.6
Alkalinity (mg/L as $CaCO_3$)	30
Vegetation	
Number of Native Species	35
NHI-Listed Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Species	Pale-yellow Iris (*Iris pseudacorus*)
Average Conservatism	6.8
Floristic Quality	27.0
Simpson's Diversity (1-D)	0.86

Descriptions of these parameters can be found within the town-wide portion of the management plan

8.7.1 North Turtle Lake Water Quality

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

In 2017, a stakeholder survey was sent to 116 North Turtle Lake riparian property owners. Forty-five (39%) of these 116 surveys were completed and returned. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of North Turtle Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about North Turtle Lake's current water quality, 82% of the respondents indicated the water quality is *good* or *excellent*, 16% indicated the water quality is *fair*, and 2% indicated the water quality is *poor* (Figure 8.7.1-1). When asked how water quality has changed in North Turtle Lake since they first visited the lake, 80% of respondents indicated water quality has *remained the same*, 2% indicated it has *somewhat improved*, 9% indicated the water quality has *somewhat degraded*, 2% indicated it has *severely degraded*, and 7% were unsure (Figure 8.7.1-1).

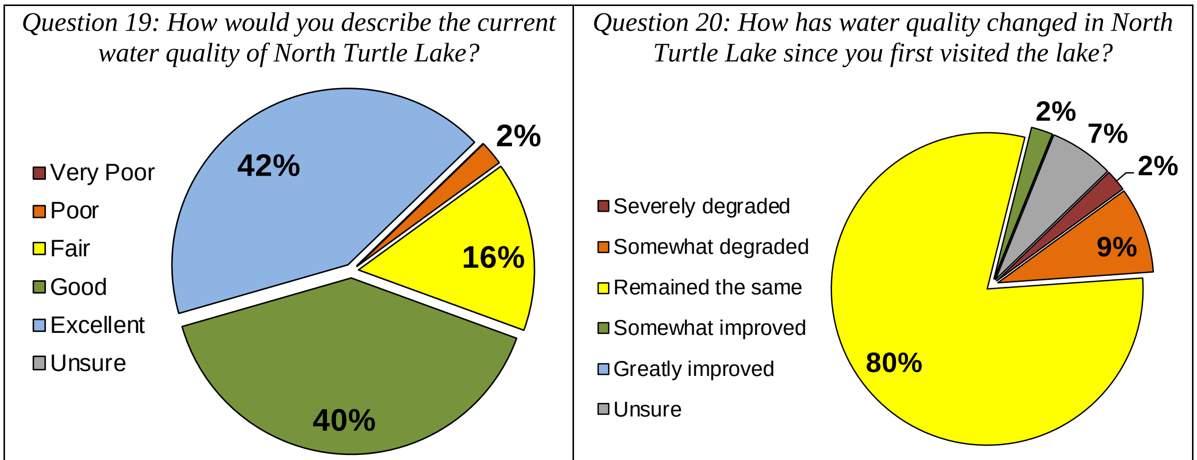


Figure 8.7.1-1. North Turtle Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 45 (39%) respondents of 116 surveys distributed.

As is discussed in the Town-Wide Report, two-story lakes like North Turtle Lake are deep lakes which thermally stratify during the summer and have the potential to support a cold, oxygenated hypolimnion (bottom waters) and coldwater fish populations (e.g. cisco, lake trout). Maintaining sufficient oxygen within the deep, cold waters of the hypolimnion in summer is essential if coldwater fish populations are to survive. Higher levels of nutrients and therefore biological production/decomposition can result in an increased rate of oxygen demand and a loss of oxygen from bottom waters in summer. Because of this, two-story lakes have the most stringent phosphorus thresholds of Wisconsin's lakes to ensure that this coldwater habitat is preserved.

Near-surface total phosphorus data for North Turtle Lake are available from 1985, 1993-2009, and 2012-2017 (Figure 8.7.1-2). Average summer total phosphorus concentrations have been somewhat variable from year to year, but overall have been relatively stable over the time period for which data are available. The weighted average summer total phosphorus concentration is 16 µg/L, falling into the *good* category for Wisconsin's two-story lakes. The average summer phosphorus concentration in 2017 was slightly above average at 18 µg/L, likely due to increased runoff from above-average precipitation. Precipitation data obtained from nearby Manitowish Waters indicates precipitation in 2017 was four inches above average. North Turtle Lake's phosphorus concentrations are lower than the median concentration for deep lowland drainage lakes in Wisconsin (23 µg/L) and lower than the median for all lake types within the Northern Lakes and Forests (NLF) ecoregion (21 µg/L). Trends analysis indicates there are no statistically valid trends (positive or negative) in total phosphorus concentrations over time in North Turtle Lake.

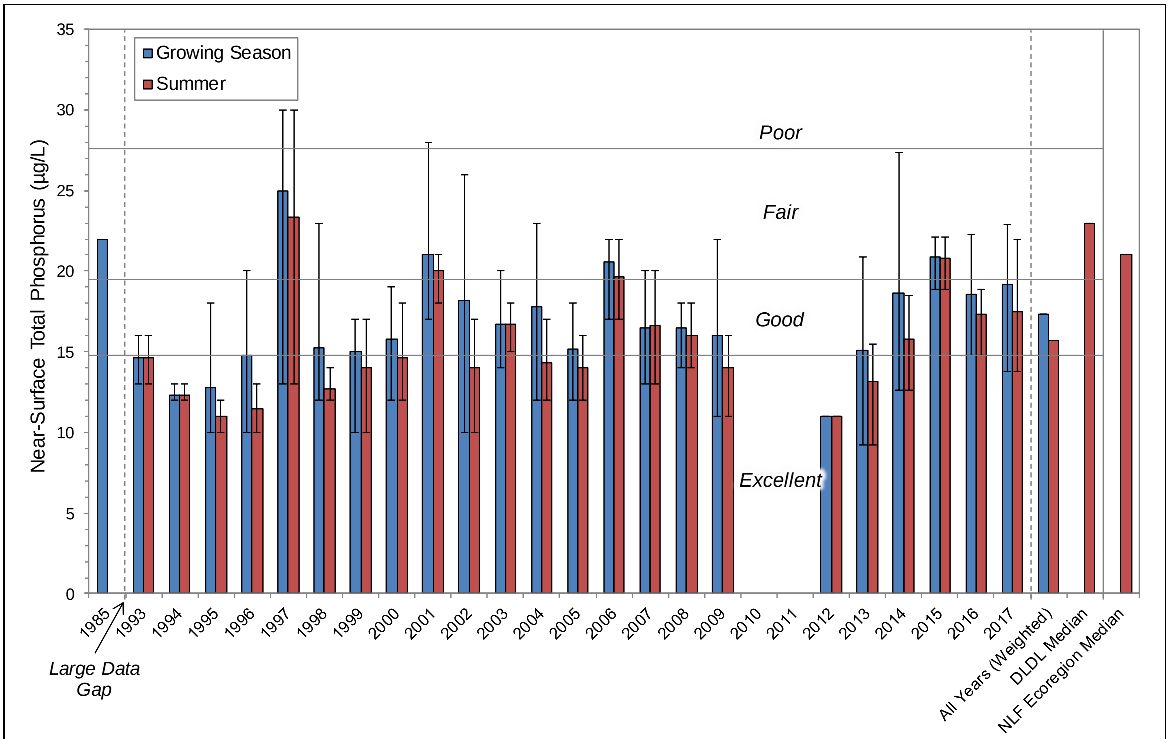


Figure 8.7.1-2. North Turtle Lake average annual near-surface total phosphorus concentrations, thresholds for two-story lakes, and median near-surface total phosphorus concentrations for deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from North Turtle Lake from 1984, 1993-2009, and 2012-2017 (Figure 8.7.1-3). Like total phosphorus concentrations, average summer chlorophyll-*a* concentrations are somewhat variable from year to year, ranging from 1.5 µg/L in 1995 to 10.7 µg/L in 2014. The weighted average summer chlorophyll-*a* concentration is 5.4 µg/L, straddling the line between *good* and *fair* for two-story lakes in Wisconsin. Summer chlorophyll-*a* concentrations in 2017 were slightly below average at 5.1 µg/L. North Turtle Lake's average summer chlorophyll-*a* concentration is lower than the median concentration for Wisconsin's deep lowland drainage lakes (7.0 µg/L) and lower than the median concentration for all lake types within the NLF ecoregion (5.6 µg/L). Like total phosphorus, trends analysis indicates no statistically valid trends (positive or negative) in chlorophyll-*a* concentrations are occurring over time in North Turtle Lake.

Secchi disk transparency data from North Turtle Lake are available from 1984-1985, 1991-2015, and 2017 (Figure 8.7.1-4). These data indicate water clarity has remained relatively stable over this time period. The weighted summer average Secchi disk depth is 8.4 feet, falling into the *good* category for two-story lakes in Wisconsin. North Turtle Lake's average summer Secchi disk depth is slightly below the median depth for Wisconsin's deep lowland drainage lakes (8.5 feet) and the median depth for all lake types within the NLF ecoregion (8.9 feet). Average summer Secchi disk depth in 2017 was 6.3 feet, over two feet below average. Given chlorophyll-*a* concentrations were below average in 2017, this indicates a factor other than increased algal production resulted in lower water clarity in 2017. As is discussed further, the lower water clarity was likely a result of higher concentrations of dissolved organic compounds entering the lake due to increased precipitation in 2017. Trends analysis of North Turtle Lake's Secchi disk data indicates no statistically valid trends (positive or negative) in water clarity are occurring over time.

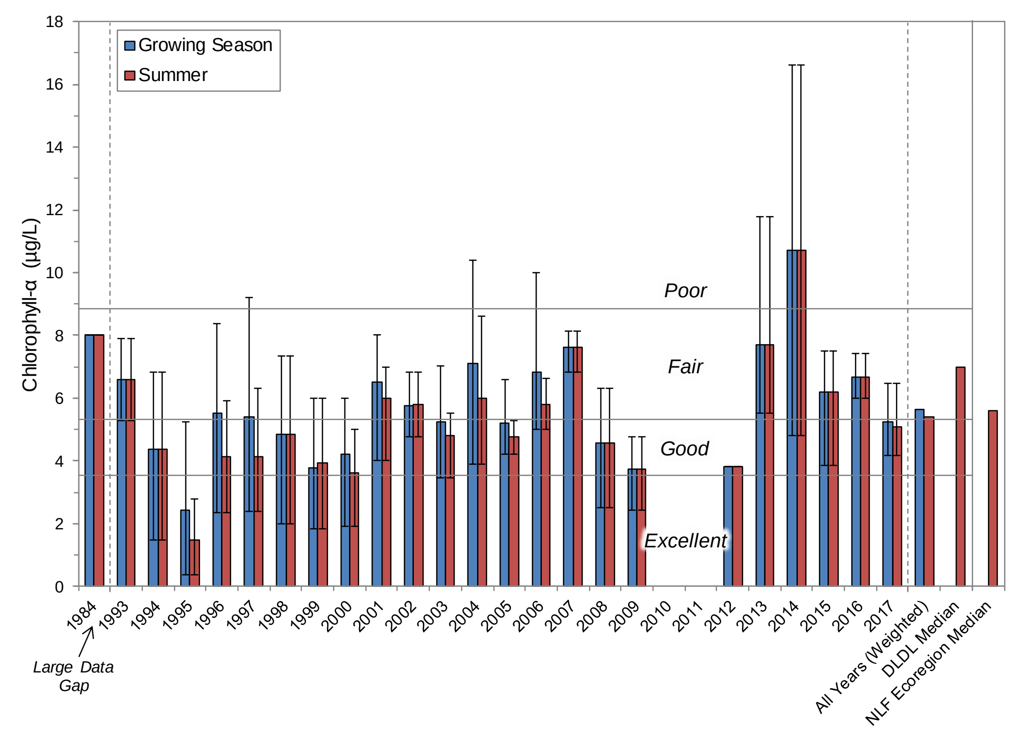


Figure 8.7.1-3. North Turtle Lake average annual chlorophyll-α concentrations, thresholds for two-story lakes, and median chlorophyll-α concentrations for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Abiotic suspended particulates, such as sediment, can also cause a reduction in water clarity. However, *total suspended solids*, a measure of both biotic and abiotic suspended particles within the water, were low in North Turtle Lake in 2017 indicating minimal amounts of suspended material within the water. While suspended particles are minimal in North Turtle Lake, water clarity can also be influenced by dissolved compounds within the water. 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 of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from North Turtle Lake in 2017 averaged 40 SU (standard units), indicating the lake's water is *lightly tea-colored* to *tea-colored*. Higher precipitation in 2017 likely resulted in a higher concentration of these dissolved organic acids in the lake, reducing water clarity below average. It is important to note that the tea-colored water in North Turtle Lake is natural, and is not an indication of degraded conditions.

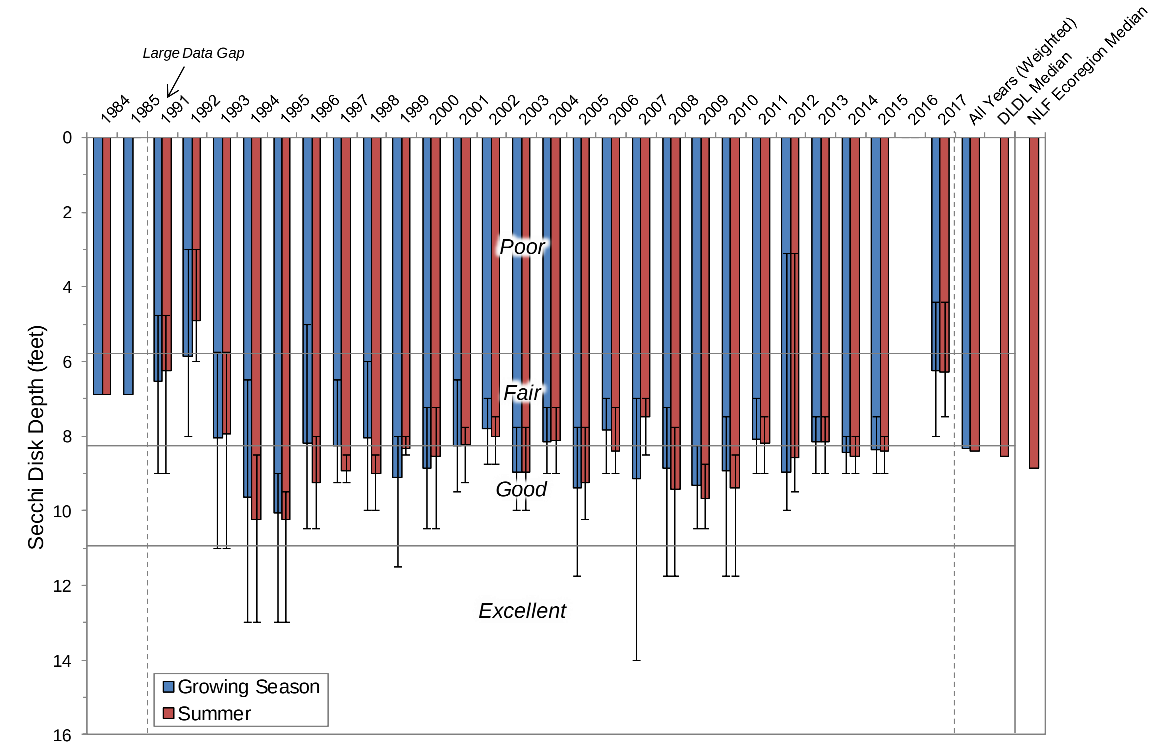


Figure 8.7.1-4. North Turtle Lake average annual Secchi disk depths, thresholds for two-story lakes, and median Secchi disk depths for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

To determine if internal nutrient loading (discussed in town-wide section of management plan) is a significant source of phosphorus in North Turtle Lake, near-bottom phosphorus concentrations are compared against those collected from the near-surface. Near-bottom total phosphorus concentrations were measured on three occasions from North Turtle Lake in 2017 and once in 2018 (Figure 8.7.1-5). Near-surface and near-bottom total phosphorus concentrations are also available from 1993, 1994, 1995, and 1996. These data indicate that near-bottom concentrations were higher when compared to surface concentrations during summer stratification. However, these bottom concentrations are relatively low and indicate the internal loading of phosphorus is not a significant source of phosphorus to North Turtle Lake.

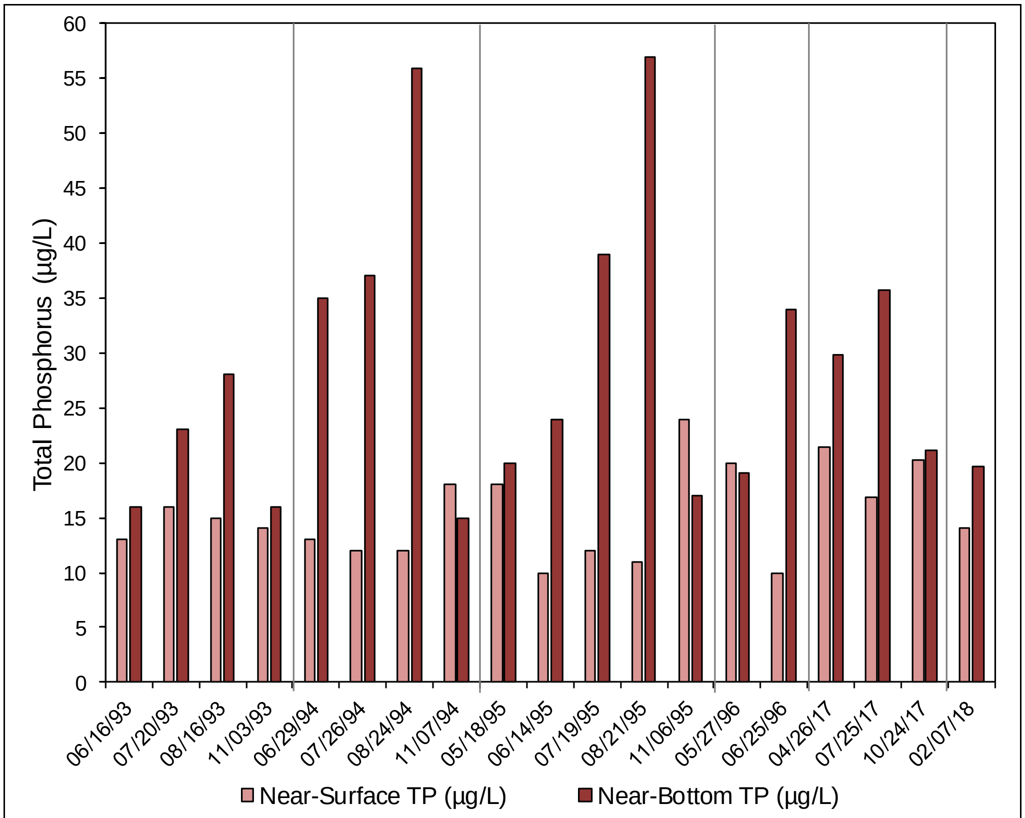


Figure 8.7.1-5. North Turtle Lake near-bottom total phosphorus concentrations and corresponding near-surface total phosphorus concentrations measured in 2017 and 2018.

North Turtle Lake Trophic State

Figure 8.7.1-6 contains the Trophic State Index (TSI) values for North Turtle Lake calculated from the data collected in 2017 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency 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 for these three parameters are to one another indicates a higher degree of correlation. The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in North Turtle Lake indicate the lake is at present in a mesotrophic state. North Turtle Lake's productivity is lower when compared to other deep lowland drainage lakes in Wisconsin and to other lakes within the NFL ecoregion.

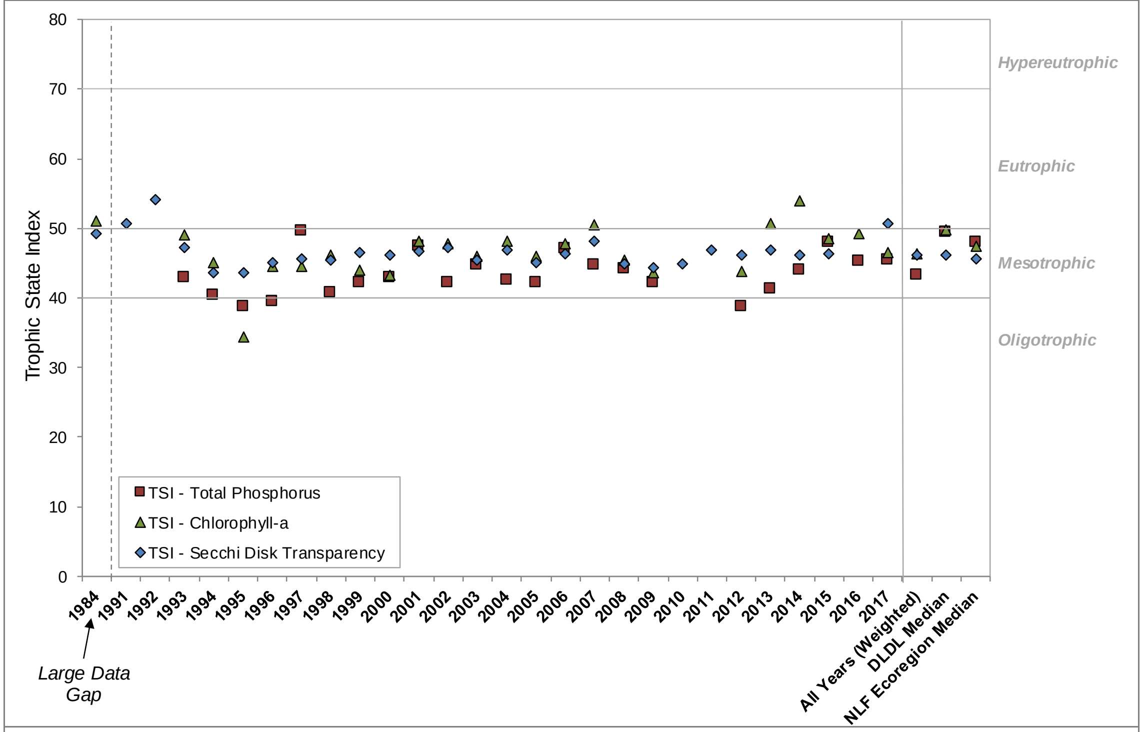


Figure 8.7.1-6. North Turtle Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in North Turtle Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling events conducted by Onterra ecologists and North Turtle Lake CLMN volunteers. These data are displayed in Figure 8.7.1-7. The temperature and dissolved oxygen data collected in 2017 indicate that North Turtle Lake developed and maintained thermal stratification over the summer, and the hypolimnion remained largely oxygenated over this period (two-story lake). Water of 30 feet and deeper began experiencing anoxic conditions in September but became oxygenated again with fall mixing. Dissolved oxygen concentrations measured through the ice in February of 2018 indicate there was sufficient oxygen (6.3 – 11.5 mg/L) throughout the entire water column to support aquatic life. Being a deeper lake, winter fish kills due to low oxygen are not a concern on North Turtle Lake.

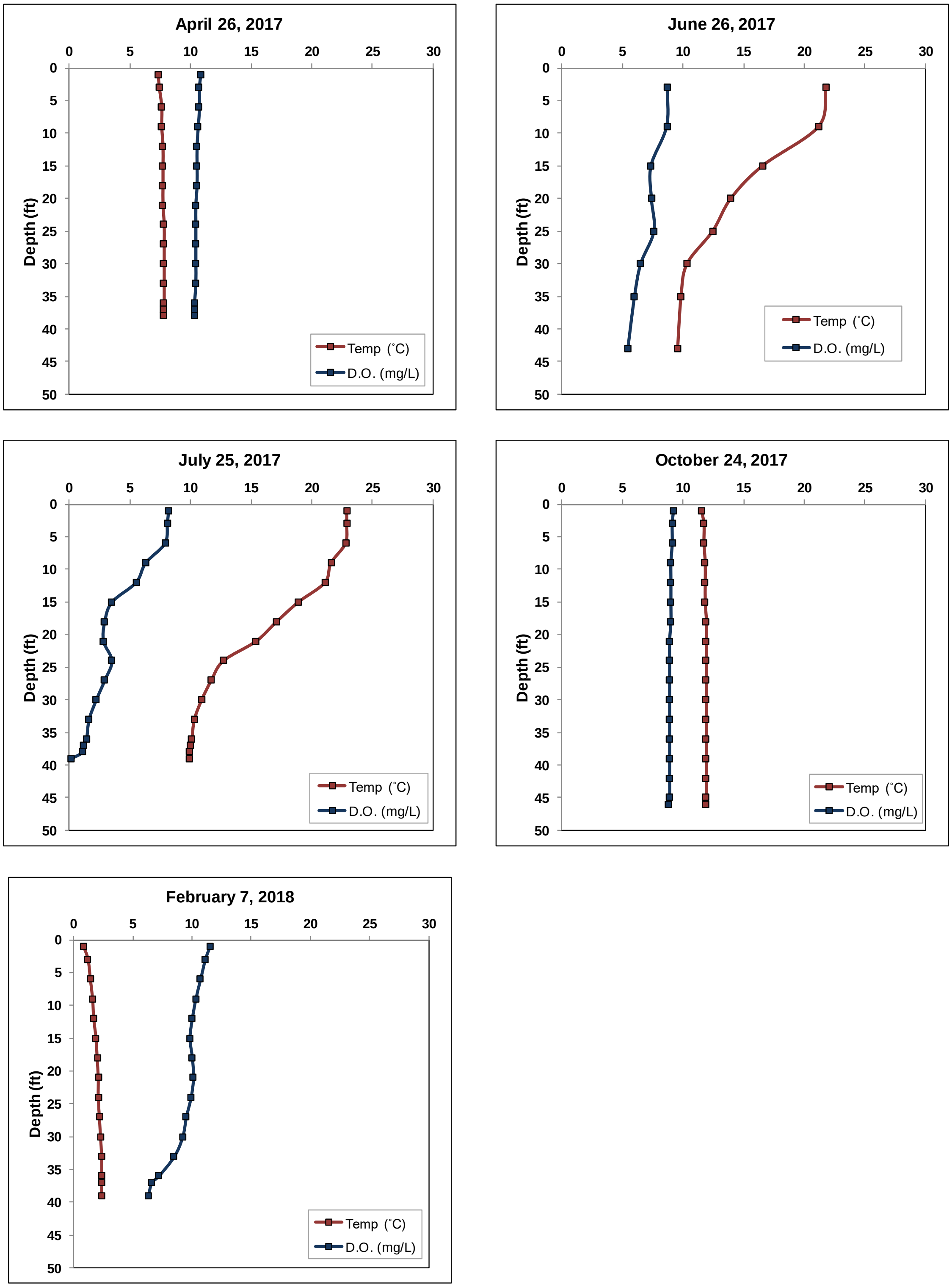


Figure 8.7.1-7. North Turtle Lake 2017/18 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from North Turtle Lake

The previous section is centered on parameters relating to North Turtle Lake's trophic state. 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 North Turtle Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. North Turtle Lake's mid-summer surface water pH was measured at 7.6 in 2017. This value indicates North Turtle Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. North Turtle Lake's average alkalinity measured in 2017 was 30.1 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while North Turtle Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from North Turtle Lake in 2017 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and North Turtle Lake's pH falls within this range. North Turtle Lake's calcium concentration in 2017 was 10.1 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in North Turtle Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys.

North Turtle Lake was placed on the 303(d) list of impaired waterbodies for contaminated fish tissue by mercury in 1998. While mercury is found naturally in the environment due to volcanic eruptions and weathering of rocks, the majority of the mercury found in Wisconsin's waterbodies is the result of coal-fired power plants and the release of mercury into the atmosphere. Mercury is deposited into lakes, rivers, and streams through precipitation and the deposition of dust particles where it converted into its mobile and harmful form, methylmercury. Methylmercury becomes stored in bodies of aquatic animals, and concentrations tend to be highest in those species at the top of the food chain. In humans, mercury affects the nervous system and is of special concern for unborn children, infants, and children. For advice on eating fish from North Turtle Lake, please see the North Turtle Lake Fisheries Data Integration Section (Section 8.7.6).

8.7.2 North Turtle Lake Watershed Assessment

North Turtle Lake's surficial watershed encompasses approximately 12,901 acres (Figure 8.7.2-1 and North Turtle Lake – Map 2) yielding a watershed to lake area ratio of 34:1. North Turtle Lake's direct watershed is comprised of land cover types including forests (38%), wetlands (39%), pasture/grass and rural open space (8%), and rural residential areas (<1%) (Figure 8.7.2-2). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that North Turtle Lake's residence time is approximately 0.63 years, or the water within the lake is completely replaced approximately 1.6 times per year.

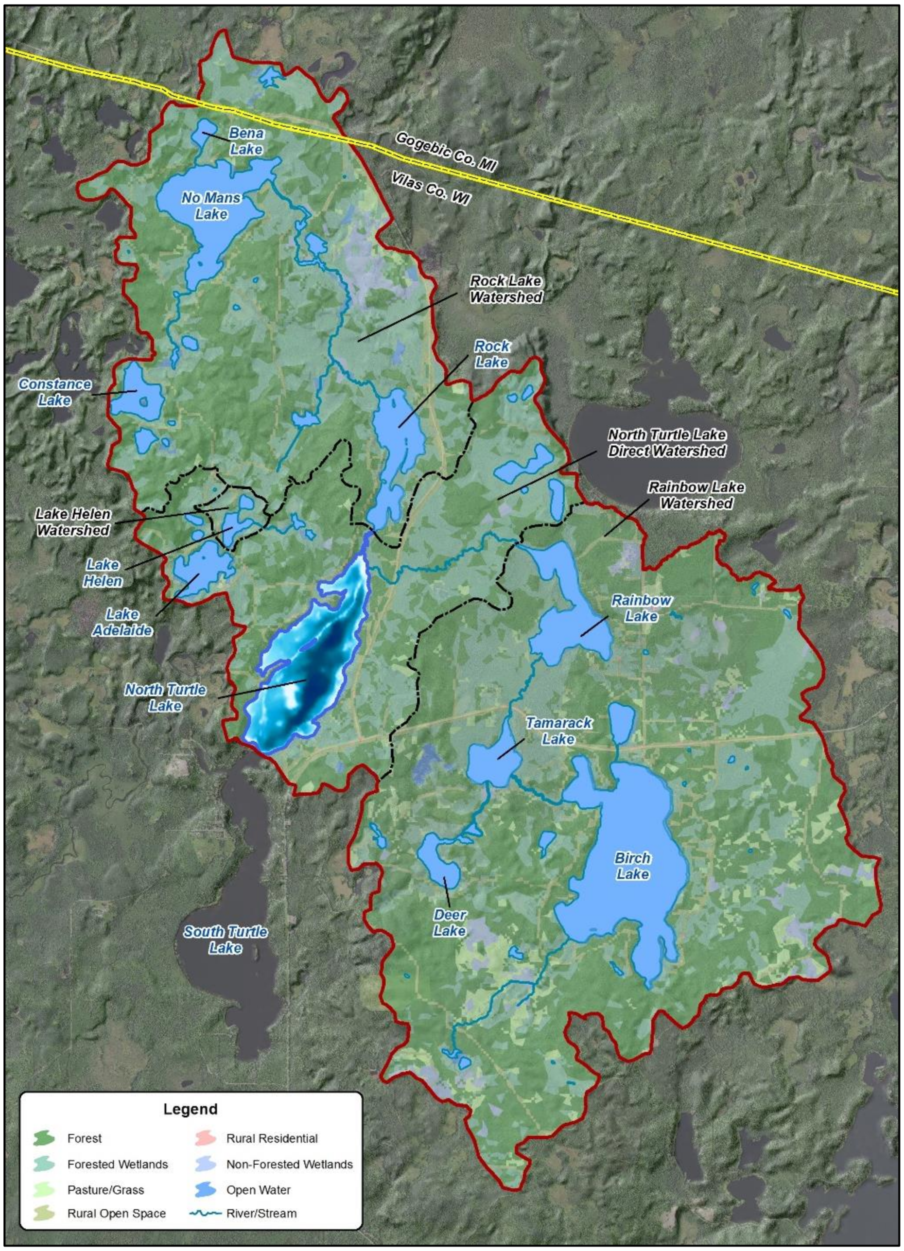


Figure 8.7.2-1. North Turtle Lake watershed boundary (red line) and land cover types. Black dashed lines indicate subwatersheds used in WiLMS modeling. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

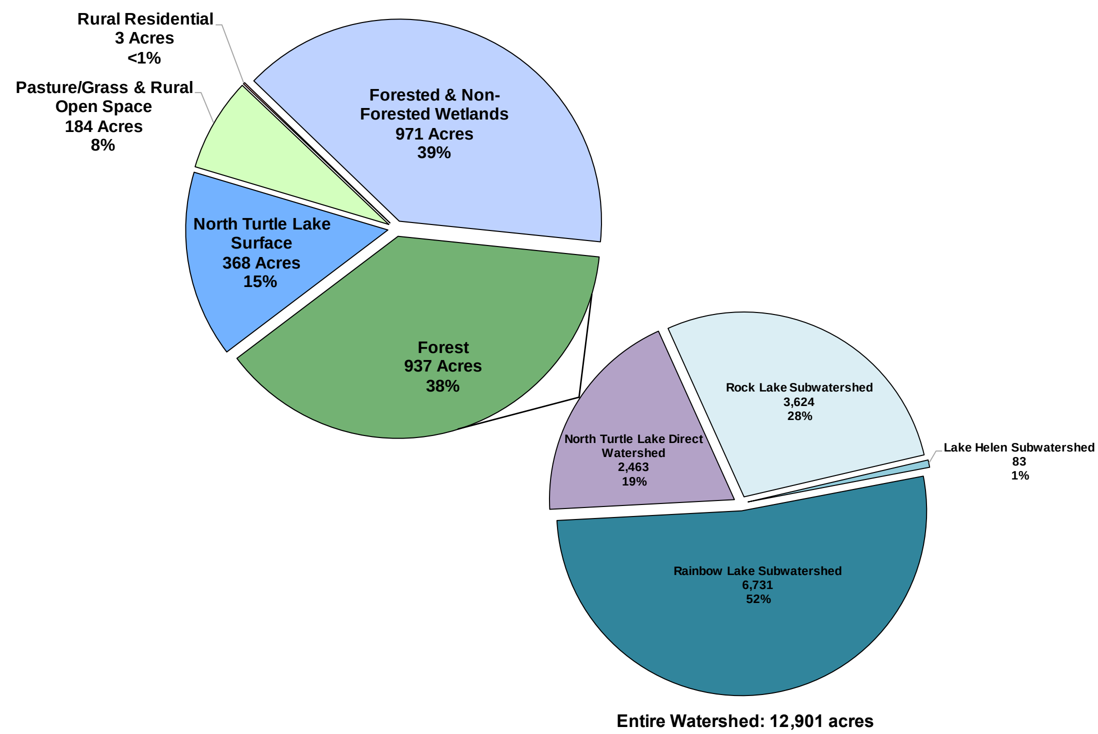


Figure 8.7.2-2. North Turtle Lake proportion of land cover types within its direct watershed and subwatersheds used in WiLMS modeling.

Using the land cover types within North Turtle Lake's direct watershed and available phosphorus data from upstream Rainbow Lake, Rock Lake, and Lake Helen, WiLMS was utilized to estimate the annual potential phosphorus load delivered to North Turtle Lake from its watershed. In addition, data obtained from a stakeholder survey sent to North Turtle Lake riparian property owners in 2017 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that approximately 1,011 pounds of phosphorus are delivered to North Turtle Lake from its watershed on an annual basis (Figure 8.5.2-3).

Of the estimated 1,011 pounds of phosphorus being delivered to North Turtle Lake on an annual basis, approximately 691 pounds (68%) originates from the Rainbow Lake, Rock Lake, and Lake Helen subwatersheds, while the remaining 320 pounds (32%) originates from the lake's direct watershed (Figure 8.7.2-3). Watershed modeling indicates that Rainbow and Rock lakes retain approximately 30% of the phosphorus they receive, acting as nutrient sinks and exporting higher-quality water downstream to North Turtle Lake. Studies have shown that upstream lakes often retain phosphorus and reduce phosphorus concentrations in downstream lakes (Zhang et al. 2012).

Within North Turtle Lake's direct watershed, atmospheric deposition onto the lake's surface accounts for 99 pounds or 10% of the annual load, wetlands account for 86 pounds (9%), forests account for 75 pounds (7%), pasture/grass and rural open space account for 49 pounds (5%), and riparian septic systems account for 10 pounds (1%) (Figure 8.7.2-3). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 19 µg/L, which is similar to the measured growing season average of 17 µg/L. The similarity between predicted and measured phosphorus concentrations indicates that the lake's watershed was modeled accurately and that there are no significant sources of unaccounted phosphorus being loaded to North Turtle Lake.

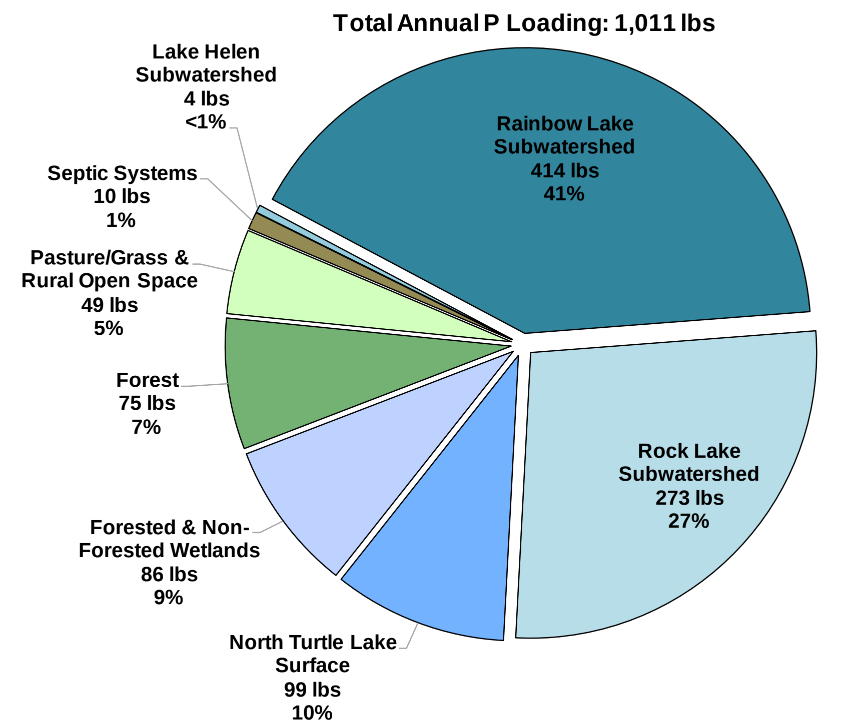


Figure 8.5.2-2. North Turtle Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.7.3 North Turtle Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the fall of 2017, the immediate shoreland of North Turtle Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

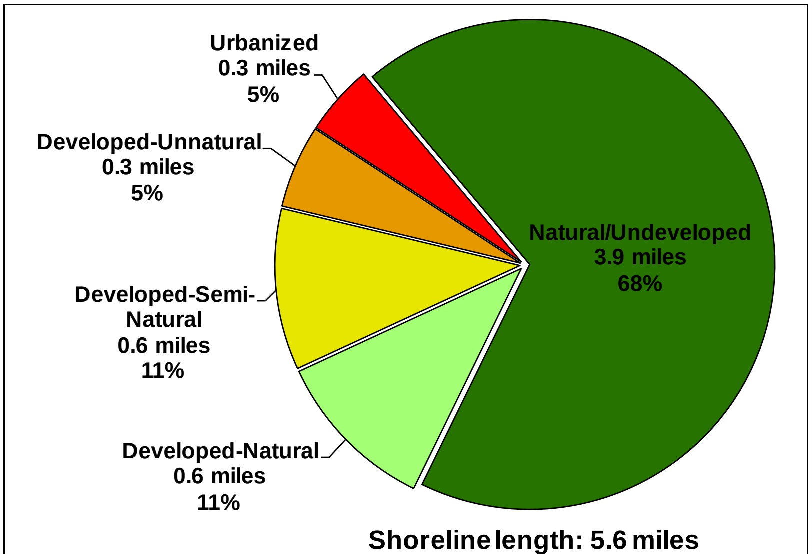


Figure 8.7.3-1. North Turtle Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on North Turtle Lake - Map 3.

The 2017 survey revealed that North Turtle Lake has stretches of shoreland that fit all five shoreland assessment categories (Figure 8.7.3-1). In total, 4.5 miles (79%) of the 5.6-mile shoreland zone were categorized as natural/undeveloped or developed-natural or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 0.6 miles (10%) of the shoreland was categorized as developed-unnatural or urbanized, shoreland areas which provide little benefit to and may actually adversely impact the lake. If restoration of North Turtle Lake's shoreland is to occur, primary focus should be placed on these highly developed shoreland areas. North Turtle Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on North Turtle Lake in 2017. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on North Turtle Lake, a total of 175 pieces were observed along 5.6 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 31:1 (Figure 8.7.3-2). Onterra ecologists have completed these surveys on 98 Wisconsin lakes since 2012, and North Turtle Lake falls in the 58th percentile for the number of coarse woody habitat pieces per shoreline mile. Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in North Turtle Lake. The locations of these coarse woody habitat pieces are displayed on North Turtle Lake – Map 4.

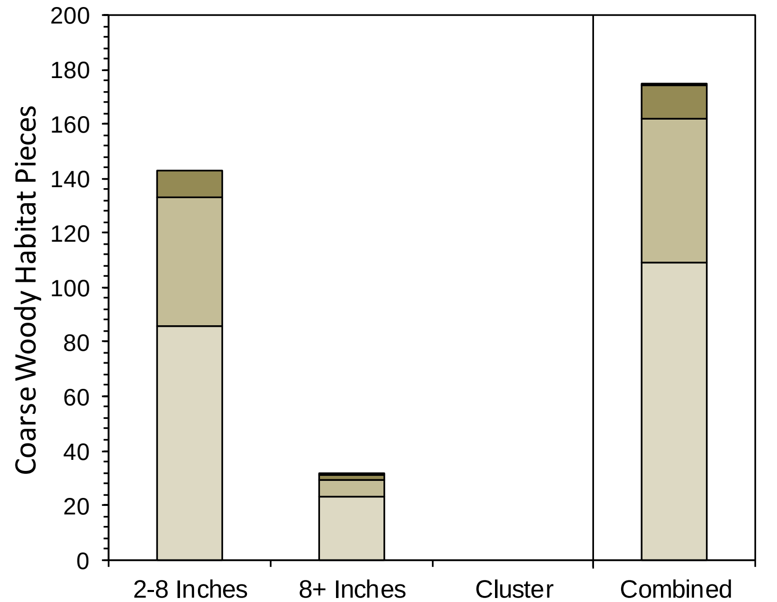


Figure 8.7.3-2. North Turtle Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of North Turtle Lake coarse woody habitat can be found on North Turtle Lake – Map 4.

8.7.4 North Turtle Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on North Turtle Lake on June 30, 2017. 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. Fortunately, no curly-leaf pondweed was located in North Turtle Lake in 2017, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. However, pale-yellow iris, a non-native wetland plant, was located in a few locations along North Turtle Lake's shoreline in 2017. Because of its ecological significance, pale-yellow iris in North Turtle Lake is discussed further in the subsequent Non-Native Aquatic Plants subsection.

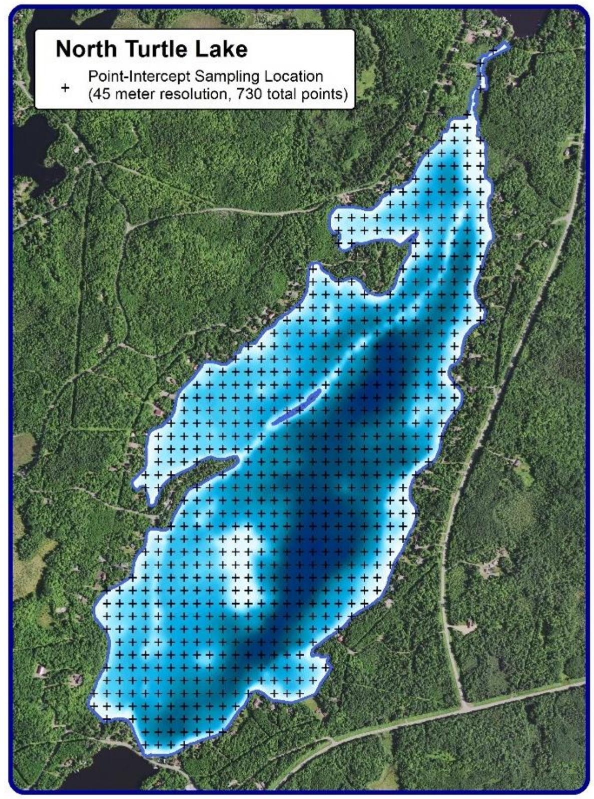


Figure 8.7.4-1. North Turtle Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on North Turtle Lake by Onterra ecologists on July 18, 2017 (Figure 8.7.4-1). During these surveys, a total of 36 aquatic plant species were located, one of which is considered to be a non-native, invasive species: pale-yellow iris (Table 8.7.4-1).

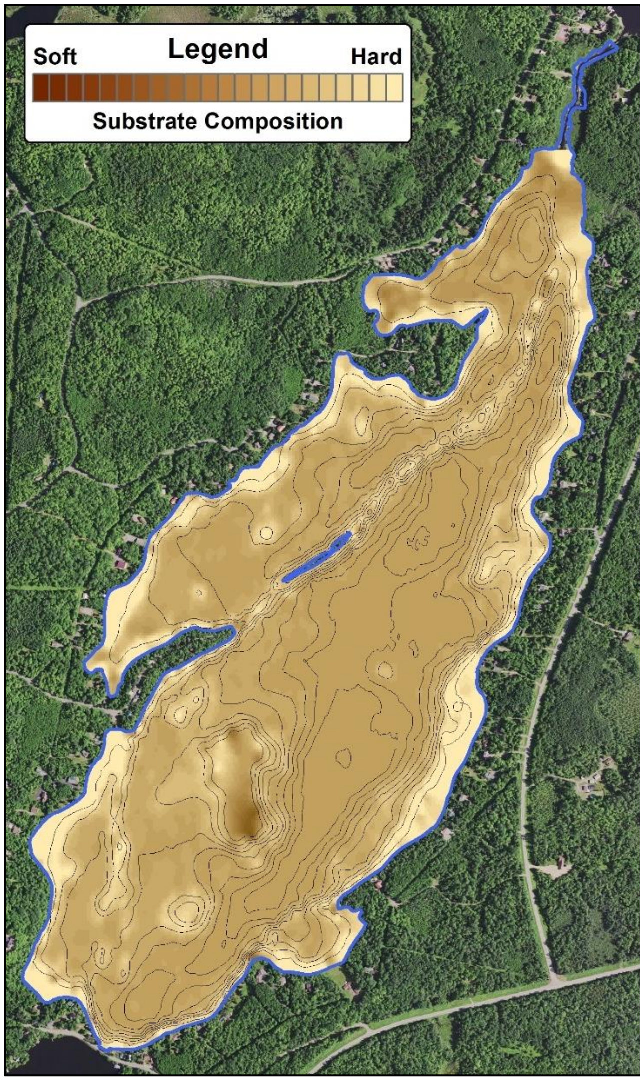
Lakes in Wisconsin vary in their morphometry, water chemistry, substrate composition, and management, all factors which influence aquatic plant community composition. In late September of 2017, Onterra ecologists completed an acoustic survey on North Turtle Lake (bathymetric results on North Turtle Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to North Turtle Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2017 acoustic survey showed that shallower areas of North Turtle Lake from 1-15 feet are primarily comprised of hard substrates, rock and sand (Figure 8.7.4-2). Softer substrates were located in a shallow area in the south-central area of the lake and near the mouth of Rainbow Creek. Beyond 15 feet, substrates are relatively hard and uniform to the deepest areas of the lake. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.7.4-1. List of aquatic plant species located in North Turtle Lake during Onterra 2017 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I
	Decodon verticillatus	Water-willow	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Glyceria canadensis	Rattlesnake grass	7	I
	Iris pseudacorus	Pale-yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Sparganium americanum	American bur-reed	8	X
	Sparganium eurycarpum	Common bur-reed	5	I
	Sparganium sp. (sterile)	Bur-reed sp. (sterile)	N/A	I
FL	*Brasenia schreberi*	Watershield	7	I
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submersed	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Chara spp.	Muskgrasses	7	X
	Isoetes lacustris	Lake quillwort	8	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Myriophyllum tenellum	Dwarf watermilfoil	10	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	I
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	I
	Potamogeton vaseyi	Vasey's pondweed	10	I
	Utricularia vulgaris	Common bladderwort	7	I
	Vallisneria americana	Wild celery	6	X
S/E	*Sagittaria cuneata*	Arum-leaved arrowhead	7	I
	Sagittaria graminea	Grass-leaved arrowhead	9	I

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



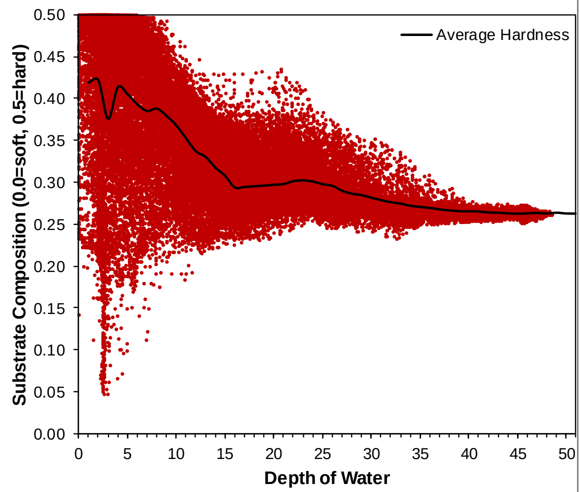


Figure 8.7.4-2. North Turtle Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Depth contours represent 5-foot intervals. Individual data points are displayed in red. Creating using data from September 2017 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2017 aquatic plant bio-volume data are displayed in Figure 8.7.4-3 and North Turtle Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red while areas of little to no aquatic plant growth are displayed in blue. The 2017 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 8 feet. However, the majority of aquatic plant growth occurs within 2.0-4.0 feet of water. The 2017 acoustic survey indicated approximately 5% (18 acres) of North Turtle Lake's area is occupied by aquatic vegetation, while the remaining 95% of the lake contains unsuitable substrates or is too deep to support aquatic plant growth.

As mentioned, aquatic plants were recorded growing to a maximum depth of 8 feet in 2017. Of the 138 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 23% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2017 indicates that 19% of the 138 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 3% had a TRF rating of 2, and 1% had a TRF rating of 3 (Figure 8.7.4-5).

The acoustic and point-intercept survey data indicate that aquatic plant occurrence and biomass in North Turtle Lake is low. Of the eight Winchester project lakes studied to date, North Turtle Lake has the lowest littoral frequency of occurrence of vegetation of 24% compared to an average of 57%. Most of the aquatic plant growth occurs in the shallower area within the south-central area of the lake and over the softer substrates in the northern portion of the lake. The low occurrence of aquatic vegetation in North Turtle Lake is likely due to two main factors: 1) the lakes morphometry which consists of steep slopes and a small littoral zone, and 2) substrates largely comprised of rock and sand which are unsuitable for most aquatic plant species.

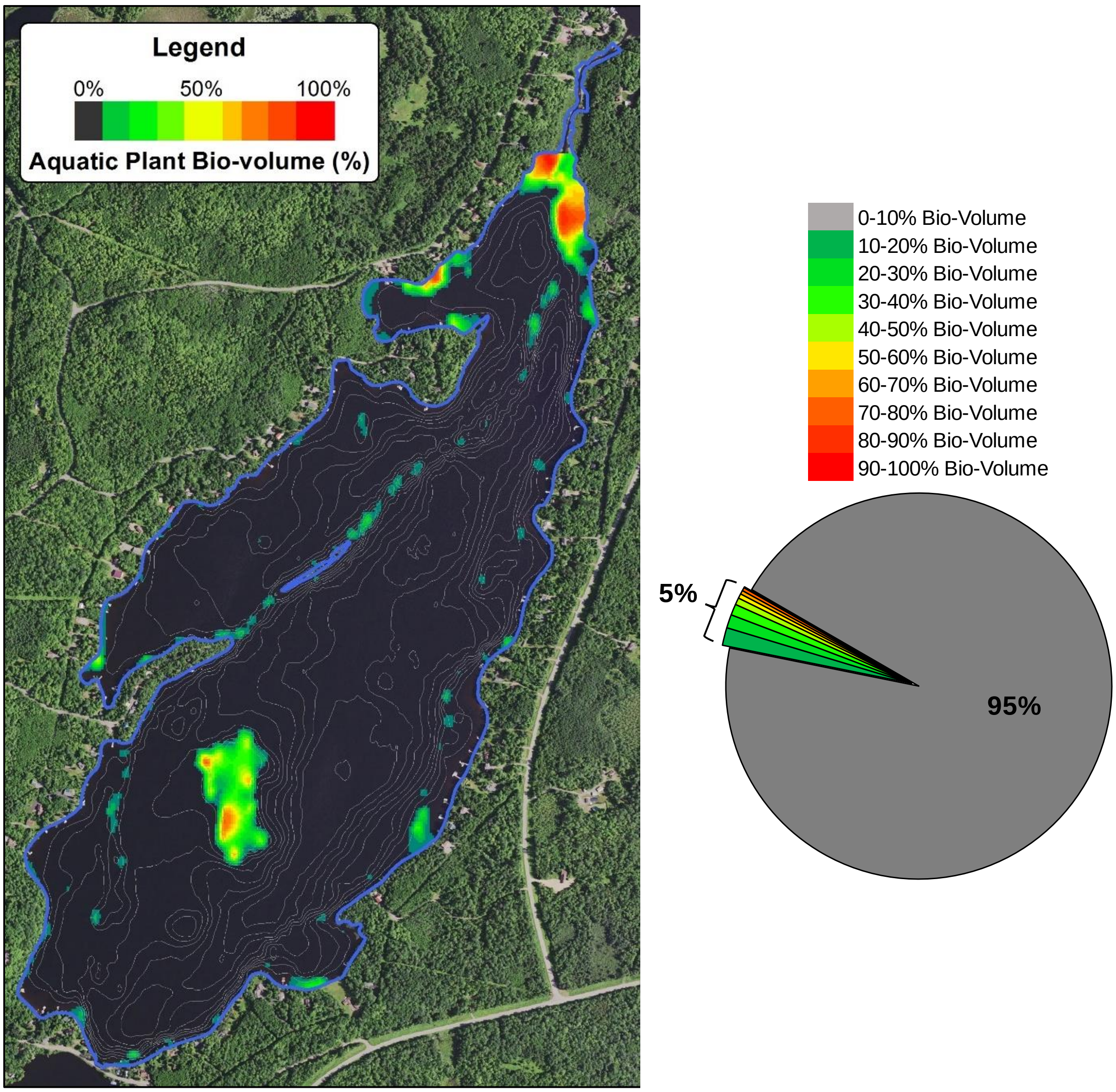


Figure 8.7.4-4. North Turtle Lake 2017 aquatic plant bio-volume. Contour lines are 5-foot intervals. Created using data from September 2017 acoustic survey data.

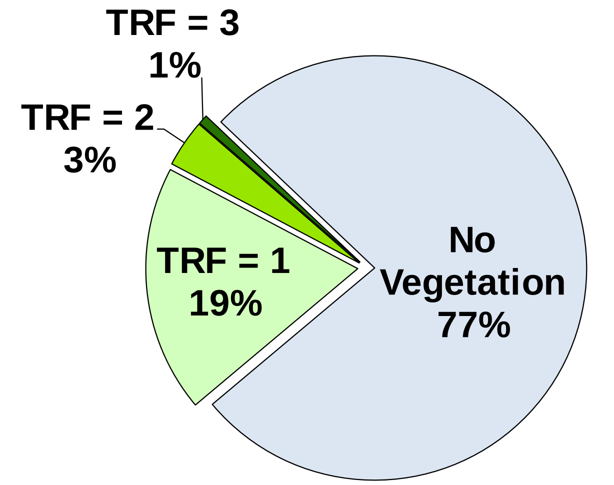


Figure 8.7.4-5. North Turtle Lake 2017 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2017 whole-lake point-intercept survey (N = 138).

Of North Turtle Lake's 368 acres, approximately 77 acres (21%) is littoral zone, or areas of the lake 8.0 feet deep or less that receive adequate light to support aquatic plant growth. In addition, the majority of the littoral zone is comprised of rock and sand. Rock substrate can be impenetrable by aquatic plant roots while sand is often nutrient-poor (Lacoul and Freedman 2006). The low abundance of aquatic plant growth in North Turtle Lake is not an indication of degraded conditions, but the result of the lake's morphometry and substrate composition.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Of the 36 aquatic plant species located in North Turtle Lake in 2017, 16 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.7.4-6). The remaining 20 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 16 species directly sampled with the rake during the point-intercept survey, wild celery, variable-leaf pondweed, and muskgrasses were the three-most frequently encountered aquatic plant species (Figure 8.7.4-6).

Wild celery, also known as tape or eelgrass, was the most frequently encountered aquatic plant species in North Turtle Lake in 2017 with a littoral frequency of occurrence of 11% (Figure 8.3.4-6). Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. North Turtle Lake's areas of sand/cobble and low light conditions as a result of its stained water favor the dominance of wild celery. In 2017, wild celery was most abundant over hard substrates in water 3.0-4.0 feet deep.

Variable-leaf pondweed and muskgrasses were the second-most frequently encountered aquatic plant species in North Turtle Lake in 2017 with a littoral occurrence of 9% each (Figure 8.3.4-6). Variable-leaf pondweed is one of several broad-leaf pondweed species that can be found in Wisconsin, and the plants size and leaf shape can vary widely depending on its growing conditions. This plant produces long, thin stems with alternating lance-shaped leaves and is typically found growing over firmer substrates. In North Turtle Lake, variable-leaf pondweed was often found growing with wild celery and muskgrasses.

Muskgrasses are a genus of macroalgae of which there are seven species in Wisconsin. Muskgrasses require lakes with good water clarity, and their large beds help to stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate incrustations which from on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops 2002). Muskgrasses were found in association with wild celery and variable-leaf pondweed in North Turtle Lake.

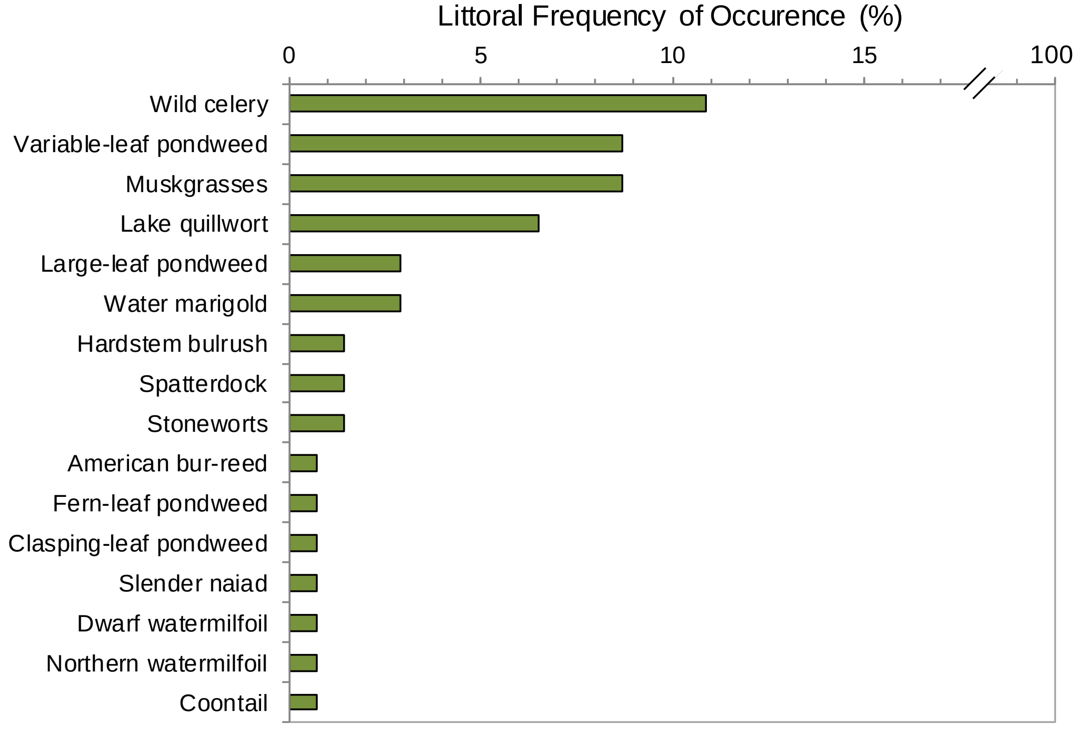


Figure 8.7.4-6. North Turtle Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data from 2017 whole-lake point-intercept survey.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.7.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.7.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum* sibiricum) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

Photo 8.7.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like North Turtle Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2017 point-intercept survey on North Turtle Lake and their conservatism values were used to calculate the FQI of North Turtle Lake's aquatic plant community (equation shown below).

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

Figure 8.7.4-7 compares the 2017 FQI components of North Turtle Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2017 (16) falls below the median value for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The lower species richness is likely due to North Turtle Lake's morphometry and substrate composition as discussed previously. The average conservatism of the

16 native aquatic plant species located in North Turtle Lake in 2017 was 6.8, exceeding the median average conservatism values for lakes within the NLFL ecoregion (6.7) and lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of North Turtle Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

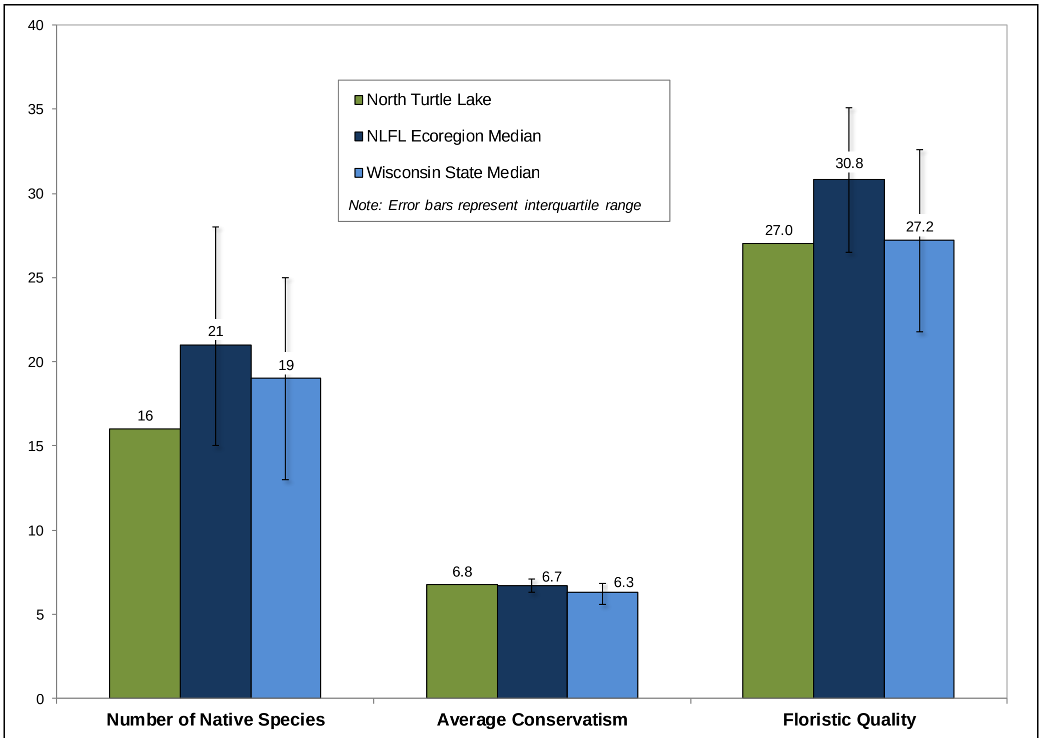


Figure 8.7.4-7. North Turtle Lake Floristic Quality Assessment. Created using data from Onterra 2017 whole-lake point-intercept survey. Analysis follows Nichols (1999).

Using North Turtle Lake's native aquatic plant species richness and average conservatism yields an FQI value of 27.0 (Figure 8.7.4-7). North Turtle Lake's FQI value falls below the median values for lakes within the NLFL ecoregion (30.8) and near the median value for lakes throughout the state (27.2). North Turtle Lake's lower FQI value is due to its lower species richness value, and as discussed earlier, is the result of natural conditions within the lake and is not an indication of environmental degradation. Overall, the FQI analysis indicates that the aquatic plant community found in North Turtle Lake contains fewer species than the majority of lakes in Wisconsin, but the species that are present are environmentally-sensitive and indicate high-quality conditions.

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because North Turtle Lake contains a lower number of aquatic plant species, one may assume the aquatic plant community has low species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how North Turtle Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.7.4-8). Using the data collected from the 2017 point-intercept survey, North Turtle Lake's aquatic plant was found to have high species diversity with a Simpson's Diversity Index value of 0.86. In other words, if two individual aquatic plants were randomly sampled from North Turtle Lake in 2017, there would be an 86% probability that they would be different species. North Turtle Lake's Simpson's Diversity value falls below the median value for lakes in the NLF ecoregion (0.88) but is comparable to the median value for lakes throughout Wisconsin (0.86).

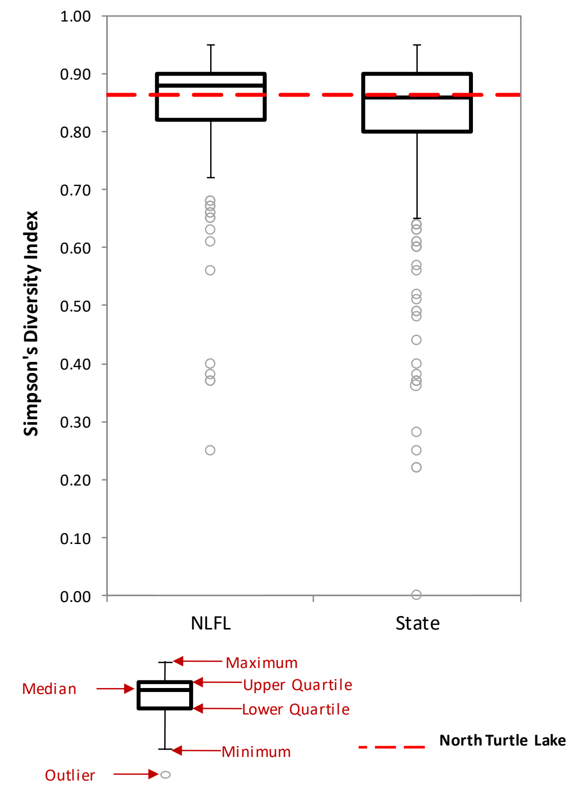


Figure 8.7.4-8. North Turtle Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

One way to visualize North Turtle Lake's species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-9 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. 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 wild celery was found at 11% of the littoral sampling locations in North Turtle Lake in 2017, its relative frequency of occurrence was 22%. Explained another way, if 100 plants were randomly sampled from North Turtle Lake in 2017, 22 of them would be wild celery.

In 2017, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in North Turtle Lake. This survey revealed North Turtle Lake contains approximately 11 acres of these communities comprised of 19 plant species (North Turtle Lake – Map 7 and Table 8.7.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within North Turtle Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

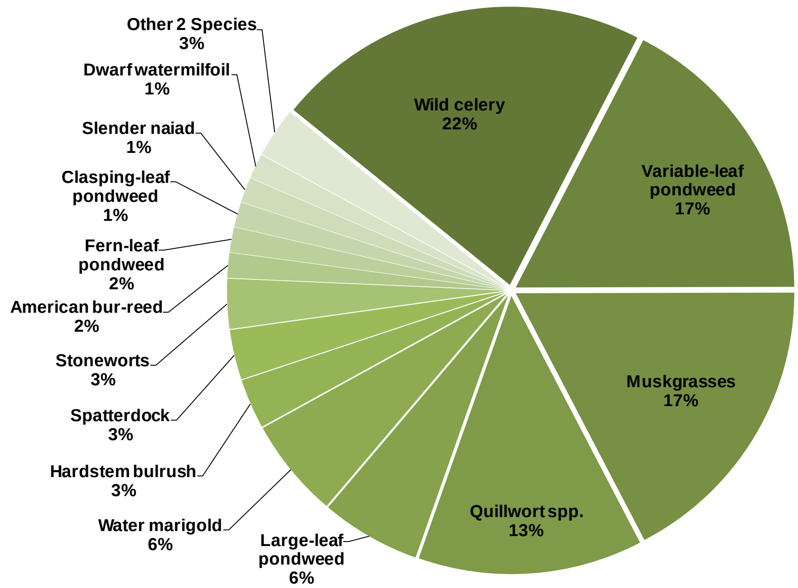


Figure 8.7.4-9. North Turtle Lake 2017 relative frequency of occurrence of aquatic plant species. Created using data from 2017 point-intercept survey.

Table 8.7.4-2. North Turtle Lake 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2017 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	5.4
Floating-leaf	0.8
Mixed Emergent & Floating-leaf	4.5
Total	**10.8**

Non-native Aquatic Plants in North Turtle Lake

Pale-Yellow Iris

Pale yellow iris (*Iris pseudacorus*; Photo 8.7.4-4 and North Turtle Lake – Map 8) 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 was located growing in a few locations along the shorelines of North Turtle Lake by NLDC and Onterra staff in 2017 (North Turtle Lake – Map 7). There are a number of control strategies that can be used to control pale-yellow iris. A strategy for managing pale-yellow iris on North Turtle Lake is discussed within the Turtle Chain Implementation Plan.

Photo 8.7.4-4. Pale-yellow iris (*Iris pseudacorus*), a non-native, invasive wetland plant found along the shorelines of North Turtle Lake in 2017. Photo credit Onterra.

8.7.5 Aquatic Invasive Species in North Turtle Lake

As of 2017, the only non-native species other than pale-yellow iris documented in North Turtle Lake is the rusty crayfish (*Orconectes rusticus*) has been documented in downstream North Turtle Lake, and it is likely that rusty crayfish are present in North Turtle Lake. Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact.

8.7.6 North Turtle Lake 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 North Turtle Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2017 & GLIFWC 2017).

North Turtle Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in North Turtle Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae, 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 8.7.6-1.

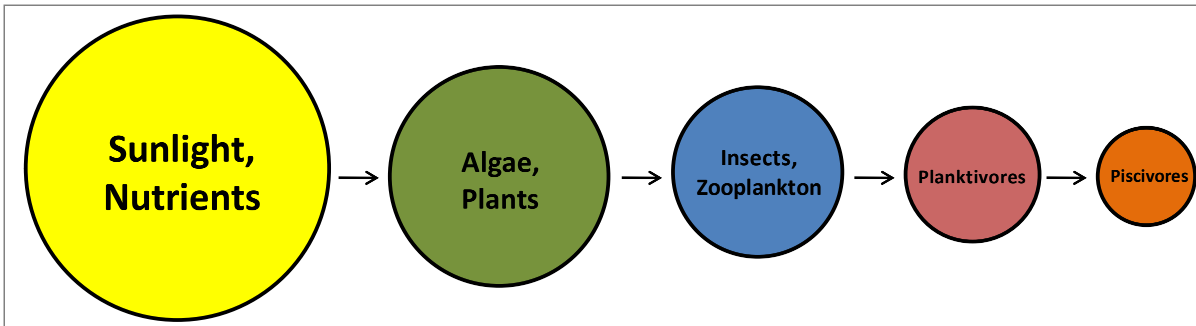


Figure 8.7.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, North Turtle Lake is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means North Turtle

Lake should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 8.7.6-1 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 surveys of North Turtle Lake include burbot (*Lota lota*), white sucker (*Catostomus commersonii*), and the greater redhorse (*Moxostoma valenciennesi*).

Table 8.7.6-1. Gamefish present in North Turtle Lake 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
Cisco (*Coregonus artedii*)	22	Late November - Early December	Various shoreline substrates.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling 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
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, 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 8.7.6-1). 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 electroshocking (Photograph 8.7.6-1). This is often done 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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 these data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 8.7.6-1. 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 fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 8.7.6-2). Stocking of 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. North Turtle Lake was stocked from 1972 to 1980 with muskellunge and walleye (Table 8.7.6-2). Stocking of walleye is not needed as North Turtle is considered a naturally reproducing walleye water by the WDNR.

Photograph 8.7.6-2. Fingerling Muskellunge.

Table 8.7.6-2. Stocking data available for North Turtle Lake (1972-1980).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1976	Muskellunge	Fingerling	400	7
1980	Muskellunge	Fingerling	700	10
1972	Walleye	Fingerling	19,000	3
1974	Walleye	Fingerling	7,000	3
1977	Walleye	Fingerling	17,000	3

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second important reason for owning property on or near North Turtle Lake (Question #17). Figure 8.7.6-2 displays the fish that North Turtle Lake stakeholders enjoy catching the most, with walleye and smallmouth bass being the most common being the most popular. Approximately 71% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 8.7.6-3). Approximately 86% of respondents who fish North Turtle Lake believe the quality of fishing has remained the same or is somewhat worse since they first started fishing the lake (Figure 8.7.6-3).

Question 11: What species of fish do you like to catch on North Turtle Lake?

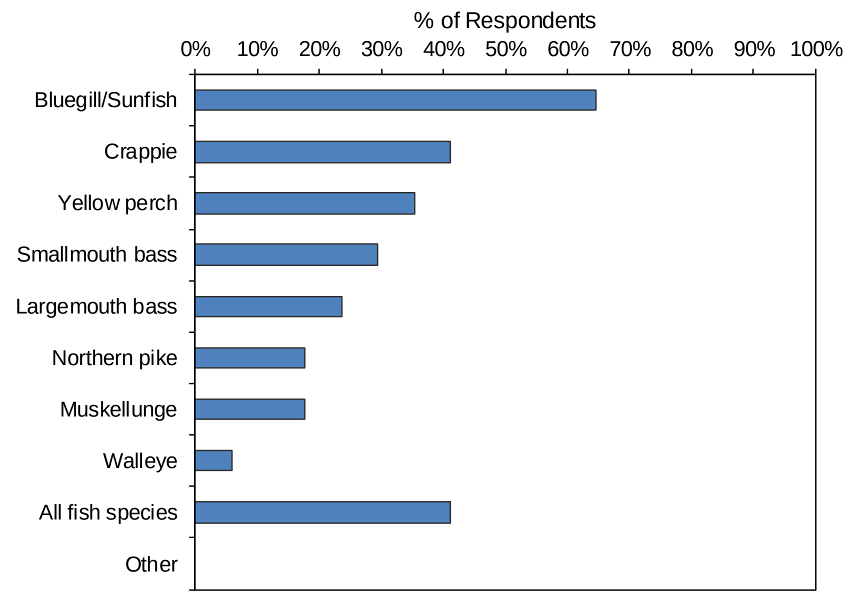


Figure 8.7.6-2. Stakeholder survey response Question 11. Created based on data from 45 respondents of 116 surveys sent (39%).

Question 12: How would you descirbe the current quality of fishing on North Turtle Lake?

Question 13: How has the quality of fishing changed since you started fishing the lake?

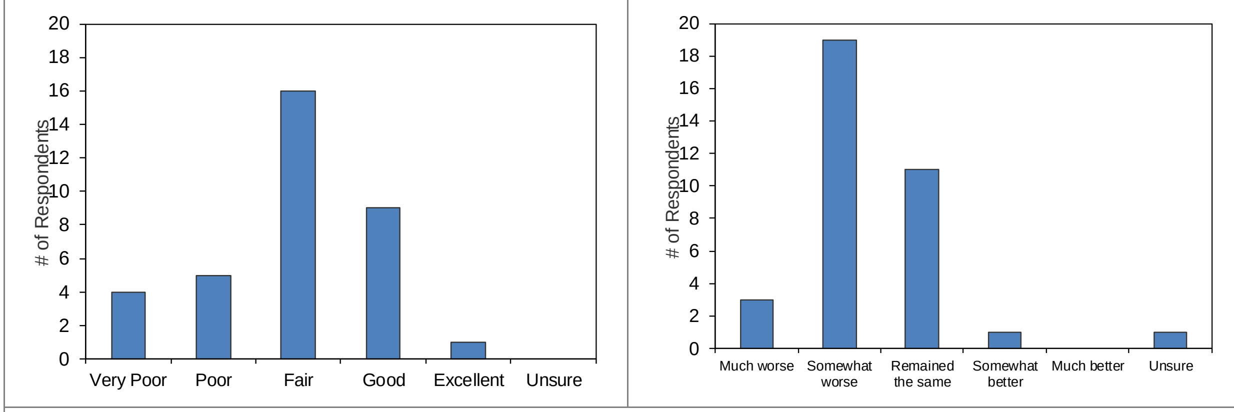


Figure 8.7.6-3. Stakeholder survey responses to questions 12 and 13. Created based on data from 45 respondents of 116 surveys sent (39%).

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. Creel surveys were completed on Rock, South Turtle and North Turtle Lakes during the 1991-92 and 2010-11 fishing seasons (Table 8.7.6-3).

Total angler effort was somewhat higher in 1991-92 (20.5 hours/acre) compared to the 2010-11 season (18.1 hours/acre). Anglers directed the largest amount of effort towards walleye and muskellunge during both the 2010-11 and 1991-92 seasons (Table 8.7.6-3).

Table 8.7.6-3. Creel Survey data for 1991-92 and 2010-11 fishing seasons.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Largemouth Bass	1991	20.5	0	0	0	0	0		
	2010	18.1	0.9	30	0.1	0	0	11.3	
Muskellunge	1991	20.5	6.7	84	0.2	0	0	45.5	
	2010	18.1	6	95	0.3	0	0	31.7	
Northern Pike	1991	20.5	0.6	62	0.2	11	0	36.2	
	2010	18.1	0.5	51	0.1	5	0	5.6	
Smallmouth Bass	1991	20.5	0.7	179	0.5	33	0.1	5.7	32.2
	2010	18.1	1.9	484	1.3	19	0.1	1.9	67.1
Walleye	1991	20.5	11.3	4457	12.1	117	0.3	0.9	37.5
	2010	18.1	10.2	2501	6.8	1249	3.4	1.5	3

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above 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 North Turtle Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on North Turtle Lake (Figure 8.7.6-2). A 2010 WDNR fisheries survey conducted on North Turtle Lake showed a high density of walleye (WDNR 2010).

Panfish

Abundant populations of yellow perch were present after the 2010 WDNR fisheries survey (WDNR 2010). The results for the stakeholder survey show anglers prefer to catch crappie on South Turtle Lake (Figure 8.7.6-2).

North Turtle Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.7.6-4). North Turtle Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake, either by spear harvest or angler 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 is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. 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 tribal or recreational harvesting means.

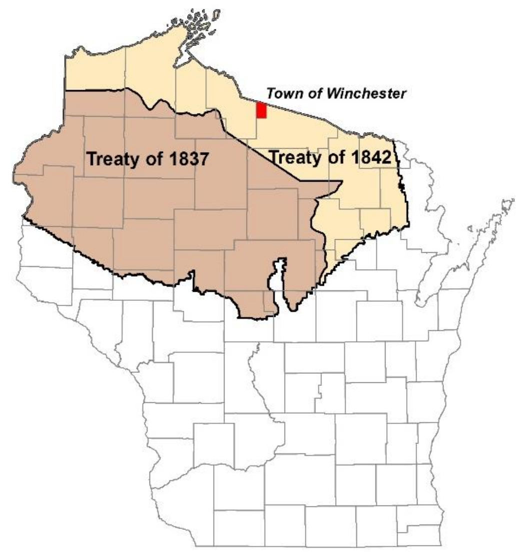


Figure 8.7.6-4. Location of Town of Winchester within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

By March 15th of each year the relevant tribal communities may declare a proportion of the total safe harvest on each lake. This declaration represents the maximum number of fish that can be taken by tribal spear harvesters or netters annually (Spangler, 2009). 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).

Spear harvesters are able to 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 2016). 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 spear harvesters may only take two walleye over 20 inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). 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 spear harvesters. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Walleye open water spear harvest records from 1999-2017 in North Turtle Lake are provided in Figure 8.7.6-5. As many as 150 walleye have been harvested from the lake in the past (2017), but the average harvest is roughly 30 fish per year. Spear harvesters on average have taken 26% of the declared quota. Additionally, on average, 11% of walleye harvested have been female.

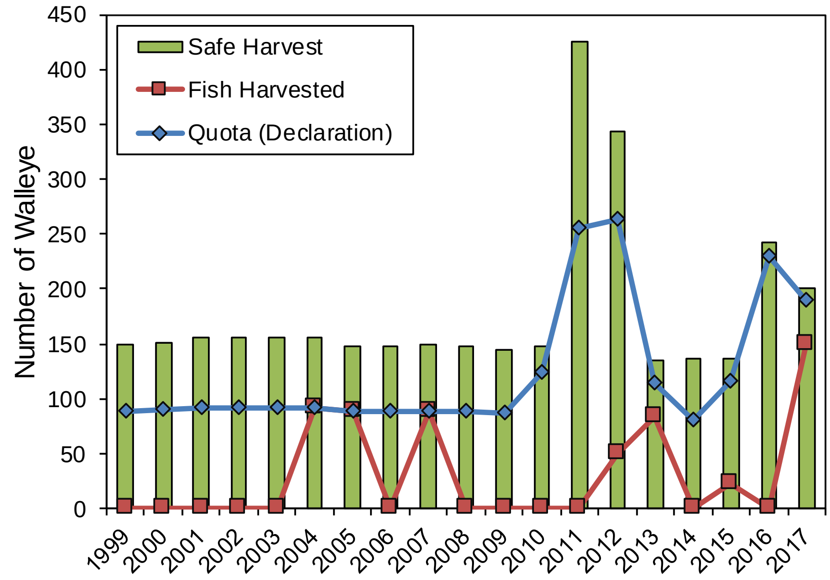


Figure 8.7.6-5. North Turtle Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records from 1999-2017 in North Turtle Lake are provided in Figure 8.7.6-6. At most, 1 muskellunge has been harvested from the lake in the past (2007), while in most years zero muskellunge are harvested. Spear harvesters on average have taken 1% of the declared quota.

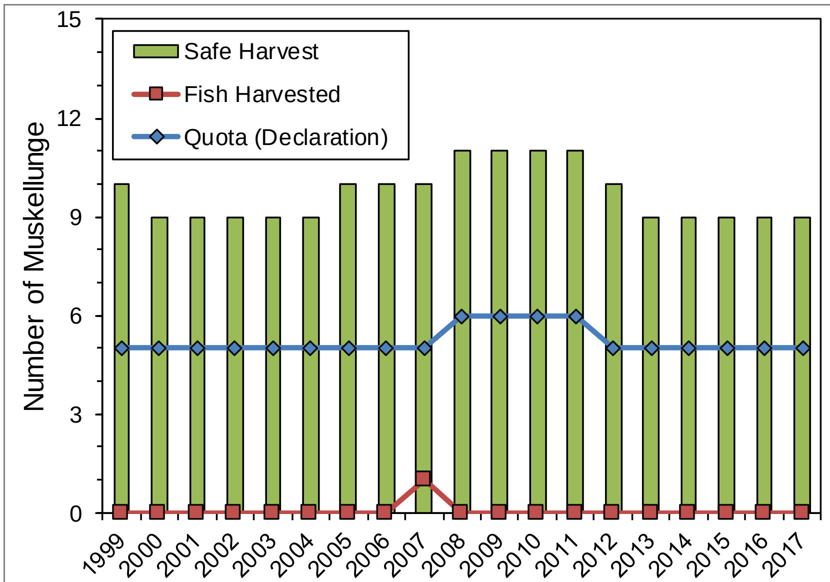


Figure 8.7.6-6. North Turtle Lake muskellunge spear harvest data. (GLIFWC 1999-2017).

North Turtle Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, evade 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 have substrates largely comprised of sand and rock 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 do 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 over soft sediments as well. According to the point-intercept survey conducted by Onterra in 2017, 37% of the substrate sampled in the littoral zone of North Turtle Lake were sand sediments, 32% composed of soft sediments and 31% composed of rock.

Woody Habitat

As discussed in the Shoreland Condition section (Section 8.7.3), 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 2006). A fall 2017 survey documented 175 pieces of coarse woody along the shores of North Turtle Lake, resulting in a ratio of approximately 31 pieces per mile of shoreline. When compared to the other 98 lakes Onterra has completed coarse woody habitat surveys on since 2012, North Turtle Lake falls in the 58th percentile for the number of course woody habitat pieces per shoreline mile.

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. 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 8.7.6-3). 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 other partner contributions.

Photograph 8.7.6-3. Examples of fish sticks (left) and half-log habitat structures (right). (Photos by WDNR).

Fish cribs are a fish habitat structure that are placed on the lakebed. Installing fish cribs may 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. Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 8.7.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 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 are spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline and are mainly installed to enhance 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 indicated the addition of rock substrate did not significantly improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structures in a lake does not require 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. The Town of Winchester should 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 North Turtle Lake.

Regulations

Regulations for North Turtle Lake gamefish species as of April 2018 are displayed in Table 8.7.6-4. 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 8.7.6-4. WDNR fishing regulations for North Turtle Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	None but only 1 fish over 14" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 3 hooks, baits, or lures maximum per boat.

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.

As discussed in the North Turtle Lake Water Quality section (Section 8.6.1), North Turtle Lake was placed on the 303(d) list of impaired waterbodies for contaminated fish tissue by mercury in 1998. General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.7.6-7. 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 than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 8.7.6-7. 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/)

Please note that study methods and explanations of analyses for South Turtle Lake can be found within the Town of Winchester Town-wide Management Plan document.

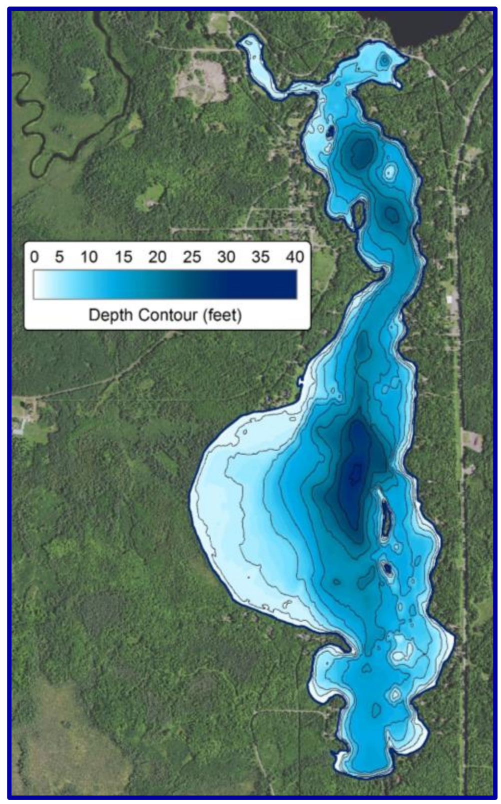
8.8 South Turtle Lake

An Introduction to South Turtle Lake

South Turtle Lake, Vilas County, is a 488-acre deep lowland, brown-water, mesotrophic drainage lake with a maximum depth of 40 feet and a mean depth of 14 feet (South Turtle Lake – Map 1). Its surficial watershed encompasses approximately 15,357 acres across portions of Vilas County, WI and Gogebic County, MI. North Turtle Lake flows into South Turtle Lake from the north and the lake is drained by the Turtle River to the northeast. In 2017, 39 native aquatic plant species were located within the lake, of which fern-leaf pondweed (*Potamogeton robbinsii*) was the most common. The non-native, invasive wetland plant pale-yellow iris (*Iris pseudacorus*) was located in a few locations along South Turtle Lake's shoreline in 2017. To date, no other non-native species have been documented in South Turtle Lake.

Lake at a Glance - South Turtle Lake

Morphometry	
LakeType	Deep Lowland Drainage
Surface Area (Acres)	488
Max Depth (feet)	40
Mean Depth (feet)	14
Perimeter (Miles)	7.7
Shoreline Complexity	6.1
Watershed Area (Acres)	15,357
Watershed to Lake Area Ratio	31:1
Water Quality	
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	22
Avg Summer Chl-α (µg/L)	9
Avg Summer Secchi Depth (ft)	7.4
Summer pH	7.7
Alkalinity (mg/L as $CaCO_3$)	36
Vegetation	
Number of Native Species	39
NHI-Listed Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Species	Pale-yellow Iris (*Iris pseudacorus*)
Average Conservatism	6.6
Floristic Quality	32.8
Simpson's Diversity (1-D)	0.90



Descriptions of these parameters can be found within the town-wide portion of the management plan

8.8.1 South Turtle Lake Water Quality

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

In 2017, a stakeholder survey was sent to 120 South Turtle Lake riparian property owners. Thirty-seven (31%) of these 120 surveys were completed and returned. Given the relatively low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of South Turtle Lake but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about South Turtle Lake's current water quality, 73% of the respondents indicated the water quality is *good* or *excellent* and 27% indicated the water quality is *fair* (Figure 8.8.1-1). When asked how water quality has changed in South Turtle Lake since they first visited the lake, 57% of respondents indicated water quality has *remained the same*, 40% indicated it has *somewhat* or *severely degraded*, and 3% indicated the water quality has *somewhat improved* (Figure 8.8.1-1). As is discussed in this section, water quality data do indicate that phosphorus and algal production have increased in South Turtle Lake over the past 25 years.

Question 19: How would you describe the current water quality of South Turtle Lake?

Question 20: How has water quality changed in South Turtle Lake since you first visited the lake?

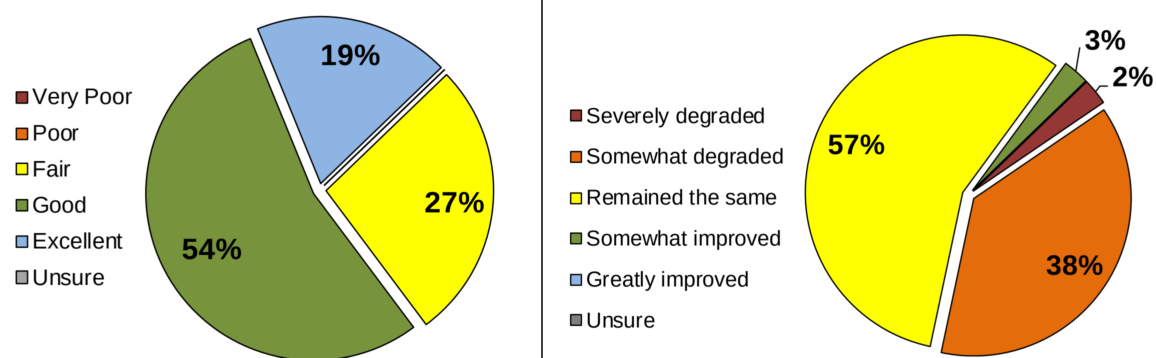


Figure 8.8.1-1. South Turtle Lake stakeholder survey responses regarding the lake's current and historical water quality. Created using responses from 37 (31%) respondents of 120 surveys distributed.

As is discussed further in the South Turtle Lake Watershed Section (Section 8.8.2), South Turtle Lake is classified as a lowland system because its watershed is approximately 24 square miles in area, greatly exceeding the watershed area threshold of 4 square miles or less used to classify lakes as headwater systems. However, given the close proximity of the inlet from North Turtle Lake and the Turtle River outlet, Onterra ecologists believe the majority of the water flowing into South Turtle Lake from North Turtle Lake flows out through the Turtle River and does not mix throughout South Turtle Lake proper.

It is believed most of the water in South Turtle Lake originates from its direct or local watershed and not from North Turtle Lake. In other words, the water quality in South Turtle Lake is largely dependent on its direct watershed and not on water originating from North Turtle Lake. For this reason, Onterra ecologists believe South Turtle Lake functions like a headwater as opposed to a lowland system and water quality data from South Turtle Lake should be compared to other deep headwater lakes in Wisconsin. As is discussed in the South Turtle Lake Watershed Section, watershed modeling agrees with this conclusion that the North Turtle Lake watershed has little influence on South Turtle Lake's water quality.

Near-surface total phosphorus data for South Turtle Lake are available from 1985, 1992-1999, and 2003-2017 (Figure 8.8.1-2). The weighted average summer total phosphorus concentration is 22 µg/L, falling into the *good* category for deep headwater drainage lakes in Wisconsin. The average summer phosphorus concentration in 2017 was above average at 26 µg/L. South Turtle Lake's average summer total phosphorus concentration is higher than the median concentration for Wisconsin's deep headwater drainage lakes and for all lake types within the NLF ecoregion.

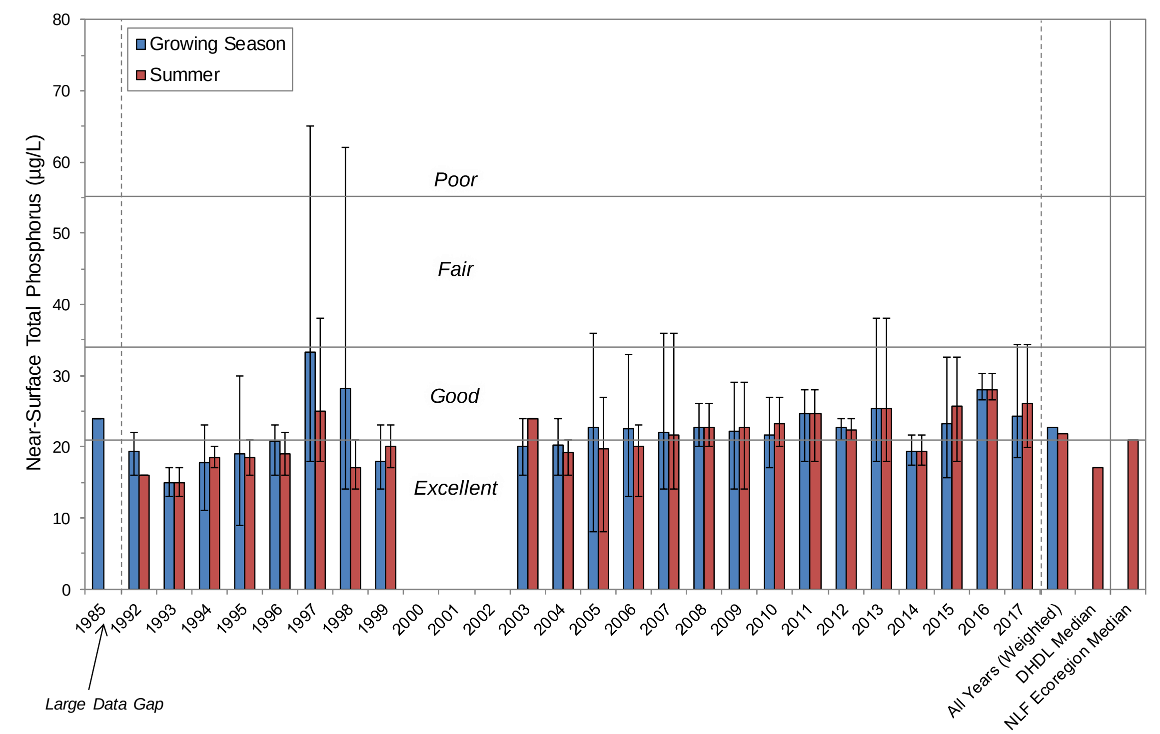


Figure 8.8.1-2. South Turtle Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Trends analysis (simple linear regression) of South Turtle Lake's annual average summer phosphorus concentrations from 1992-2017 indicated a statistically valid (p-value <0.001), increasing trend (R^2 = 0.58) in concentration has occurred over this time period (Figure 8.8.1-3). Average summer total phosphorus concentrations have increased from an average of approximately 16 µg/L in 1992 to 25 µg/L in 2017. When significant increases in phosphorus are observed, lake managers first examine the lake's watershed to determine if any significant disturbances (e.g. residential development, agriculture, clear-cutting, etc.) have occurred that may result in increased nutrient runoff to the lake. Examination of South Turtle Lake's direct watershed using aerial imagery available from 1992-2017 did not reveal any significant changes in land cover, indicating the increase in phosphorus is not likely due to disturbances within the watershed.

Changes in phosphorus concentrations from year to year can often be attributed to changes in precipitation and the amount of external runoff that enters the lake. To determine if changes in precipitation could account for the changes in phosphorus concentrations measured in South Turtle Lake, annual precipitation data were obtained from a monitoring station in nearby Manitowish Waters. Analyses showed no significant relationship between annual precipitation and phosphorus concentrations in South Turtle Lake, indicating the increase in phosphorus over this time period was likely not due to increases in external inputs from the watershed.

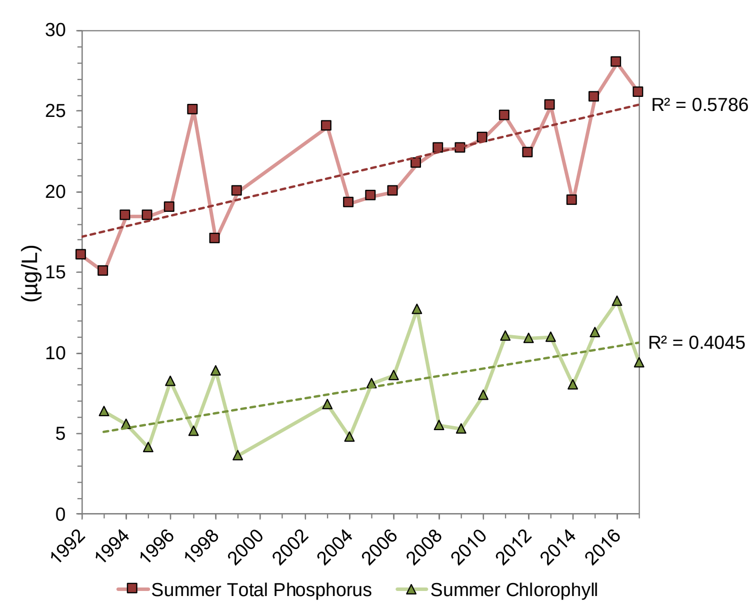


Figure 8.8.1-3. Linear regressions of average summer near-surface total phosphorus and chlorophyll-α concentrations in South Turtle Lake from 1992-2017. Both trends were statistically valid (p-value ≤ 0.001).

Because the measured increase in phosphorus since the early 1990s is likely not due to increases in the external input of phosphorus to the lake, the available water quality data suggest this phosphorus may be originating from within the lake itself through a process known as *internal nutrient loading*. Internal nutrient loading involves the release of phosphorus (and other nutrients) from lake bottom sediments into the overlying water. In general, lakes tend to act as phosphorus sinks, meaning they accumulate phosphorus over time within lake sediments. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel 2001). If this phosphorus remains bound within bottom sediments, it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson 1998).

Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density. As surface waters warm in late-spring/early summer, they become less dense and float atop a colder, denser layer of water below. The large density gradient between the upper, warm layer of water (epilimnion) and lower, cold layer of water (hypolimnion) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the water of the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton. These deep lakes remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall (dimictic lakes). In deep lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate nuisance algal blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in shallow, polymictic lakes, or moderately shallow lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms.

Phosphorus from bottom waters can also be mobilized to the surface in polymictic lakes through entrainment, or the continual deepening of the epilimnion and erosion of the metalimnion (transition zone or thermocline) and hypolimnion (Wetzel 2001). Wind-driven water generates turbulence across the thermal barrier between the epilimnion and the metalimnion and the metalimnion is eroded, mixing sediment-released nutrients into the epilimnion above. Both periodic mixing and entrainment act as “nutrient pumps” in polymictic lakes, delivering sediment-released nutrients in bottom waters to surface waters (Orihel et al. 2015). While a continuum exists between dimictic and polymictic lakes, the Osgood Index (Osgood 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake’s mean depth to its surface area. Lakes with an Osgood Index of less than 4.0 are deemed polymictic. South Turtle Lake has an Osgood Index value of 3.0, indicating it is a polymictic system.

An increase in external nutrient input and resulting increase in biological production through natural or human-made processes causes increased decomposition and oxygen demand in bottom waters. When oxygen demand reaches a rate at which anoxic conditions develop, sediment-bound nutrients which had largely been unavailable for biological use are released into the overlying water. If these nutrients become available for biological use through one of the mobilization processes discussed previously, this can lead to the consumption of more oxygen and the release of more nutrients from bottom sediments. The initial onset of anoxia in bottom waters can result in a positive feedback cycle where more nutrients and released (Cole and Weihe 2016). As a result, the lake may shift to a higher nutrient state.

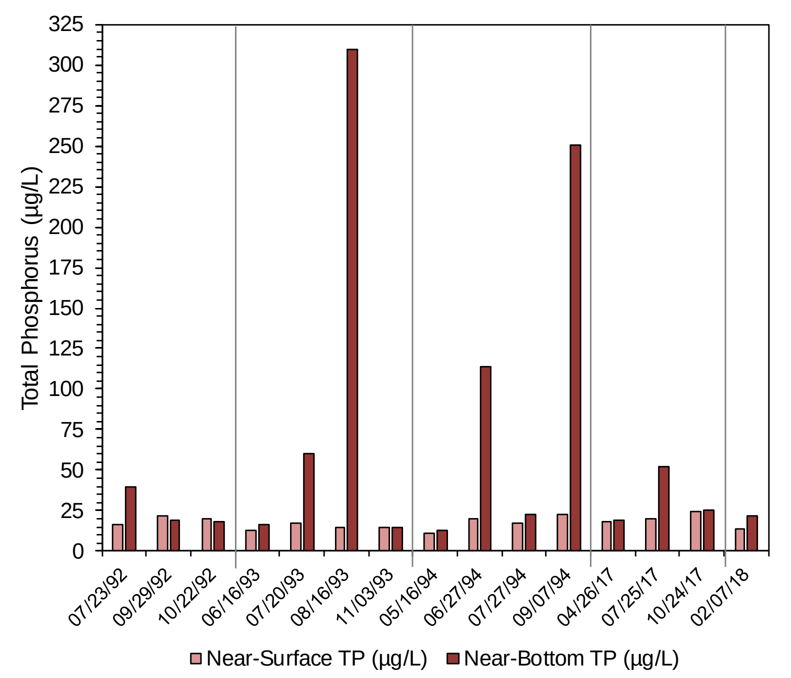


Figure 8.8.1-4. South Turtle Lake available near-bottom and corresponding near-surface total phosphorus concentrations.

In South Turtle Lake, data collected in 2017 along with available historical data indicate that internal nutrient loading does occur in South Turtle Lake. The first indication that internal nutrient loading occurs in South Turtle Lake is the concentration of phosphorus within the anoxic hypolimnion during the summer months. Summer hypolimnetic phosphorus concentrations are available from 1992, 1993, 1994, and 2017 (Figure 8.8.1-4). Mid-summer hypolimnetic phosphorus was not overly elevated in 2017 with a concentration of 52 µg/L, but concentrations measured in 1993 and 1994 exceeded 250 µg/L. These higher hypolimnetic phosphorus concentrations indicate internal nutrient loading does occur during summer stratification in South Turtle Lake. It is not necessarily significant that measured concentrations in the bottom waters were higher in 1993 and 1994 compared with 2017. The samples in 1993 and 1994 may have been collected during an extended period of stratification while the 2017 sample may have been collected shortly after the lake had mixed.

These higher hypolimnetic phosphorus during summer stratification are not unique to South Turtle Lake. Other Winchester project lakes including Harris, Birch, and Rainbow lakes also had similar hypolimnetic phosphorus concentrations during summer stratification. However, these lakes were found to maintain strong thermal stratification during the summer, and the phosphorus released from bottom sediments into the hypolimnion was not mobilized to the surface until fall mixing. In South Turtle Lake, historical temperature and dissolved oxygen profiles indicate that the epilimnion gets driven deeper over the course of the summer, cutting into the metalimnion (transition zone or thermocline) and hypolimnion and presumably mobilizing sediment-released nutrients to surface waters (Figure 8.8.1-5). This entrainment of phosphorus from the hypolimnion to the epilimnion is believed to have occurred in the summer of 2017 which resulted in a near-surface phosphorus "pulse" in August, where phosphorus concentrations increased by 10 µg/L (Figure 8.8.1-6).

The increasing trend in phosphorus in South Turtle Lake is an indication that internal nutrient loading is having a growing effect on the lake's water quality. Closer examination of the phosphorus data shows that the largest increase in phosphorus concentration has occurred in July and August (Figure 8.8.1-7), adding weight to the idea that phosphorus is being entrained from bottom waters to the surface following deepening of the epilimnion. Average June phosphorus concentrations from 1992-1999 and more recently from 2003-2017 are relatively similar at 18 and

19 µg/L, respectively (Figure 8.8.1-7). However, average July and August phosphorus concentrations have increased from 18 µg/L and 17 µg/L in 1992-1999 to 23 µg/L and 27 µg/L, respectively.

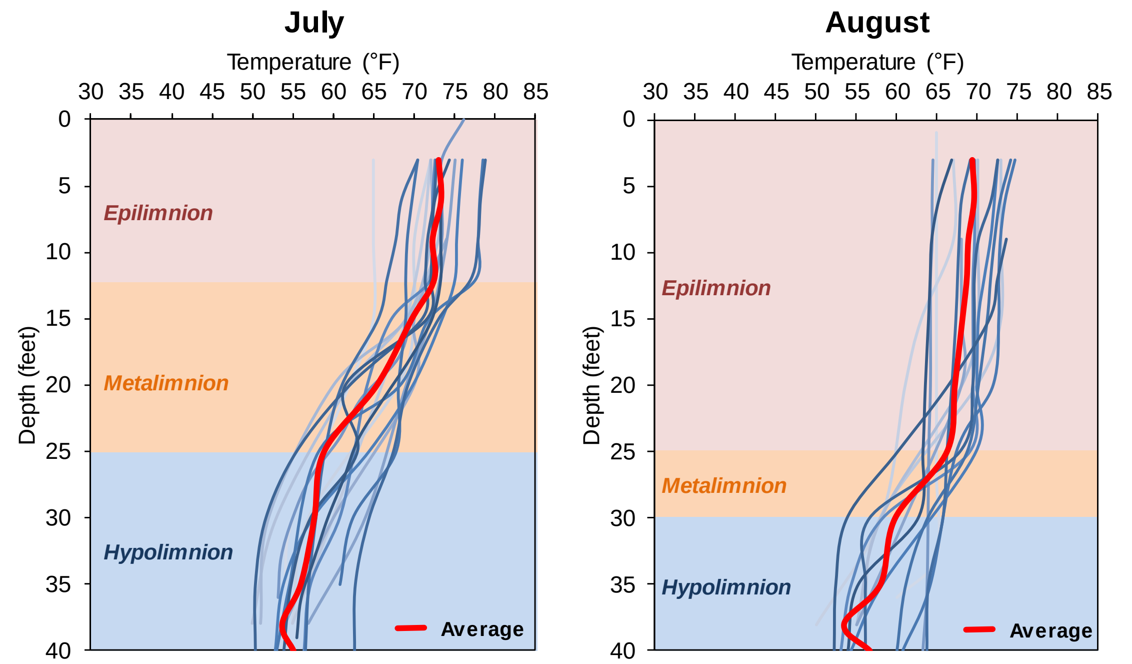


Figure 8.8.1-5. South Turtle Lake temperature profiles from July (1993-2017) and August (1992-2015) and average epilimnetic, metalimnetic, and hypolimnetic depths. These temperature profiles illustrate the deepening of the epilimnion from July to August resulting in the likely entrainment of sediment-released phosphorus from the anoxic metalimnion/hypolimnion to the epilimnion.

Increasing productivity in South Turtle Lake is also evidenced from dissolved oxygen profiles collected from 1993-1999, 2003, and 2017 (Figure 8.8.1-8). For most years from 1993-1999, South Turtle Lake maintained oxygenated conditions within bottom waters in July. In July of 2003 and 2017, bottom waters approximately 20 feet and deeper were found to be anoxic. Bacterial decomposition of organic matter which falls from surface waters consumes oxygen within the metalimnion and hypolimnion. The accelerated loss of oxygen in bottom waters in South Turtle Lake is an indication of eutrophication, or the lake becoming more productive. The increasing duration of anoxia in bottom waters is likely leading to more phosphorus being released from bottom sediments. The mobilization of this phosphorus from bottom waters to the surface is increasing biological production, which in turn increases biological decomposition and the consumption of more oxygen. This positive-feedback cycle is believed to be process resulting in increasing phosphorus concentrations in South Turtle Lake.

The initial onset of anoxia in bottom waters within a lake can be caused by increasing external nutrient inputs from the watershed due to human development. In Kentuck Lake (Forest and Vilas counties), sediment core analysis revealed that external nutrient input began to increase following disturbances within the watershed (logging and shoreline development). While the increase in external nutrient input was gradual, it eventually led to higher productivity within the lake and the onset of anoxia in bottom waters. Internal nutrient loading became a significant source of phosphorus for Kentuck Lake in the 1970s, which has since made the lake significantly more productive (Onterra 2018). The development of anoxia in bottom waters and release of sediment-bound nutrients in South Turtle Lake may also be the result of historical watershed disturbances which increased external nutrient input to the lake.

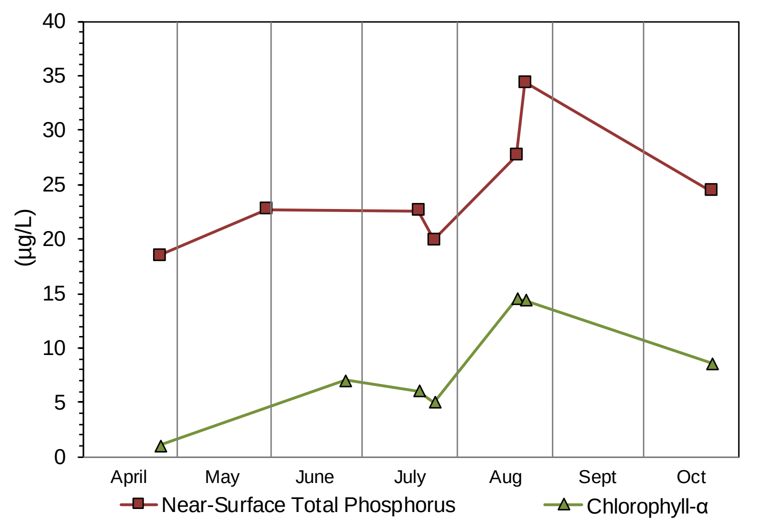


Figure 8.8.1-6. South Turtle Lake 2017 near-surface total phosphorus and chlorophyll-α concentrations illustrating "pulse" of phosphorus in August presumed to be caused by entrainment from the hypolimnion.

The presumed increasing magnitude of internal nutrient loading in South Turtle Lake could also be related to climate. Kraemer et al. (2015) found that average water temperature in lakes are increasing worldwide, and consequently are experiencing longer periods of stratification. These longer periods of stratification can result in longer periods of anoxia and release of nutrients from bottom sediments (Battarbee et al. 2012).

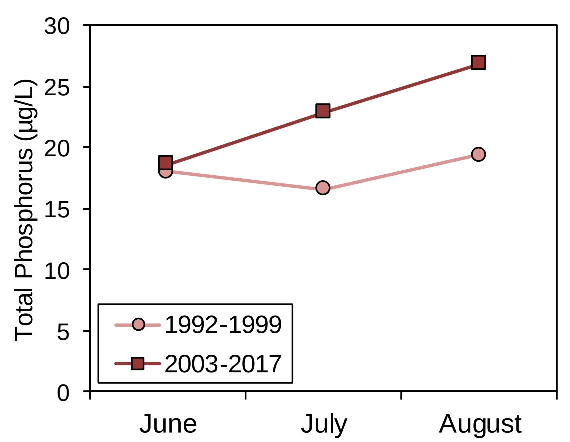


Figure 8.8.1-7. South Turtle Lake average summer near-surface total phosphorus concentrations from 1992-1999 and 2003-2017. These data illustrate that the largest increase in phosphorus concentration over this period has occurred in July and August.

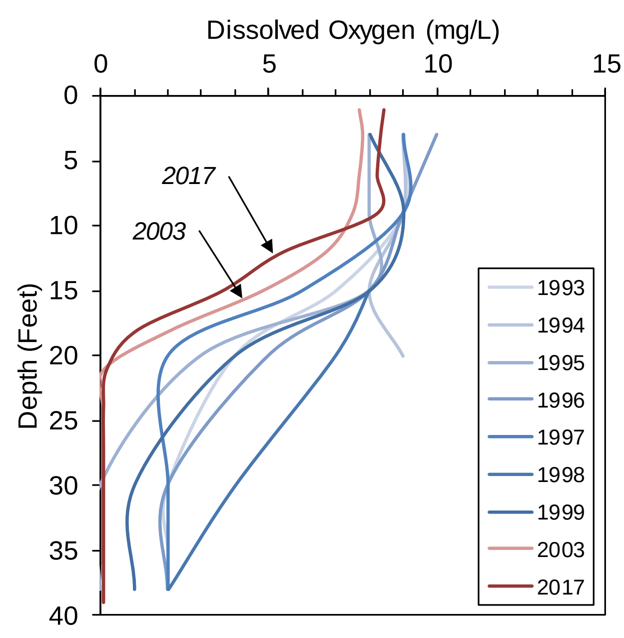


Figure 8.8.1-8. South Turtle Lake July dissolved oxygen profiles from 1993-1999, 2003, and 2017. The increased anoxia in bottom waters in 2003 and 2017 is an indication of eutrophication, or increasing nutrient concentrations and productivity.

More detailed studies of South Turtle Lake could be completed to accurately quantify the amount of phosphorus originating from internal nutrient loading. However, while phosphorus concentrations have increased over the past 25 years, summer phosphorus concentrations still fall into the *good* category for Wisconsin's deep headwater drainage lakes. Ongoing monitoring of the lake's water quality through the CLMN program will reveal if phosphorus concentrations continue to increase over time. If phosphorus concentrations continue to increase and algal blooms become more frequent, additional studies should be completed to determine if there are any applicable management strategies (e.g. alum treatment) that could be implemented to reduce the internal release of phosphorus from deep-water bottom sediments.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from South Turtle Lake from 1984, 1993-1999, and 2003-2017 (Figure 8.8.1-9). As expected, chlorophyll-*a* concentrations have seen a statistically valid (p-value = 0.001) increasing trend (R^2 = 0.40) over the time period from 1993-2017 corresponding with the increase in total phosphorus concentrations. The weighted average summer chlorophyll-*a* concentration is 8.4 µg/L, falling into the *good* category for deep headwater drainage lakes in Wisconsin. Summer chlorophyll-*a* concentrations in 2017 were slightly above average at 9.4 µg/L. South Turtle Lake's average summer chlorophyll-*a* concentration is higher than the median concentration for Wisconsin's deep headwater drainage lakes (5.0 µg/L) and higher than the median concentration for all lake types within the NLF ecoregion (5.6 µg/L).

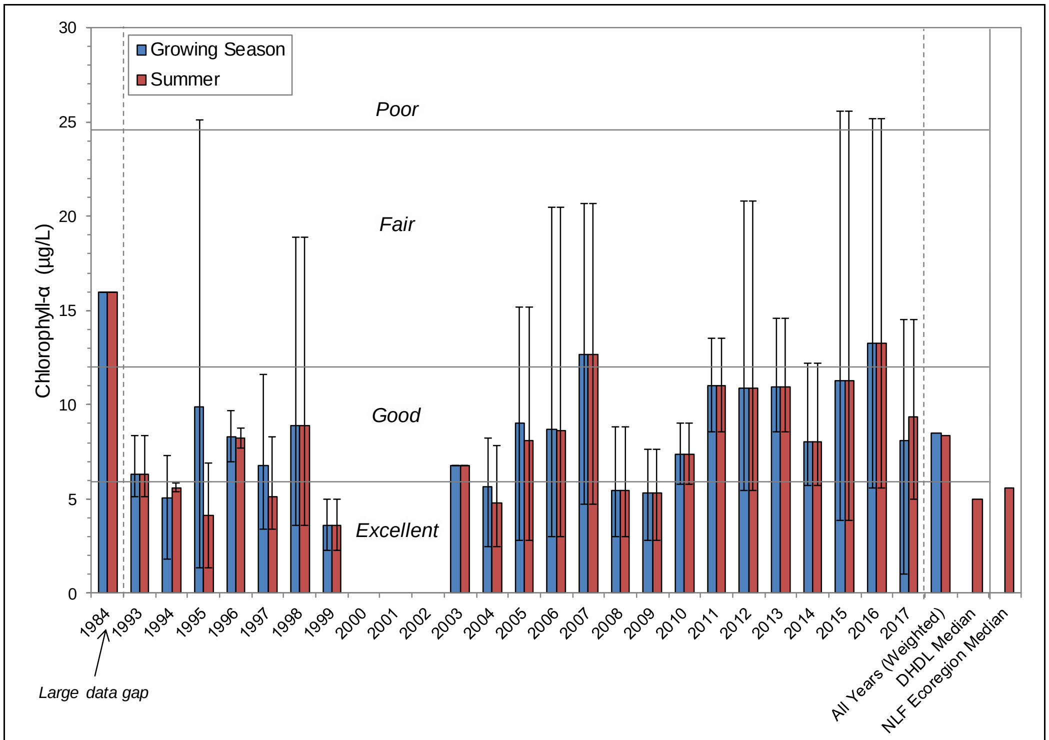


Figure 8.8.1-9. South Turtle Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

While average summer chlorophyll-*a* concentrations in South Turtle Lake fall into the *good* category, the lake was placed on the 303(d) list of impaired waterbodies in 2018 for chlorophyll concentrations which exceed the threshold for recreational use. Every two years, this list of lakes that are not meeting water quality standards under the Clean Water Act are submitted by the state to the Environmental Protection Agency. Wisconsin's deep drainage lakes are considered impaired for chlorophyll concentrations exceed 20 µg/L for >5% of the days between July 15 and September 15.

Using chlorophyll data from 2012-2016 in South Turtle Lake, the WDNR found that chlorophyll concentrations exceeded 20 µg/L greater than 5% of the days between July 15 and September 15 of these years, and the lake was placed on the list of impaired waters in 2018. This list aids managers in determining possible management actions that are required to meet water quality standards. While chlorophyll concentrations exceed the recreational threshold, total phosphorus concentrations fall below the recreational threshold of 30 µg/L.

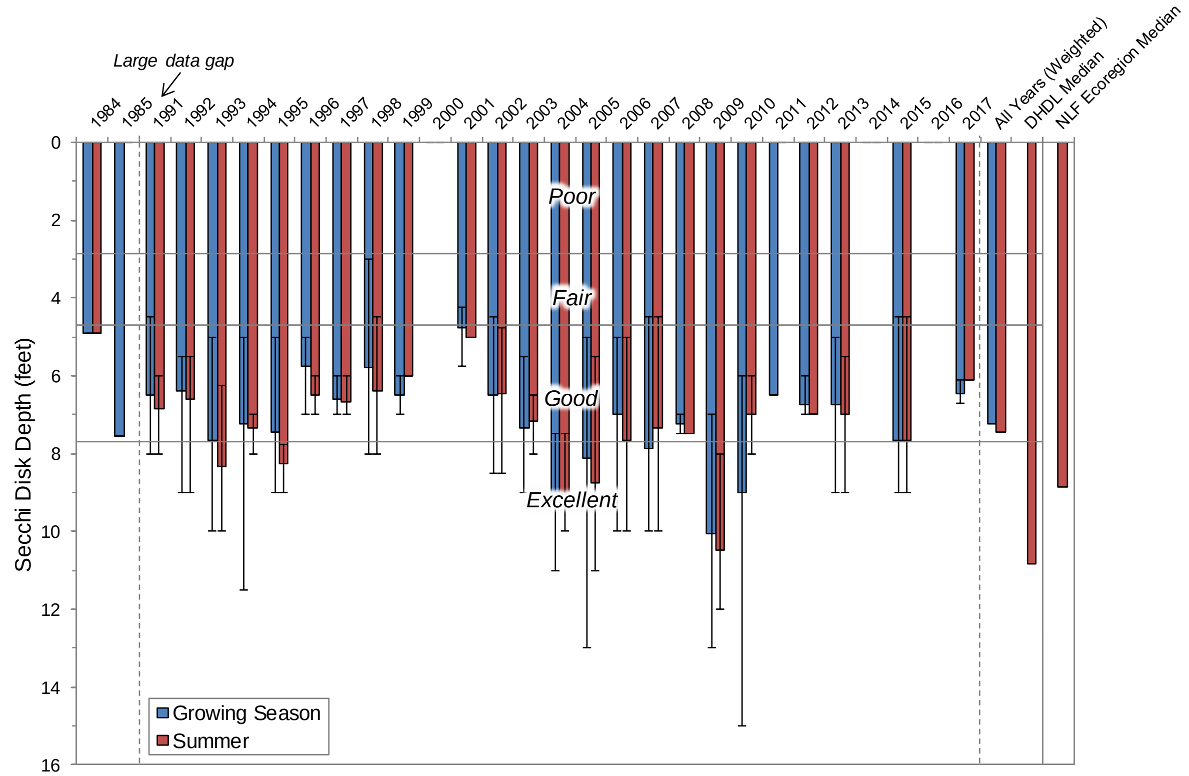


Figure 8.8.1-10. South Turtle Lake average annual Secchi disk depth and median Secchi disk depth for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Secchi disk transparency data from South Turtle Lake are available from 1984-1985, 1991-1999, 2001-2013, 2015, and 2017 (Figure 8.8.1-10). The weighted summer average Secchi disk depth is 7.4 feet, falling into the *good* category for deep headwater lakes in Wisconsin. South Turtle Lake's average summer Secchi disk depth is lower than the median depth for Wisconsin's deep headwater drainage lakes (10.8 feet) and the median depth for all lake types within the NLF ecoregion (8.9 feet). Average summer Secchi disk depth in 2017 was below average at 6.1 feet. Despite an increase in chlorophyll-*a* concentrations from 1993-2017, there has been no statistically valid trend (positive or negative) in average summer Secchi disk depth over this period (p-value = 0.55) (Figure 8.8.1-11).

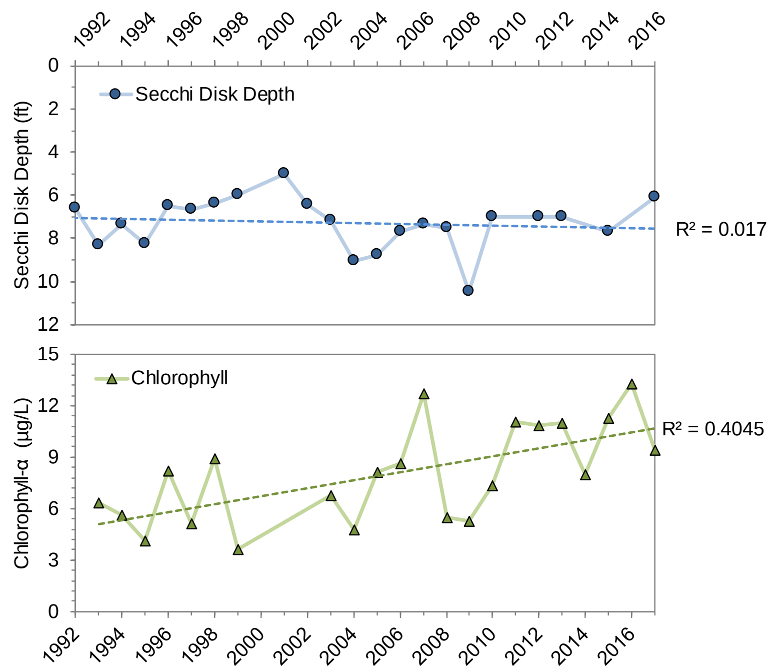


Figure 8.8.1-11. South Turtle Lake linear regressions of average summer Secchi disk depth (1992-2017) and chlorophyll-α (1993-2017). Change in Secchi disk depth was not statistically valid (p-value = 0.55); change in chlorophyll concentrations was statistically valid (p-value = 0.001).

Water clarity in South Turtle Lake has not declined despite increased algal production because its water clarity is largely regulated by dissolved humic substances. These humic substances originate from decaying vegetation within wetlands and forests and give the water a brown or tea-like color. A measure of water clarity once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from South Turtle Lake in 2017 averaged 40 SU (standard units), indicating the lake's water is *lightly tea-colored* to *tea-colored*.

Based on the average summer chlorophyll-*a* concentration of 6.0 µg/L from 1993-1999 in South Turtle Lake, the average summer Secchi disk depth was predicted to be 9.4 feet. However, the measured average summer Secchi disk depth during this period was 7.1 feet, over two feet lower than predicted. This is an indication that a factor other than phytoplankton, likely dissolved humic substances, were influencing water clarity. Based on the average summer chlorophyll-*a* concentration from 2003-2017 of 8.9 µg/L, average summer Secchi disk depth was predicted to be 7.7 feet, identical to the measured Secchi disk depth during this period. This indicates that the concentration of dissolved organic compounds may have declined when compared to the early 1990s, and water clarity in South Turtle Lake is currently regulated primarily by phytoplankton production. In 2017, Secchi disk depth was approximately 1.0 foot lower than predicted based upon chlorophyll concentrations. Above average precipitation in 2017 likely resulted in a higher input of dissolved humic substances and reducing water clarity. It is important to note that the tea-colored water in South Turtle Lake is natural, and is not an indication of degraded conditions.

South Turtle Lake Trophic State

Figure 8.8.1-12 contains the Trophic State Index (TSI) values for South Turtle Lake calculated from the data collected in 2017 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency 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 humic substances. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The TSI values for South Turtle Lake indicate that the lake was historically in a mesotrophic state and has transitioned to a eutrophic state around 2011. In 2017, TSI values for both phosphorus and chlorophyll indicated eutrophic conditions. While the weighted mean TSI values using available data falls within the mesotrophic category, recent data indicates the lake is currently in a eutrophic state. As discussed previously, the increase in South Turtle Lake's productivity is believed to be due to increasing effects from internal nutrient loading. South Turtle Lake's productivity is higher when compared to the majority of deep headwater drainage lakes in Wisconsin and all lakes within the NLF ecoregion.

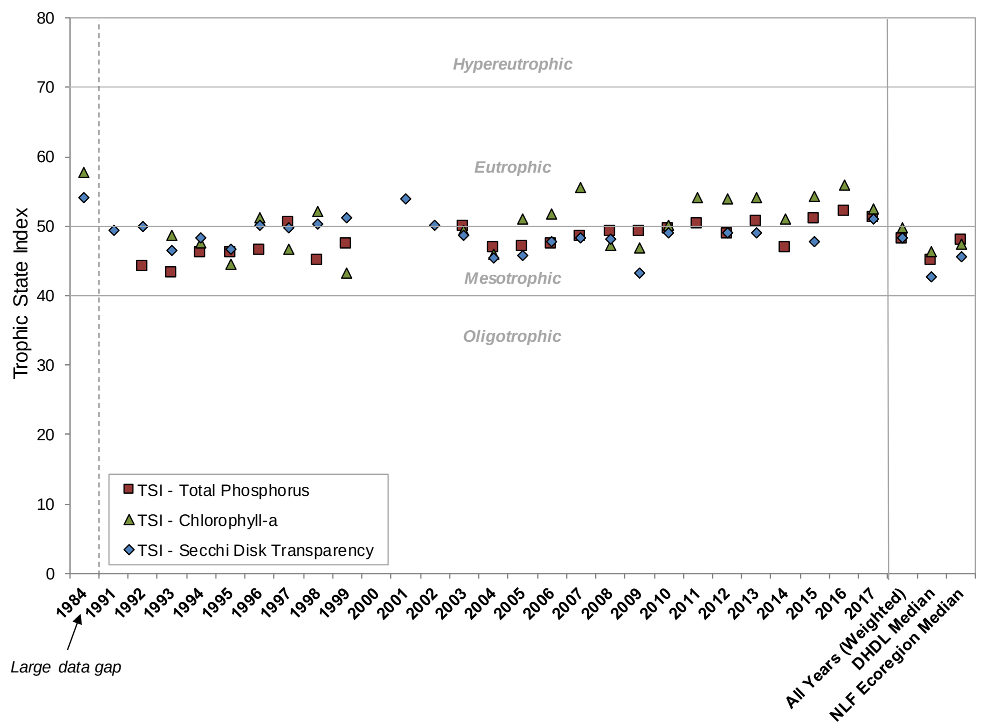


Figure 8.8.1-11. South Turtle Lake, statewide deep headwater drainage lakes (DHDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in South Turtle Lake

Dissolved oxygen and temperature profile data were collected during each water quality sampling events conducted by Onterra ecologists and South Turtle Lake CLMN volunteers. These data are displayed in Figure 8.8.1-12. The temperature and dissolved oxygen data collected in 2017 indicate that South Turtle Lake developed and maintained thermal stratification over the summer. Bottom waters were found to be anoxic in July at 20 feet and deeper. While historical temperature and dissolved oxygen profiles indicate the epilimnion in South Turtle Lake gets driven deeper over the course of the summer, profile data were not collected in August of 2017. In October 2017, temperature and dissolved oxygen were relatively uniform throughout the water column indicating fall mixing had occurred. Temperature and dissolved oxygen profiles were also collected through the ice in February of 2018. This sampling found that South Turtle Lake maintained sufficient oxygen throughout the water column to support aquatic life under the ice and that winter fish kills are not a concern.

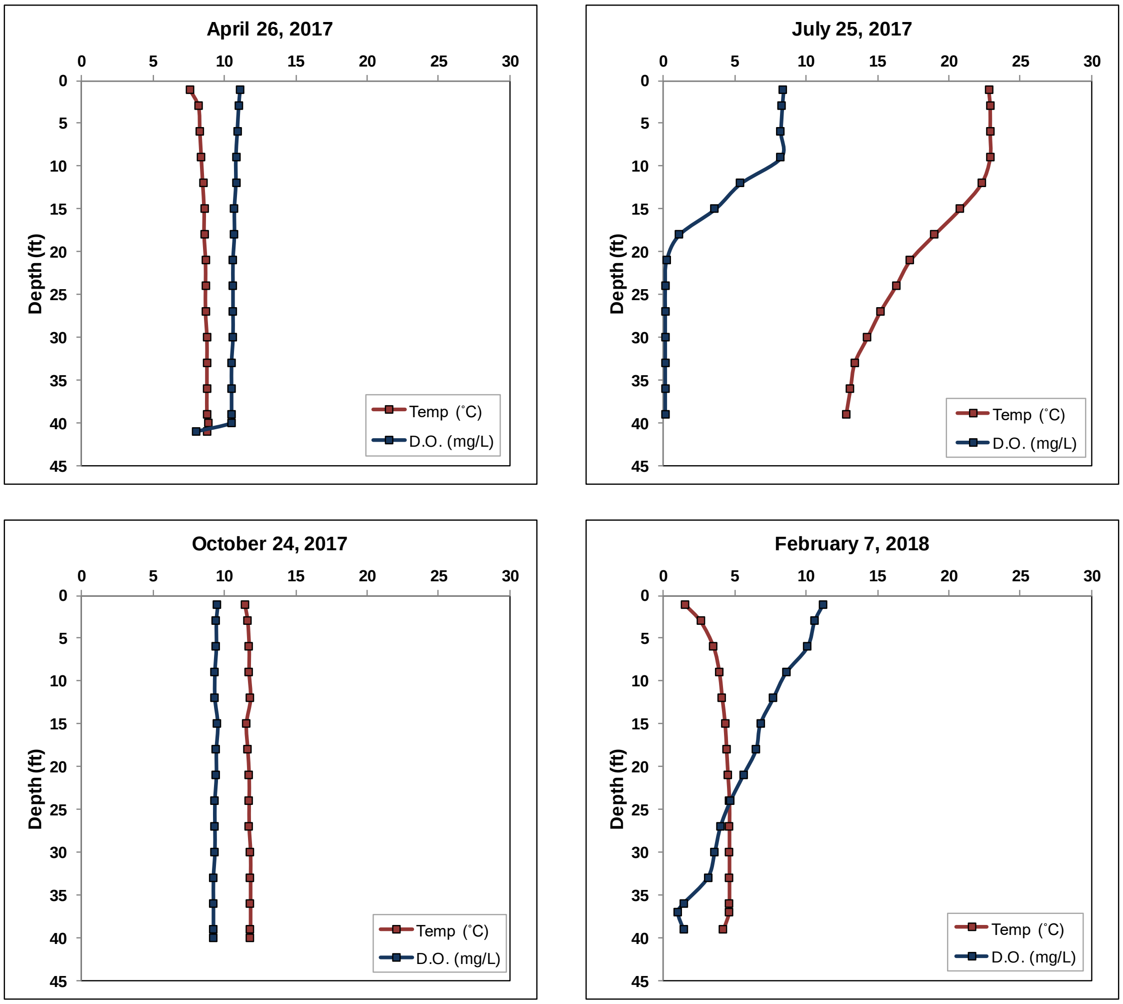


Figure 8.8.1-7. South Turtle Lake 2017/18 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected from South Turtle Lake

The previous section is centered on parameters relating to South Turtle Lake's trophic state. 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 South Turtle Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

As the Town-wide 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. South Turtle Lake's mid-summer surface water pH was measured at 7.7 in 2017. This value indicates South Turtle Lake's water is alkaline and falls within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality are common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds carbon dioxide to water, thereby increasing acidity. A lake's pH is primarily determined by the water's alkalinity, or a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. South Turtle Lake's average alkalinity measured in 2017 was 36.4 mg/L as $CaCO_3$. This value falls within the expected range for northern Wisconsin lakes, and indicates that while South Turtle Lake is considered a softwater lake, it is not sensitive to fluctuations in pH from acid rain.

Water quality samples collected from South Turtle Lake in 2017 were also analyzed for calcium. Calcium concentrations, along with pH, are currently being used to determine if a waterbody is suitable to support the invasive zebra mussel, as these animals require calcium for the construction of their shells. Zebra mussels typically require higher calcium concentrations than Wisconsin's native mussels, and lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The accepted suitable pH range for zebra mussels is 7.0 – 9.0, and South Turtle Lake's pH falls within this range. South Turtle Lake's calcium concentration in 2017 was 11.7 mg/L, indicating the lake has *very low susceptibility* to zebra mussel establishment. Plankton tows were completed by Onterra ecologists at three locations in South Turtle Lake in 2017 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2017 surveys.

As discussed earlier in this section, South Turtle Lake was recently placed on the 303(d) list of impaired waters due to chlorophyll concentrations which exceed the recreational threshold. South Turtle Lake was also placed on the 303(d) list for contaminated fish tissue by mercury in 1998. While mercury is found naturally in the environment due to volcanic eruptions and weathering of rocks, the majority of the mercury found in Wisconsin's waterbodies is the result of coal-fired power plants and the release of mercury into the atmosphere. Mercury is deposited into lakes, rivers, and streams through precipitation and the deposition of dust particles where it converted into its mobile and harmful form, methylmercury. Methylmercury becomes stored in bodies of aquatic animals, and concentrations tend to be highest in those species at the top of the food chain. In humans, mercury affects the nervous system and is of special concern for unborn children, infants, and children. For advice on eating fish from South Turtle Lake, please see the South Turtle Lake Fisheries Data Integration Section (Section 8.8.6).

8.8.2 South Turtle Lake Watershed Assessment

South Turtle Lake's surficial watershed encompasses approximately 12,901 acres (Figure 8.8.2-1 and South Turtle Lake – Map 2) yielding a watershed to lake area ratio of 34:1. However, as mentioned in the South Turtle Lake Water Quality Section (Section 8.8.1), given the close proximity of the inlet from North Turtle Lake and the Turtle River outlet, Onterra ecologists believe the majority of the water flowing into South Turtle Lake from North Turtle Lake flows out through the Turtle River and does not mix throughout South Turtle Lake proper. In other words, it is believed that the North Turtle Lake watershed has minimal influence on South Turtle Lake's water quality and its water quality is primarily influenced from its local or direct watershed. For this reason, modeling of South Turtle Lake's watershed involved estimations of phosphorus loading from its direct watershed and phosphorus inputs from the North Turtle Lake watershed were excluded.

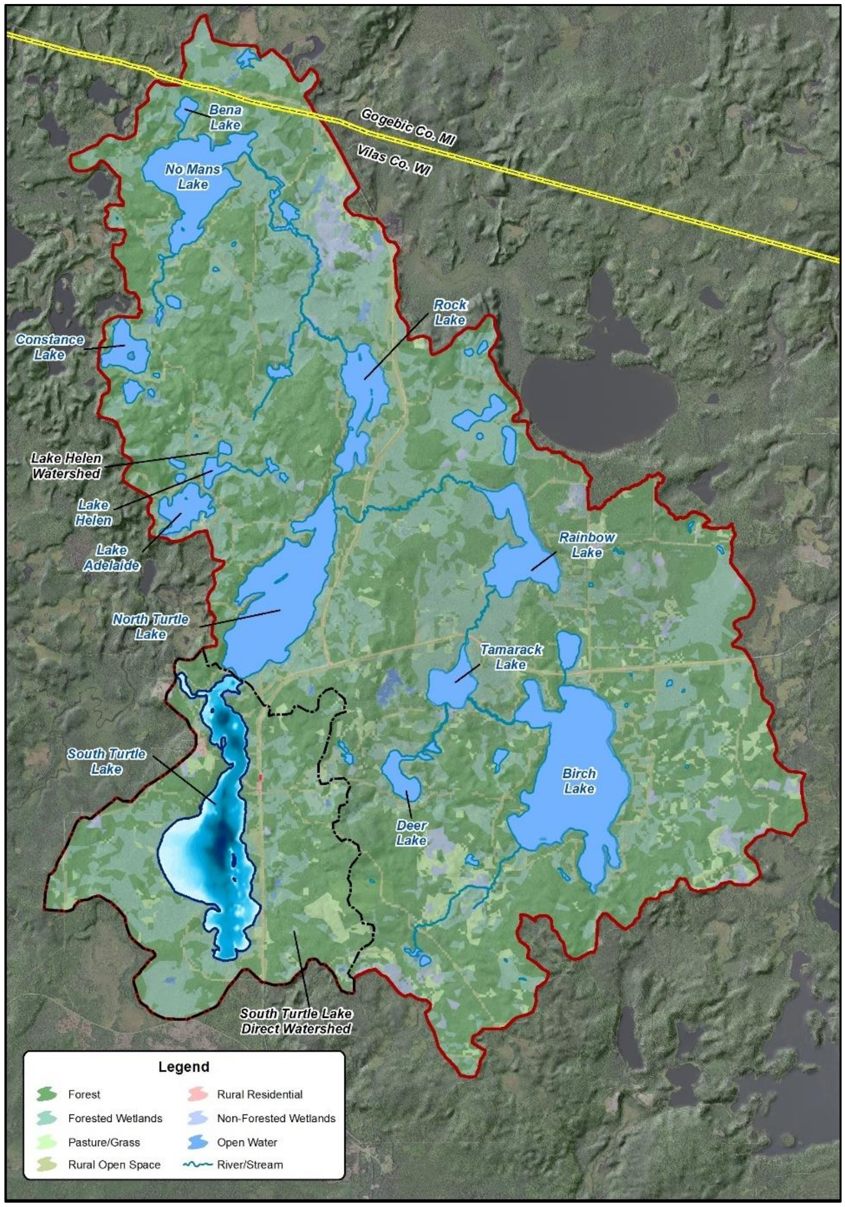


Figure 8.8.2-1. South Turtle Lake watershed boundary (red line), direct watershed (black dashed line) and land cover types. Black dashed lines indicate subwatersheds used in WiLMS modeling. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

South Turtle Lake's direct watershed encompasses approximately 2,455 acres and is comprised of land cover types including forests (43%), wetlands (27%), the lake's surface itself (20%), pasture/grass and rural open space (8%), and rural residential areas (<1%) (Figure 8.8.2-2). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that South Turtle Lake's water residence time is approximately 2.7 years, or the water within the lake is completely replaced once every 2.7 years.

Using the land cover types within South Turtle Lake's direct watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to South Turtle Lake. In addition, data obtained from a stakeholder survey sent to South Turtle Lake riparian property owners in 2017 was also used to estimate the amount of phosphorus loading to the lake from riparian septic systems. The model estimated that approximately 351 pounds of phosphorus are delivered to South Turtle Lake from its watershed on an annual basis (Figure 8.5.2-3).

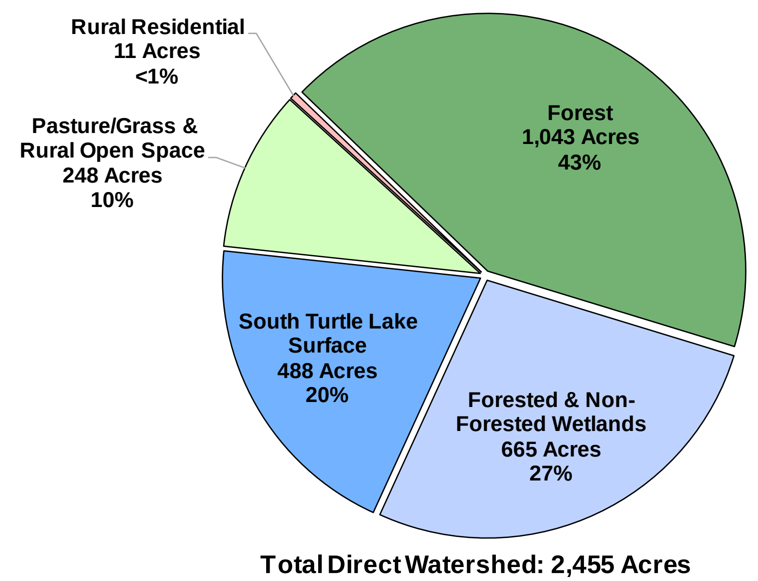


Figure 8.8.2-1. South Turtle Lake watershed boundary (red line), direct watershed (black dashed line) and land cover types. Black dashed lines indicate subwatersheds used in WiLMS modeling. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the estimated annual potential phosphorus load of 351 pounds, WiLMS predicted an in-lake growing season average total phosphorus concentration of 19 µg/L, which is 18% lower than the measured weighted average growing season mean of 23 µg/L and 23% lower than the measured growing season mean in 2017 of 24 µg/L. The higher measured phosphorus relative to the model-predicted phosphorus is an indication that an additional source of phosphorus is likely being loaded to South Turtle Lake that was not accounted for within the model. As is discussed in the South Turtle Lake Water Quality Section (Section 8.8.1), it is believed that phosphorus released from bottom sediments during summer stratification is being mobilized to the surface in late-summer through entrainment. The WiLMS modeling indicates that in order to achieve the measured concentrations of phosphorus in South Turtle Lake, and additional 100-200 pounds of phosphorus have to be loaded to the lake annually. Given the available data, it is believed this additional phosphorus originates from internal nutrient loading.

With the addition of the estimated internal nutrient loading, it is estimated that South Turtle Lake receives an average of 441-551 pounds of phosphorus per year (Figure 8.8.2-2). Internal nutrient loading accounts for approximately 36% of this load, direct atmospheric deposition onto the lake's surface accounts for 24%, forests account for 15%, pasture/grass and rural open space account for 12%, wetlands account for 11%, and riparian septic systems account for an estimated 11%.

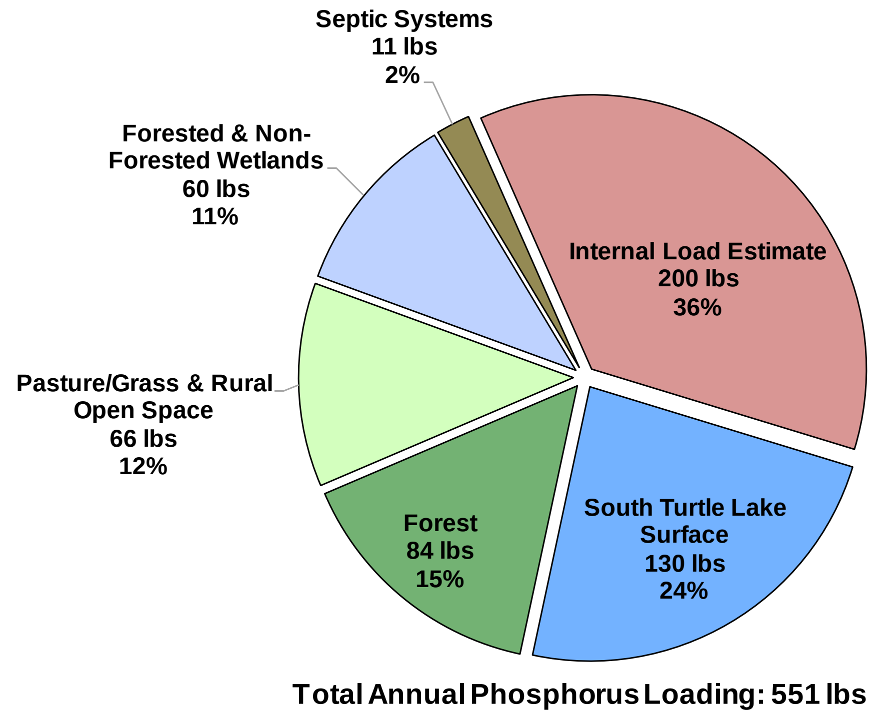


Figure 8.5.2-2. South Turtle Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.8.3 South Turtle Lake Shoreland Condition

Shoreland Development

As is discussed within the Town-wide Section, one of the most sensitive areas of a lake's watershed is the immediate shoreland zone. This transition zone between the aquatic and terrestrial environment is the last source of protection for the lake against pollutants originating from roads, driveways, and yards above, and is also a critical area for wildlife habitat and overall lake ecology. In the fall of 2017, the immediate shoreland of South Turtle Lake was assessed in terms of its development, and the shoreland zone was characterized with one of five shoreland development categories ranging from urbanized to completely undeveloped.

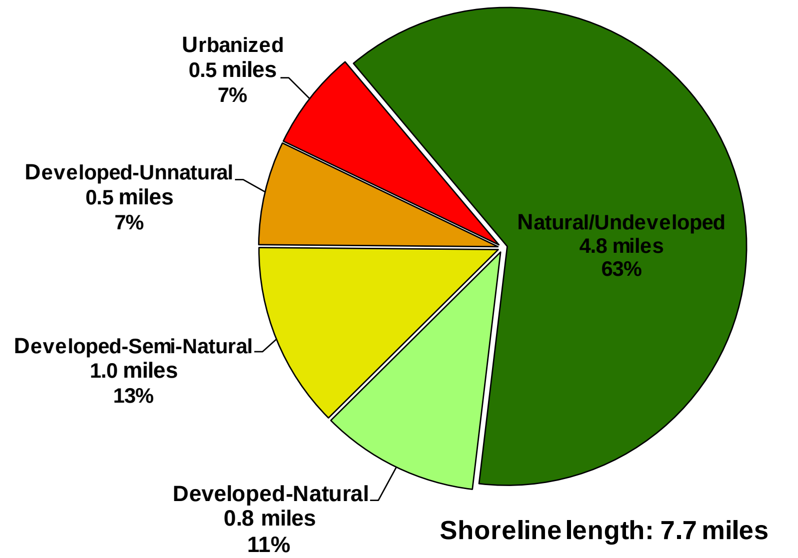


Figure 8.8.3-1. South Turtle Lake shoreland categories and total lengths. Based upon a fall 2017 survey. Locations of these categorized shorelands can be found on South Turtle Lake - Map 3.

The 2017 survey revealed that South Turtle Lake has stretches of shoreland that fit all five shoreland assessment categories (Figure 8.8.3-1). In total, 5.6 miles (74%) of the 7.7-mile shoreland zone were categorized as natural/undeveloped or developed-natural or shoreland types that provide the most benefit to the lake and should be left in their natural state if possible. Approximately 1.0 miles (14%) of the shoreland was categorized as developed-unnatural or urbanized, shoreland areas which provide little benefit to and may actually adversely impact the lake. If restoration of South Turtle Lake's shoreland is to occur, primary focus should be placed on these highly developed shoreland areas. South Turtle Lake – Map 3 displays the locations of these shoreland categories around the entire lake.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on South Turtle Lake in 2017. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Town-wide Section, 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 the coarse woody habitat survey on South Turtle Lake, a total of 299 pieces were observed along 7.7 miles of shoreline, yielding a coarse woody habitat to shoreline mile ratio of 39:1 (Figure 8.8.3-2). Onterra ecologists have completed these surveys on 98 Wisconsin lakes since 2012, and South Turtle Lake falls in the 75th percentile for the number of coarse woody habitat pieces per shoreline mile. Refraining from removing these woody habitats from the shoreland area will ensure this high-quality habitat remains in South Turtle Lake. The locations of these coarse woody habitat pieces are displayed on South Turtle Lake – Map 4.

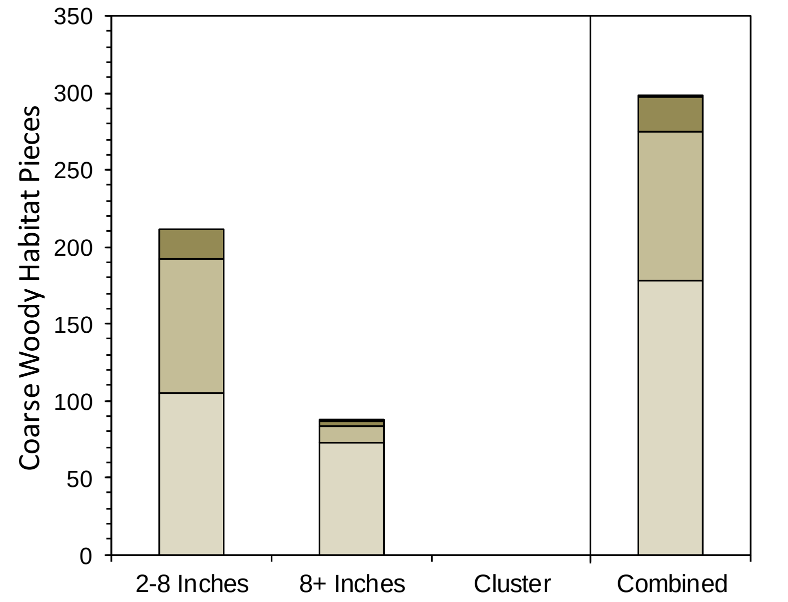


Figure 8.8.3-2. South Turtle Lake coarse woody habitat survey results. Based upon a fall 2017 survey. Locations of South Turtle Lake coarse woody habitat can be found on South Turtle Lake – Map 4.

8.8.4 South Turtle Lake Aquatic Vegetation

An Early-Season Aquatic Invasive Species (ESAIS) Survey was conducted by Onterra ecologists on South Turtle Lake on June 27 and 28, 2017. 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. Fortunately, no curly-leaf pondweed was located in South Turtle Lake in 2017, and it is believed that curly-leaf pondweed is not present within the lake or exists at an undetectable level. However, pale-yellow iris, a non-native wetland plant, was located in a few locations along South Turtle Lake's shoreline in 2017. Because of its ecological significance, pale-yellow iris in South Turtle Lake is discussed further in the subsequent Non-Native Aquatic Plants subsection.

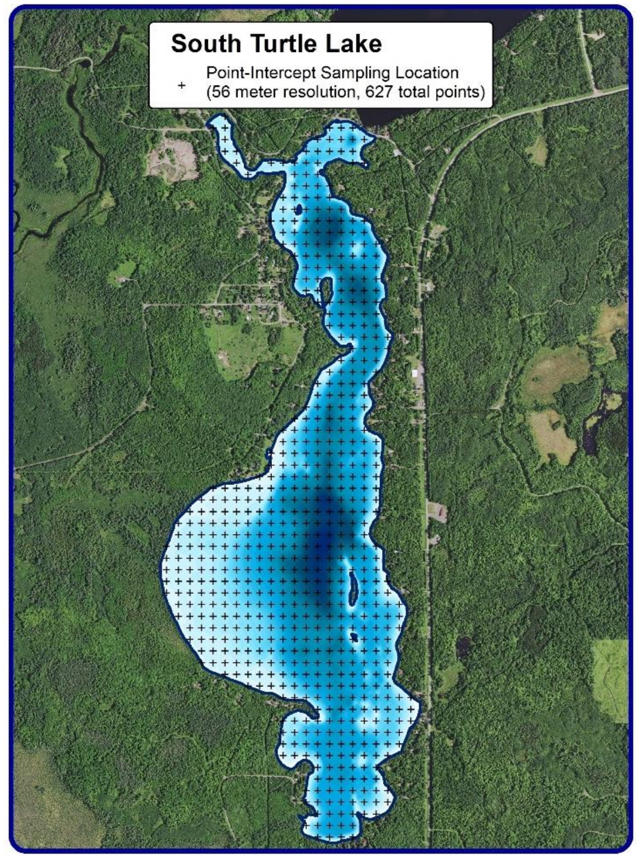


Figure 8.8.4-1. South Turtle Lake whole-lake point-intercept survey sampling locations.

The whole-lake aquatic plant point-intercept survey and emergent and floating-leaf aquatic plant community mapping survey were conducted on South Turtle Lake by Onterra ecologists on July 17 and 18, 2017 (Figure 8.8.4-1). During these surveys, a total of 41 aquatic plant species were located, one of which is considered to be a non-native, invasive species: pale-yellow iris (Table 8.8.4-1).

Lakes in Wisconsin vary in their morphometry, water chemistry, substrate composition, and management, all factors which influence aquatic plant community composition. In late September of 2017, Onterra ecologists completed an acoustic survey on South Turtle Lake (bathymetric results on South Turtle Lake – Map 1). The sonar-based technology records aquatic plant bio-volume, or the percentage of the water column that is occupied by aquatic plants at a given location. Data pertaining to South Turtle Lake's substrate composition were also recorded during this survey. The sonar records substrate hardness, ranging from the hardest substrates (i.e. rock and sand) to the more flocculent, softer organic sediments.

Data regarding substrate hardness collected during the 2017 acoustic survey showed that shallower areas of South Turtle Lake from approximately 1 to 10 feet contained both the hardest and softest substrates within the lake. The shallowest areas within the large bay on the southwest side of the lake contained some of the softest substrates, while hard substrates were found throughout shallower areas elsewhere around the lake. Beyond 10 feet to the deepest areas in the lake, substrates were moderately hard and more uniform when compared to shallower areas. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types;

some species are only found growing in soft substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because of the different habitat types that are available.

Table 8.8.4-1. List of aquatic plant species located in South Turtle Lake during Onterra 2017 aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	2017 (Onterra)
Emergent	*Acorus americanus*	Sweetflag	7	I
	Carex comosa	Bristly sedge	5	I
	Carex retrorsa	Retrorse sedge	6	I
	Decodon verticillatus	Water-willow	7	I
	Dulichium arundinaceum	Three-way sedge	9	I
	Eleocharis palustris	Creeping spikerush	6	I
	Equisetum fluviatile	Water horsetail	7	I
	Iris pseudacorus	Pale yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Pontederia cordata	Pickerelweed	9	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus acutus	Hardstem bulrush	5	X
FL	*Brasenia schreberi*	Watershield	7	X
	Nuphar variegata	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
	Sparganium fluctuans	Floating-leaf bur-reed	10	X
Submersed	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Ceratophyllum echinatum	Spiny hornwort	10	X
	Chara spp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Elodea nuttallii	Slender waterweed	7	X
	Fontinalis sphagnifolia	Rolled water moss	N/A	X
	Heteranthera dubia	Water stargrass	6	X
	Isoetes spp.	Quillwort spp.	8	I
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella spp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton gramineus	Variable-leaf pondweed	7	X
	Potamogeton natans	Floating-leaf pondweed	5	I
	Potamogeton praelongus	White-stem pondweed	8	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern-leaf pondweed	8	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	I
	*Potamogeton vaseyi**	Vasey's pondweed	10	I
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern in Wisconsin by WDNR Natural Heritage Inventory*

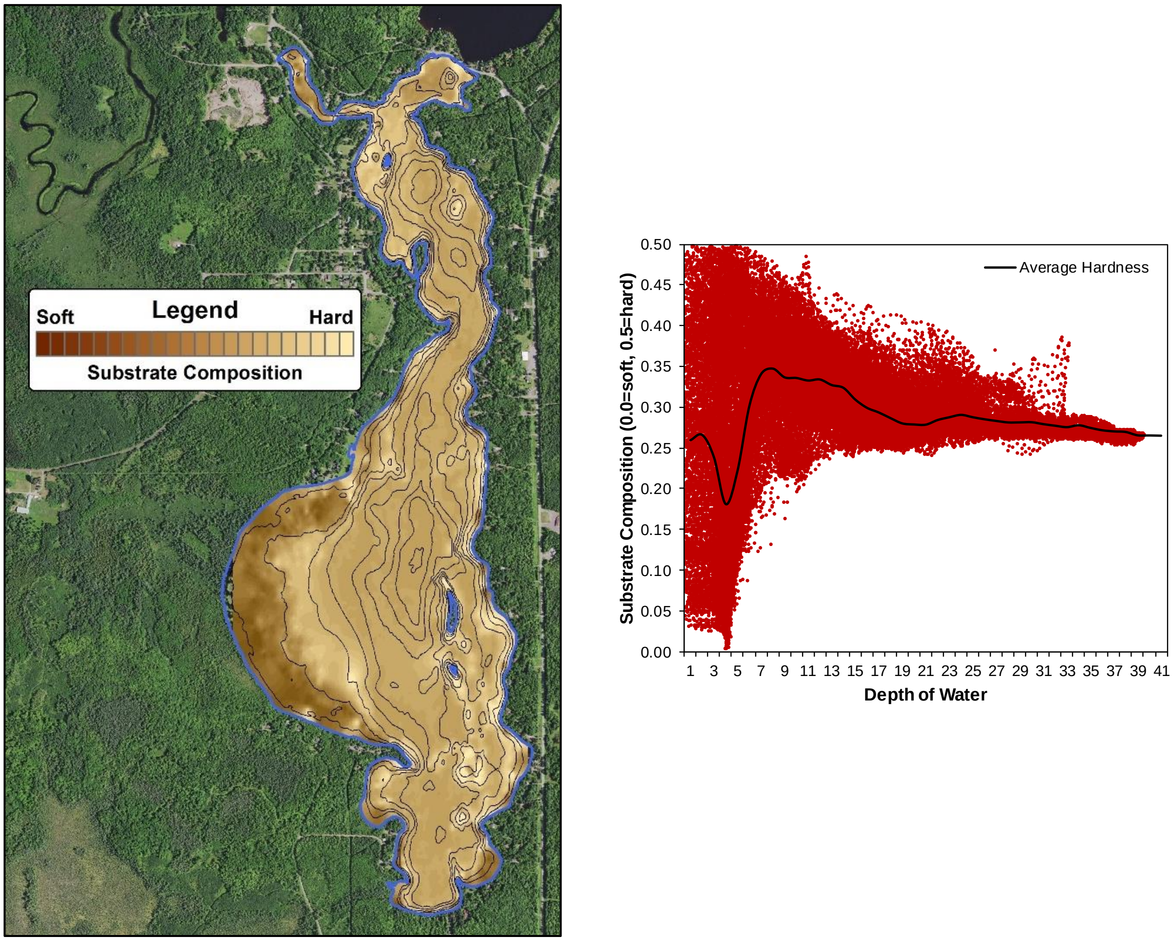


Figure 8.8.4-2. South Turtle Lake spatial distribution of substrate hardness (left) and substrate hardness across water depth (right). Depth contours represent 5-foot intervals. Individual data points are displayed in red. Creating using data from September 2017 acoustic survey.

The acoustic survey also recorded aquatic plant bio-volume throughout the entire lake. As mentioned earlier, aquatic plant bio-volume is the percentage of the water column that is occupied by aquatic plants. The 2017 aquatic plant bio-volume data are displayed in Figure 8.8.4-3 and South Turtle Lake – Map 6. Areas where aquatic plants occupy most or all of the water column are indicated in red. The 2017 whole-lake point-intercept survey found aquatic plants growing to a maximum depth of 10 feet. However, the majority of aquatic plant growth occurs within 3.0-7.0 feet of water. The 2017 acoustic survey indicated approximately 24% (117 acres) of South Turtle Lake's area is occupied by aquatic vegetation, while the remaining 76% of the lake contains unsuitable substrates or is too deep to support aquatic plant growth.

As mentioned, aquatic plants were recorded growing to a maximum depth of 10 feet in 2017. Of the 247 point-intercept sampling locations that fell at or shallower than the maximum depth of plant growth (littoral zone), approximately 61% contained aquatic vegetation. Aquatic plant rake fullness data collected in 2017 indicates that 22% of the 247 littoral sampling locations contained vegetation with a total rake fullness rating (TRF) of 1, 14% had a TRF rating of 2, and 25% had a TRF rating of 3 (Figure 8.8.4-4). These TRF ratings indicate that the biomass of aquatic vegetation in South Turtle Lake is moderate.

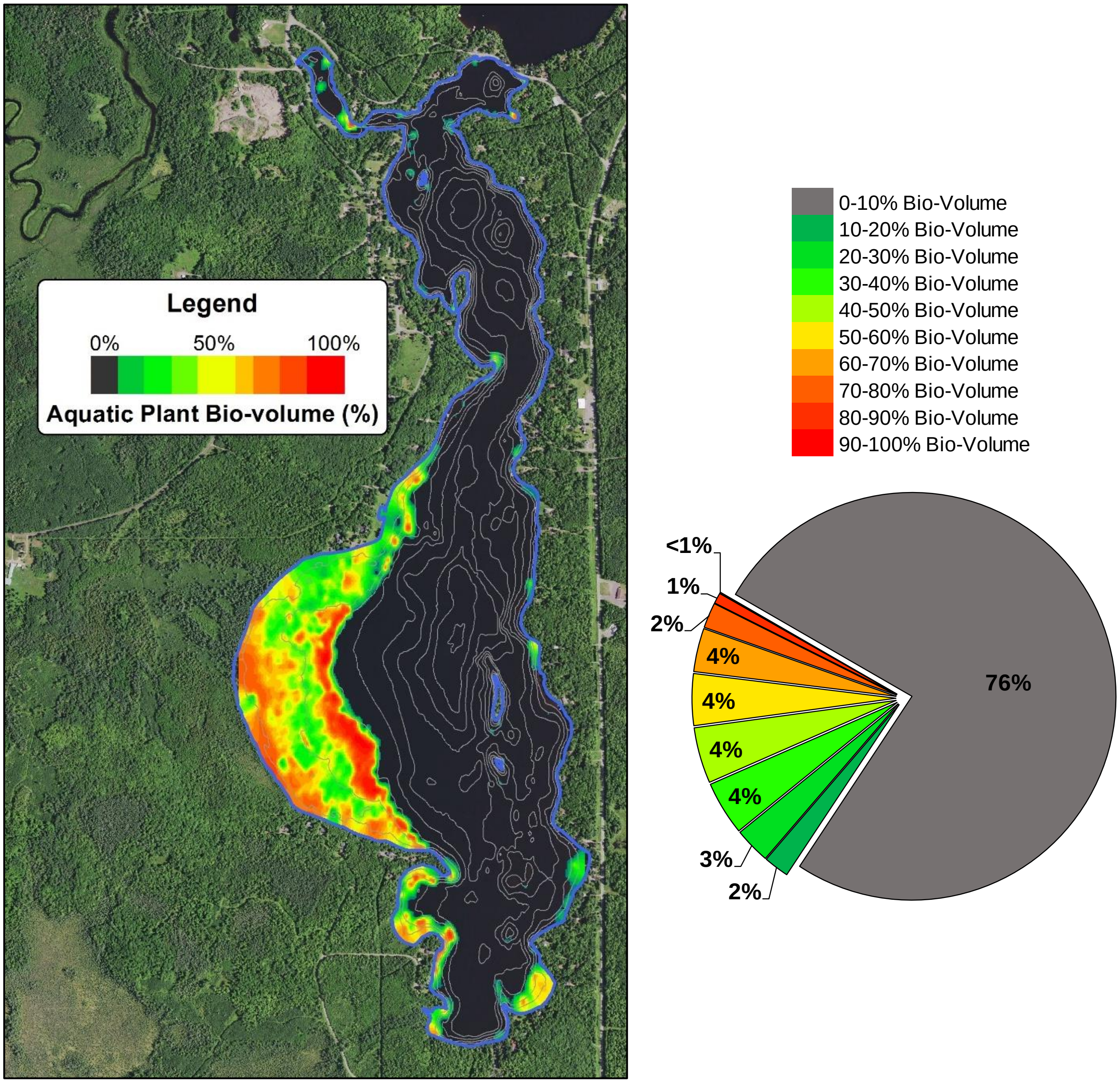


Figure 8.8.4-3. South Turtle Lake 2017 aquatic plant bio-volume. Contour lines are 5-foot intervals. Created using data from September 2017 acoustic survey data.

While the acoustic mapping is an excellent survey for understanding the distribution and levels of aquatic plant growth throughout the lake, this survey does not determine what aquatic plant species are present. Whole-lake point-intercept surveys are used to quantify the abundance of individual species within the lake. Of the 41 aquatic plant species located in South Turtle Lake in 2017, 26 were encountered directly on the rake during the whole-lake point-intercept survey (Figure 8.8.4-6). The remaining 15 species were located incidentally, meaning they were observed by Onterra ecologists while on the lake but they were not directly sampled on the rake at any of the point-intercept sampling locations. Incidental species typically include emergent and floating-leaf species that are often found growing on the fringes of the lake and submersed species that are relatively rare within the plant community. Of the 26 species directly sampled with the rake during the point-intercept survey, fern-leaf pondweed, small pondweed, and wild celery were the three-most frequently encountered aquatic plant species (Figure 8.8.4-5).

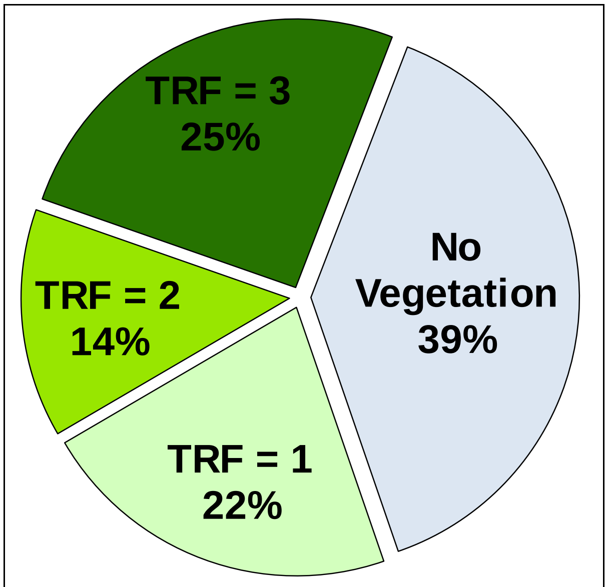


Figure 8.8.4-4. South Turtle Lake 2017 aquatic vegetation total rake fullness ratings (TRF). Created from data collected during the 2017 whole-lake point-intercept survey (N = 247).

Fern-leaf pondweed was the most frequently encountered aquatic plant species in South Turtle Lake in 2017 with a littoral frequency of occurrence of 35% (Figure 8.8.4-5). Fern-leaf pondweed is a common plant in softwater lakes in northern Wisconsin, and is often one of the most abundant. It can be found in shallow to deep water typically over soft sediments. Large beds of fern-leaf pondweed provide excellent structural habitat for aquatic wildlife and help to prevent the suspension of the soft bottom sediments in which they grow. In South Turtle Lake, fern-leaf pondweed, fern-leaf pondweed was most abundant between 4.0 and 6.0 feet of water over areas of soft sediment.

Small pondweed was the second-most frequently encountered aquatic plant in South Turtle Lake in 2017 with a littoral occurrence of 15% (Figure 8.8.4-5). Small pondweed is one of several narrow-leaf pondweed (*Potamogeton*) species that can be found in Wisconsin. While their name suggests these plants are small in stature, small pondweed often produces long stems (up to 17 feet; Onterra, personal obs.) with alternate, linear-shaped leaves. Small pondweed can often form dense colonies, and larger colonies of small pondweed were observed in the large bay on the southwest side of South Turtle Lake in 2017. Their dense network of stems and leaves provide excellent structural habitat and aid in reducing sediment resuspension. Small pondweed was most abundant between 6.0 and 9.0 feet in South Turtle Lake.

Wild celery, also known as tape or eelgrass, was the third-most frequently encountered aquatic plant species in South Turtle Lake in 2017 with a littoral frequency of occurrence of 13% (Figure 8.8.4-5). Wild celery produces long, ribbon-like leaves which emerge from a basal rosette, and it prefers to grow over harder substrates and is tolerant of low-light conditions. Its long leaves provide valuable structural habitat for the aquatic community while its network of roots and rhizomes help to stabilize bottom sediments. In mid- to late-summer, wild celery often produces abundant fruit which are important food sources for wildlife including migratory waterfowl. South Turtle Lake's areas of sand/cobble and low light conditions as a result of its stained water favor the dominance of wild celery. In 2017, wild celery was most abundant over hard substrates in water 2.0-5.0 feet deep in South Turtle Lake.

Submersed aquatic plants can be grouped into one of two general categories based upon their morphological growth form and habitat preferences. These two groups include species of the *isoetid* growth form and those of the *elodeid* growth form. Plants of the isoetid growth form are small, slow-growing, inconspicuous submerged plants (Photo 8.8.4-2). These species often have evergreen, succulent-like leaves and are usually found growing in sandy/rocky soils within near-shore areas of a lake (Boston and Adams 1987, Vestergaard and Sand-Jensen 2000).

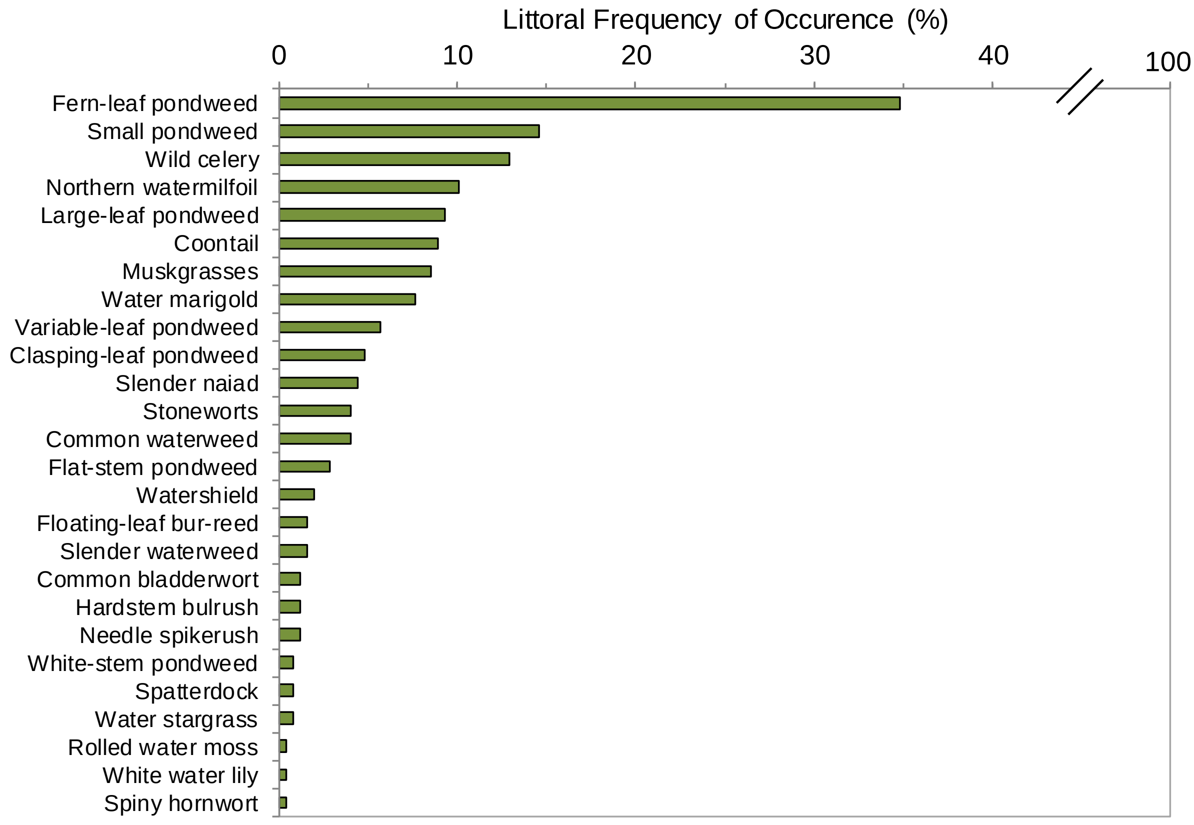


Figure 8.8.4-5. South Turtle Lake 2017 littoral frequency of occurrence of aquatic plant species. Created using data from 2017 whole-lake point-intercept survey.

In contrast, aquatic plant species of the elodeid growth form have leaves on tall, erect stems which grow up into the water column, and are the plants that lake users are likely more familiar with (Photo 8.8.4-2). It is important to note that the definition of these two groups is based solely on morphology and physiology and not on species' relationships. For example, dwarf-water milfoil (*Myriophyllum tenellum*) is classified as an isoetid, while all of the other milfoil species in Wisconsin such as northern water milfoil (*Myriophyllum* sibiricum) are classified as elodeids.

Alkalinity, as it relates to the amount of bicarbonate within the water, is the primary water chemistry factor for determining a lake's aquatic plant community composition in terms of isoetid versus elodeid growth forms (Vestergaard and Sand-Jensen 2000). Most aquatic plant species of the elodeid growth form cannot inhabit lakes with little or no alkalinity because their carbon demand for photosynthesis cannot be met solely from the dissolved carbon dioxide within the water and must be supplemented from dissolved bicarbonate.

On the other hand, aquatic plant species of the isoetid growth form can thrive in lakes with little or no alkalinity because they have the ability to derive carbon dioxide directly from the sediment, and many also have a modified form of photosynthesis to maximize their carbon storage (Madsen et al. 2002). While isoetids are able to grow in lakes with higher alkalinity, their short stature makes them poor competitors for space and light against the taller elodeid species. Thus, isoetids are most prevalent in lakes with little to no alkalinity where they can avoid competition from elodeids. However, in lakes with moderate alkalinity, like South Turtle Lake, the aquatic plant community can be comprised of isoetids growing beneath a scattered canopy of the larger elodeids. Isoetid communities are vulnerable to sedimentation and eutrophication (Smolders et al. 2002), and a number are listed as special concern (e.g. northeastern bladderwort) or threatened in Wisconsin due to their rarity and susceptibility to environmental degradation.


Photo 8.8.4-2. Lake quillwort (*Isoetes lacustris*) of the isoetid growth form (left) and variable pondweed (*Potamogeton gramineus*) and fern pondweed (*P. robbinsii*) of the elodeid growth form (right).

As discussed in the Town-Wide Section, the calculations used to create the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and do not include incidental species. The native species encountered on the rake during 2017 point-intercept survey on South Turtle Lake and their conservatism values were used to calculate the FQI of South Turtle Lake's aquatic plant community (equation shown below).

FQI = Average Coefficient of Conservatism * √ Number of Native Species

Figure 8.8.4-6 compares the 2017 FQI components of South Turtle Lake to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) ecoregion and lakes throughout Wisconsin. The native species richness, or number of native aquatic plant species located on the rake in 2017 (26) falls above the median value for lakes in the NLFL ecoregion (21) and for lakes throughout Wisconsin (19) (Figure 3.3.4-7). The average conservatism of the 26 native aquatic plant species located in South Turtle Lake in 2017 was 6.6, falling just below the median average conservatism values for lakes within the NLFL ecoregion (6.7) but above the median value for lakes throughout Wisconsin (6.3) (Figure 3.3.4-7). This indicates that a higher proportion of South Turtle Lake's aquatic plant community is comprised of environmentally-sensitive species, or species with higher conservatism values.

Using South Turtle Lake's native aquatic plant species richness and average conservatism yields a high FQI value of 33.4 (Figure 8.8.4-6). South Turtle Lake's FQI value exceeds the median values for lakes within the NLFL ecoregion (30.8) and the median value for lakes throughout the state (27.2). Overall, the FQI analysis indicates that the aquatic plant community found in South Turtle Lake is of higher quality when compared to the majority of lakes in Wisconsin.

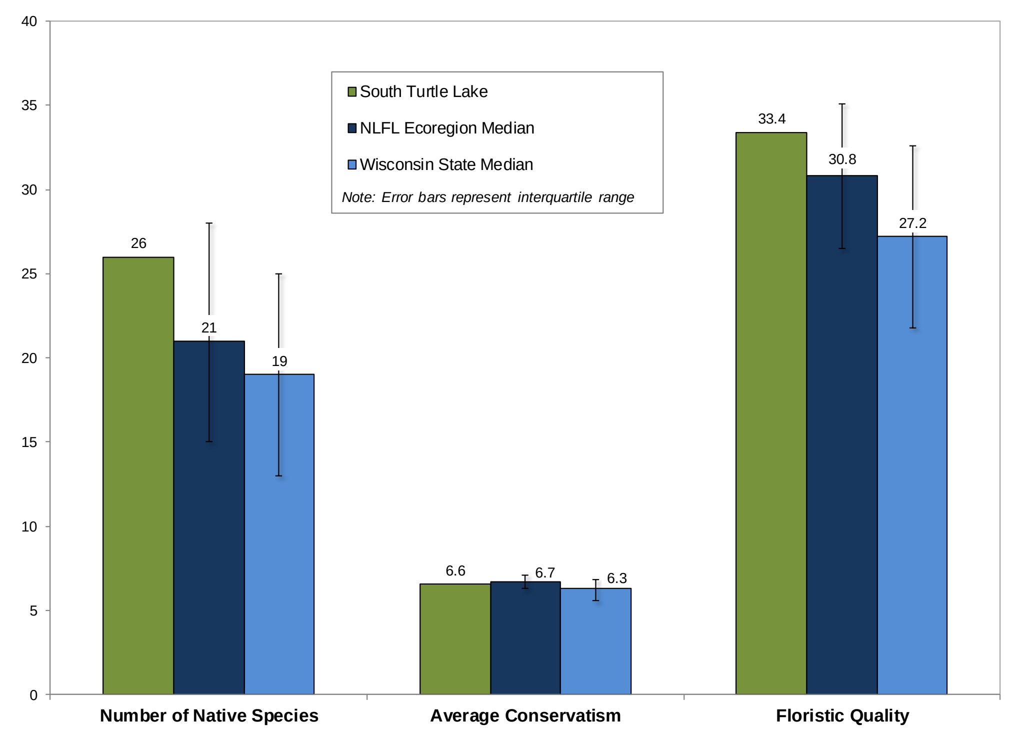


Figure 8.8.4-6. South Turtle Lake Floristic Quality Assessment. Created using data from Onterra 2017 whole-lake point-intercept survey. Analysis follows Nichols (1999).

As explained in the Town-wide section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, 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. Because South Turtle Lake contains a lower number of aquatic plant species, one may assume the aquatic plant community has low species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how South Turtle Lake's diversity value ranks. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL ecoregion (Figure 8.8.4-7). Using the data collected from the 2017 point-intercept survey, South Turtle Lake's aquatic plant was found to have high species diversity with a Simpson's Diversity Index value of 0.90. In other words, if two individual aquatic plants were randomly sampled from South Turtle Lake in 2017, there would be a 90% probability that they would be different species. South Turtle Lake's Simpson's Diversity exceeds the median value for lakes in the NLF ecoregion (0.88) and the median value for lakes throughout Wisconsin (0.86).

One way to visualize South Turtle Lake's species diversity is to look at the relative occurrence of aquatic plant species. Figure 8.1.4-8 displays the relative frequency of occurrence of aquatic plant species created from the 2017 whole-lake point-intercept survey and illustrates the relatively even distribution of aquatic plant species within the community. A plant community that is dominated by just a few species yields lower species diversity. 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 fern-leaf pondweed was found at 35% of the littoral sampling locations in South Turtle Lake in 2017, its relative frequency of occurrence was 24%. Explained another way, if 100 plants were randomly sampled from South Turtle Lake in 2017, 24 of them would be fern-leaf pondweed.

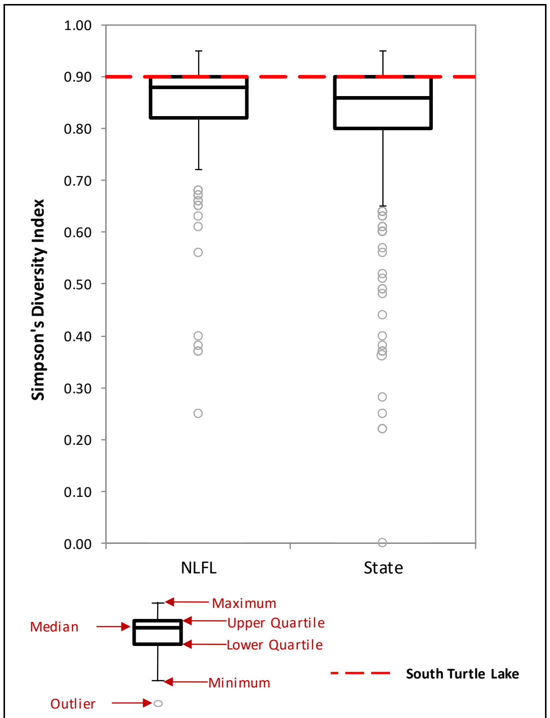


Figure 8.8.4-7. South Turtle Lake species diversity index. Created using data from Onterra 2016 point-intercept survey.

In 2017, Onterra ecologists also conducted a survey aimed at mapping emergent and floating-leaf aquatic plant communities in South Turtle Lake. This survey revealed South Turtle Lake contains approximately 23 acres of these communities comprised of 16 plant species (South Turtle Lake – Map 7 and Table 8.8.4-2). These native emergent and floating-leaf plant communities provide valuable fish and wildlife habitat that is important to the ecosystem of the lake. These areas are particularly important during times of fluctuating water levels, since structural habitat of fallen trees and other forms of course-woody habitat can be quite sparse along the shores of receding water lines. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within South Turtle Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

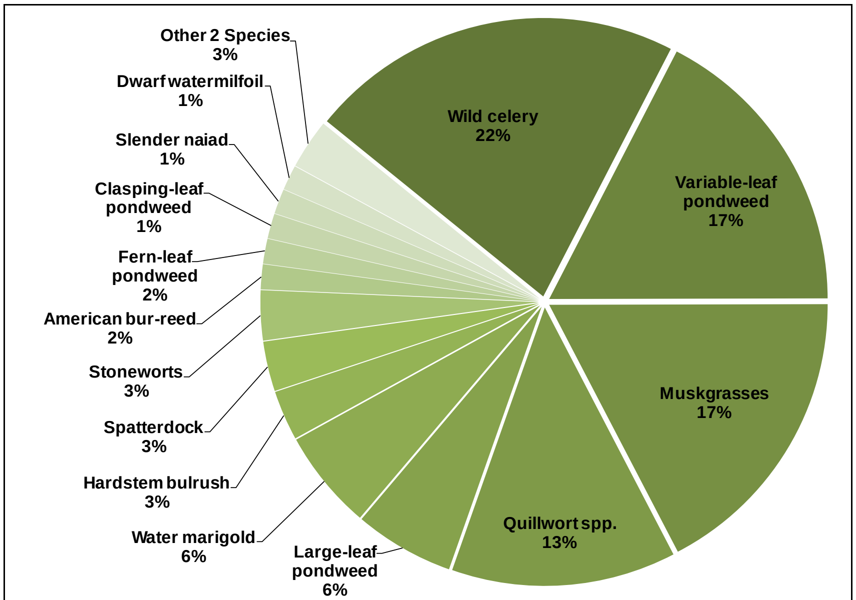


Figure 8.8.4-9. South Turtle Lake 2017 relative frequency of occurrence of aquatic plant species. Created using data from 2017 point-intercept survey.

Table 8.8.4-2. South Turtle Lake 2017 acres of emergent and floating-leaf aquatic plant communities. Created using data from 2017 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	6.7
Floating-leaf	13.0
Mixed Emergent & Floating-leaf	3.7
Total	**23.3**

Non-native Aquatic Plants in South Turtle Lake

Pale-Yellow Iris

Pale yellow iris (*Iris pseudacorus*; Photo 8.8.4-4 and South Turtle Lake – Map 8) 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 was located growing in a few locations along the shorelines of South Turtle Lake by NLDC and Onterra staff in 2017 (South Turtle Lake – Map 7). There are a number of control strategies that can be used to control pale-yellow iris. A strategy for managing pale-yellow iris on South Turtle Lake is discussed within the Turtle Chain Implementation Plan.

Photo 8.8.4-4. Pale-yellow iris (*Iris pseudacorus*), a non-native, invasive wetland plant found along the shorelines of South Turtle Lake in 2017. Photo credit Onterra.

8.8.5 Aquatic Invasive Species in South Turtle Lake

As of 2017, the only non-native species documented in South Turtle Lake is pale-yellow iris (*Iris pseudacorus*). However, the non-native rusty crayfish (*Orconectes rusticus*) has been documented in North Turtle Lake, and it is likely that rusty crayfish are present in South Turtle Lake. Rusty crayfish were introduced to Wisconsin from the Ohio River Basin in the 1960's likely via anglers' discarded bait. In addition to displacing native crayfish (*O. virilis* and *O. propinquus*), rusty crayfish also degrade the aquatic habitat by reducing aquatic plant abundance and diversity and have also been shown to consume fish eggs. While there is currently no control method for eradicating rusty crayfish from a waterbody, aggressive trapping and removal has been shown to significantly reduce populations and minimize their ecological impact. While it is possible these species are present in South Turtle Lake, their presence has not been officially verified.

8.8.6 South Turtle Lake 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 South Turtle Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2017 & GLIFWC 2017).

South Turtle Lake Fishery

Energy Flow of a Fishery

When examining the fishery of a lake, it is important to remember what drives that fishery, or what is responsible for determining its mass and composition. The gamefish in South Turtle Lake are supported by an underlying food chain. At the bottom of this food chain are the elements that fuel algae and plant growth – nutrients such as phosphorus and nitrogen and sunlight. The next tier in the food chain belongs to zooplankton, which are tiny crustaceans that feed upon algae, 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 8.8.6-1.

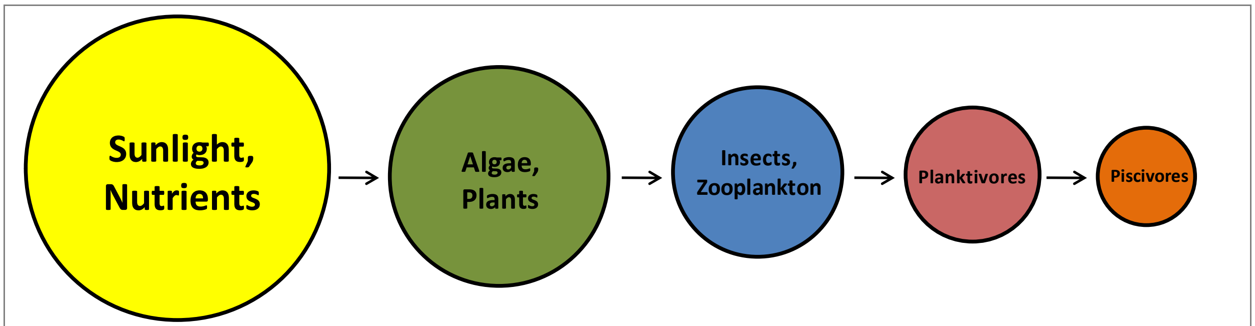


Figure 8.8.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section (Section 8.8.1), South Turtle Lake is a eutrophic system, meaning it has high nutrient content and thus relatively high primary productivity. Simply put, this means South Turtle Lake should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust. Table 8.8.6-1 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 surveys of South Turtle Lake include burbot (*Lota lota*), white sucker (*Catostomus commersonii*), and the greater redhorse (*Moxostoma valenciennesi*).

Table 8.8.6-1. Gamefish present in South Turtle Lake 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
Cisco (*Coregonus artedii*)	22	Late November - Early December	Various shoreline substrates.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling 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
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass (*Micropterus dolomieu*)	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, 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 8.8.6-1). 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 electroshocking (Photograph 8.8.6-1). This is often done 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 easy for fisheries technicians to net and place into a livewell to recover. Contrary to what some may believe, electroshocking 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 these data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 8.8.6-1. 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 fry, fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 8.8.6-2). Stocking of 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. South Turtle Lake was stocked from 1972 to 2000 with muskellunge and walleye (Tables 8.8.6-2 and 8.8.6-3).

Photograph 8.8.6-2. Fingerling Muskellunge.

Table 8.8.6-2. Stocking data available for muskellunge in South Turtle Lake (1980-2000).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1980	Muskellunge	Fingerling	900	10
1987	Muskellunge	Fingerling	1,500	12
1989	Muskellunge	Fingerling	500	11
1991	Muskellunge	Fingerling	250	11
1992	Muskellunge	Fingerling	250	11
1996	Muskellunge	Fingerling	368	10.8
1998	Muskellunge	Large Fingerling	450	12.2
2000	Muskellunge	Large Fingerling	450	10.8

Table 8.8.6-3. Stocking data available for walleye in South Turtle Lake (1972-1977).

Year	Species	Age Class	# Fish Stocked	Avg Fish Length (in)
1972	Walleye	Fingerling	22,500	3
1974	Walleye	Fingerling	10,000	3
1977	Walleye	Fingerling	22,000	3

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing was the second important reason for owning property on or near South Turtle Lake (Question #17). Figure 8.8.6-2 displays the fish that South Turtle Lake stakeholders enjoy catching the most, with bluegill/sunfish and walleye being the most popular. Approximately 34% of these same respondents believed that the quality of fishing on the lake was good, 25% believed fair and 28% believed poor (Figure 8.8.6-3). Approximately 72% of respondents who fish South Turtle Lake believe the quality of fishing has been somewhat or much worse since they started fishing the lake (Figure 8.8.6-3).

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. Creel surveys were completed on Rock, South Turtle and South Turtle Lakes during the 1991-92 and 2010-11 fishing seasons (Table 8.8.6-5).

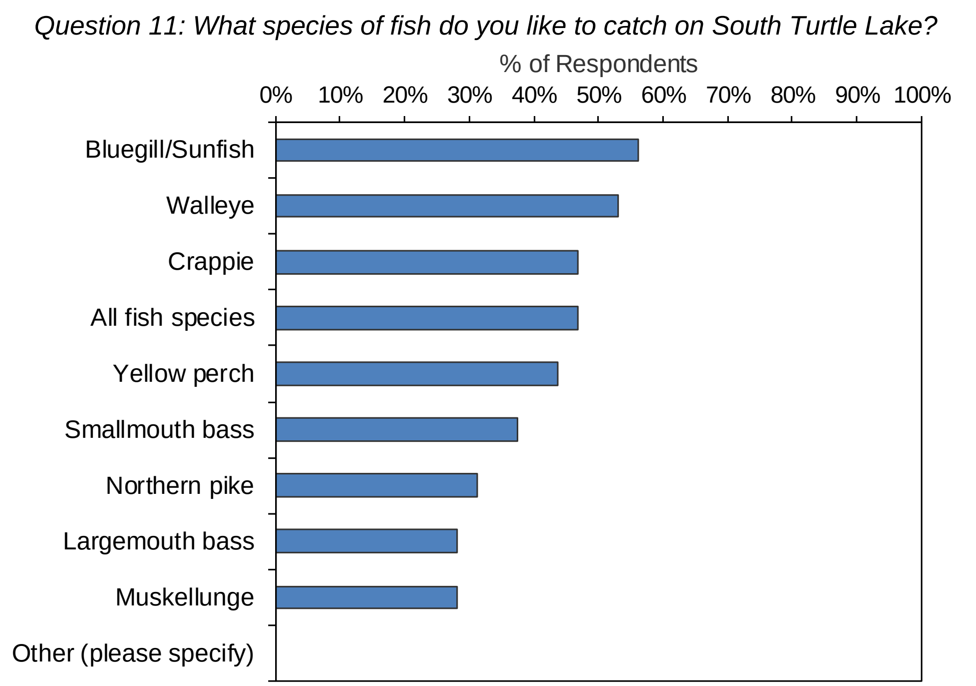


Figure 8.8.6-2. Stakeholder survey response Question 11. Created based on data from 37 respondents of 120 surveys sent (39%).

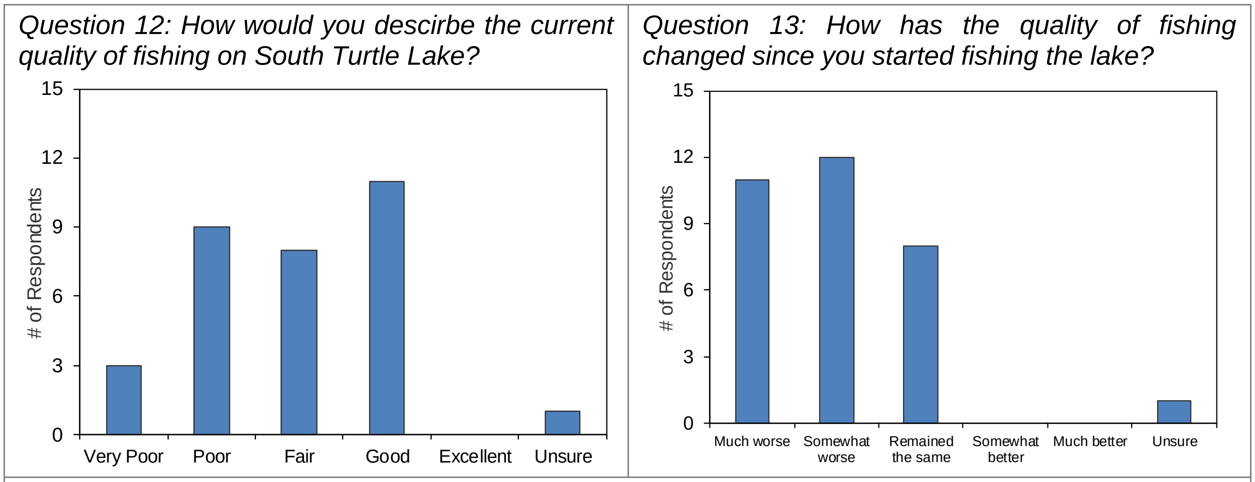


Figure 8.8.6-3. Stakeholder survey responses to questions 12 and 13. Created based on data from 37 respondents of 120 surveys sent (39%).

Total angler effort was somewhat higher in 1991-92 (20.5 hours/acre) compared to the 2010-11 season (18.1 hours/acre). Anglers directed the largest amount of effort towards walleye and muskellunge during both the 2010-11 and 1991-92 seasons (Table 8.8.6-5).

Table 8.8.6-5. Creel Survey data for 1991-92 and 2010-11 fishing seasons.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch	Catch / Acre	Harvest	Harvest / Acre	Hours of Directed Effort / Fish Caught	Hours of Directed Effort / Fish Harvested
Largemouth Bass	1991	20.5	0	0	0	0	0		
	2010	18.1	0.9	30	0.1	0	0	11.3	
Muskellunge	1991	20.5	6.7	84	0.2	0	0	45.5	
	2010	18.1	6	95	0.3	0	0	31.7	
Northern Pike	1991	20.5	0.6	62	0.2	11	0	36.2	
	2010	18.1	0.5	51	0.1	5	0	5.6	
Smallmouth Bass	1991	20.5	0.7	179	0.5	33	0.1	5.7	32.2
	2010	18.1	1.9	484	1.3	19	0.1	1.9	67.1
Walleye	1991	20.5	11.3	4457	12.1	117	0.3	0.9	37.5
	2010	18.1	10.2	2501	6.8	1249	3.4	1.5	3

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 South Turtle Lake represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch walleye on South Turtle Lake (Figure 8.8.6-2). A 2010 WDNR fisheries survey conducted on South Turtle Lake showed a moderate density of walleye (WDNR 2010).

Panfish

Abundant populations of yellow perch were present with moderate numbers of black crappie, bluegill and rock bass found after the 2010 WDNR fisheries survey (WDNR 2010). The results for the stakeholder survey show anglers prefer to catch bluegill/sunfish on South Turtle Lake (Figure 8.8.6-2).

South Turtle Lake Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 8.8.6-4). South Turtle Lake falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process.

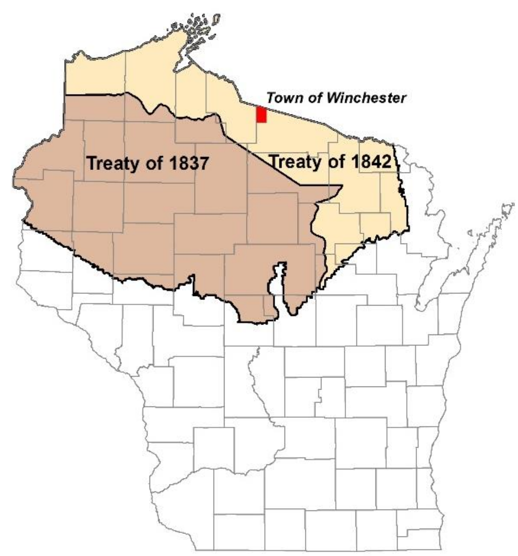


Figure 8.8.6-4. Location of Town of Winchester within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

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 is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. 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 tribal or recreational harvesting means.

By March 15th of each year the relevant tribal communities may declare a proportion of the total safe harvest on each lake. This declaration represents the maximum number of fish that can be taken by tribal spear harvesters or netters annually (Spangler, 2009). 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).

Spear harvesters are able to 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 2016). 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 spear harvesters may only take two walleye over 20 inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). 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 spear harvesters. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations.

Walleye open water spear harvest records from 1999-2017 in South Turtle Lake are provided in Figure 8.8.6-5. As many as 151 walleye have been harvested from the lake in the past (2010), but the average harvest is roughly 46 fish per year. Spear harvesters on average have taken 38% of the declared quota. Additionally, on average, 8% of walleye harvested have been female.

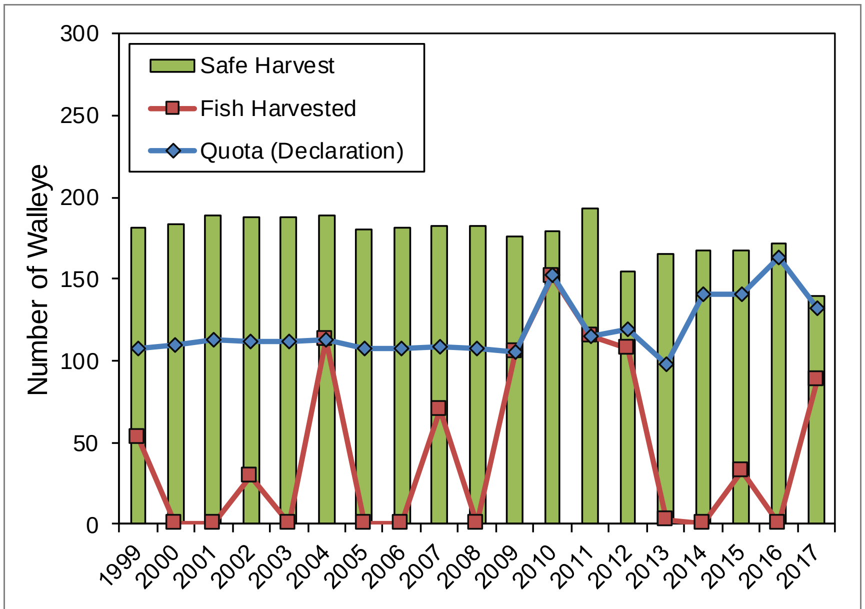


Figure 8.8.6-5. South Turtle Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records from 1999-2017 in South Turtle Lake are provided in Figure 8.8.6-6. A maximum of one muskellunge has been harvested from the lake in the past (2007), while most years have seen zero muskellunge harvested. Spear harvesters on average have taken 0% of the declared quota.

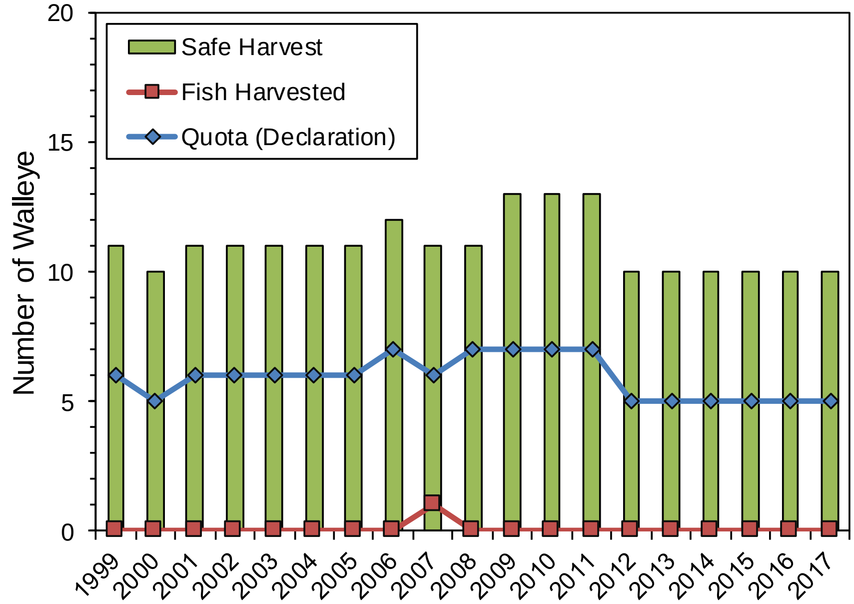


Figure 8.8.6-6. South Turtle Lake muskellunge spear harvest data. (GLIFWC 1999-2017).

South Turtle Lake Fish Habitat

Substrate Composition

Just as forest wildlife require proper trees and understory growth to flourish, fish require certain substrates and habitat types to nest, spawn, evade 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 have substrates largely comprised of sand and rock 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 do 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 over soft sediments as well. According to the point-intercept survey conducted by Onterra in 2017, 54% of the substrate sampled in the littoral zone of South Turtle Lake were soft sediments, 25% was composed of sand and 21% were composed of rock sediments.

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 2006). A fall 2017 survey documented 299 pieces of coarse woody along the shores of South Turtle Lake, resulting in a ratio of approximately 39 pieces per mile of shoreline. When compared to the other 98 lakes Onterra has completed coarse woody habitat surveys on since 2012, South Turtle Lake falls in the 75^{h} percentile for the number of course woody habitat pieces per shoreline mile.

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. 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 8.8.6-3). 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 other partner contributions.

Photograph 8.8.6-3. Examples of fish sticks (left) and half-log habitat structures (right). (Photos by WDNR).

Fish cribs are a fish habitat structure that are placed on the lakebed. Installing fish cribs may 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. Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 8.8.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills 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 are spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline and are mainly installed to enhance 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 indicated the addition of rock substrate did not significantly improve walleye reproduction (WDNR 2004).

Placement of a fish habitat structures in a lake does not require 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. The Town of Winchester should 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 South Turtle Lake.

Regulations

Regulations for South Turtle Lake gamefish species as of April 2018 are displayed in Table 8.8.6-6. 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 8.8.6-6. WDNR fishing regulations for South Turtle Lake (As of April 2018).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	None	Open All Year
Smallmouth bass (Early Season)	Catch and release only	None	May 5, 2018 to June 15, 2018
Smallmouth bass	5	14"	June 16, 2018 to March 3, 2019
Largemouth bass	5	14"	May 5, 2018 to March 3, 2019
Muskellunge and hybrids	1	40"	May 26, 2018 to November 30, 2018
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	None but only 1 fish over 14" is allowed.	May 5, 2018 to March 3, 2019
Bullheads	Unlimited	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 3 hooks, baits, or lures maximum per boat.

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.

As discussed in the South Turtle Lake Water Quality section (Section 8.8.1), South Turtle Lake was placed on the 303(d) list of impaired waterbodies for contaminated fish tissue by mercury in 1998. General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 8.8.6-7. 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 than that amount, and you should rarely eat more than 4 servings of fish within a week.*

Figure 8.8.6-7. 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/)

8.9 Turtle Lakes Chain Implementation Plan

The Implementation Plan presented in this section was created through the collaborative efforts of the Turtle Lakes Chain Association (TLCA) Planning Committee, Onterra ecologists, and North Lakeland Discovery Center (NLDC) and WDNR staff. It represents the path the TLCA 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 Turtle Lakes Chain stakeholders as portrayed by the members of the Planning Committee and the communications between Planning Committee members and the chain stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the chain, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue monitoring of Turtle Lakes Chain water quality through the WDNR Citizens Lake Monitoring Network (CLMN).
Timeframe:	Continuation and expansion of current effort
Facilitator:	TLCA Board of Directors
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Continued monitoring of all chain lakes can lead to early detection of potential negative trends and may lead to the reason to why the trend is developing. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the TLCA have been measuring Secchi disk transparency on Rock Lake and Secchi disk transparency, total phosphorus, and chlorophyll-*a* on North and South Turtle Lakes for many years. The TLCA realizes the importance of continuing this effort which will supply them with valuable data about the chain. Funding from the WDNR for advanced water quality monitoring (addition of total phosphorus and chlorophyll-*a* over Secchi disk transparency) has been increasingly difficult to acquire as the list of lakes desiring to be in the advanced program increases in the Northern Region of the WDNR. Rock Lake intercepts a portion of the surface water flowing into North Turtle Lake, acting as a sedimentation basin North Turtle, therefore, it is important to monitor more than Secchi disk transparency in Rock Lake. While attempting to get Rock Lake into the advanced water quality category of the CLMN program will be the first step and primary objective, the TLCA will consider approaching the Town of Winchester to assist in funding the analysis of water samples of total

phosphorus and chlorophyll-*a* from Rock Lake through the Wisconsin State Lab of Hygiene. It is important to have the samples analyzed through the state lab not only because it is an excellent analytics lab, but also because the data is automatically loaded into the WDNR database, Surface Water Integrated Monitoring System (SWIMS). This may be a workable solution for the Town as other lake groups and lakes in the Town may make the same inquiry.

As discussed in the South Turtle Lake Water Quality Section 8.8.1, an increasing trend in total phosphorus concentrations was discovered as a part of this planning project. While the lake's water quality is currently considered as good, it is very important to continue water quality monitoring to confirm if the trend is continuing, leveling off, or declining. Continued CLMN water quality monitoring is obviously important for South Turtle Lake because it is the source of long-term trend data.

Maintaining the volunteer force to continue this important task requires diligence on the part of the TCLA. The Board of Directors will confirm each year that the current CLMN volunteers will continue the monitoring on all three lakes. If new volunteers are needed, the Board of Directors will recruit them and contact Sandy Wickman (715.365.8951), or the appropriate WDNR/UW-Extension staff, to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their SWIMS by the volunteer.

Action Steps:

1. Board of Directors contacts Sandy Wickman (715.365.8951) to add Rock Lake to the advanced water quality program waiting list.
2. Board of Directors confirm annually that current volunteers will continue to monitor their respective lakes.
3. New volunteer(s) contact Sandy Wickman (715.365.8951) as needed.
4. Volunteer(s) reports results to WDNR SWIMS database and to TCLA members during annual meeting.

Management Goal 2: Control Existing AIS in the Turtle Lakes Chain and Prevent Further AIS Introductions

Management Action:	Continue Clean Boats Clean Waters watercraft inspections at Turtle Lakes Chain public access sites.
Timeframe:	Continuation current effort
Potential Grant:	WDNR Clean Boats Clean Waters Grant
Facilitator:	TLCA Board of Directors
Description:	Volunteers from the TLCA have completed over 220 hours of Clean Boats Clean Waters (CBCW) monitoring as a part of the volunteer efforts put forth as an inkind match for the planning project. The association understands the importance of this program in preventing the introduction of AIS to the Turtle Lakes Chain; therefore, it will strive to continue this program beyond the completion of the Town of Winchester Management Planning Project. The CBCW program benefits extend beyond the actual physical prevention of AIS introduction by literally stopping infested watercraft from being launched into the system, by spreading important information to watercraft owners regarding their potential role in spreading AIS. The primary hinderance to this activity is often the willingness of lake group members to volunteer to participate in the program. While this is likely the best source of labor for this program because it assures buy-in, and subsequently quality, conscientious inspectors, it is not always realistic for a lake group to be able to produce sufficient volunteers. Unfortunately, the lack of volunteer involvement often leads to the demise of the program on some lakes. The TLCA will complete actions (see below) aimed at increasing volunteerism on the lake; therefore, staffing the Turtle Lakes Chain CBCW program with volunteers from the association will be the primary objective. If sufficient volunteers cannot be enlisted, the association will consider hiring inspectors through the Town of Winchester, NLDC, and/or Vilas County. The WDNR has a streamlined application process allowing qualified lake groups to apply for funding for CBCW program activities. Grant funding is available for 75% of project costs up to a maximum of $4,000 per boat landing or pair of landings. The remaining 25% of the project cost must come from the project sponsor in the form of cash, donated labor or services, or “in-kind” items. These grants are reimbursement grants, meaning all costs must first be paid by project sponsor before reimbursement can be requested from the DNR. A 25% advance payment will be automatically provided to help get the project started. More information can be found on the WDNR Surface Water Grants website (dnr.wi.gov/aid/surfacewater.html).

Action Steps:

1. Board of Directors recruits a volunteer to act as the CBCW program coordinator for the TLCA.
2. Board of Directors and program coordinator recruit volunteers for the chain CBCW program.
3. Volunteers attend CBCW training session.
4. Coordinator schedules volunteers to assure public access sites will be staffed at the busiest times of the year.
5. CBCW coordinator reports results to WDNR SWIMS database and to TCLA members during annual meeting.

Management Action:	Coordinate annual volunteer monitoring for Aquatic Invasive Species in the Turtle Lakes Chain.
Timeframe:	Begin 2019
Facilitator:	TLCA Board of Directors
Description:	In lakes without Eurasian watermilfoil and other submersed invasive species like curly-leaf pondweed, early detection of pioneer colonies commonly leads to successful control and in cases of very small infestations, possibly even eradication. One way in which lake residents can spot early infestations of AIS is through conducting "Lake Sweeps" on their lake. During a lake sweep, volunteers monitor the entire area of the system in which plants grow (littoral zone) twice annually in search of non-native plant species. This program uses an "adopt-a-shoreline" approach where volunteers are responsible for surveying specified areas of the system. In order for accurate data to be collected during these sweeps, volunteers must be able to identify non-native species such as Eurasian watermilfoil and curly-leaf pondweed. Distinguishing these plants from native look-a-likes is very important. To effectively facilitate this program, the TLCA has recruited two volunteers from each lake to act as Lake Representatives. The Lake Representatives will facilitate the volunteer monitoring on their respective lake, communicate with local experts if suspect plants are located, and report monitoring results at the TLCA annual meeting. The Lake Representatives would initiate the rapid response plan detailed below. The TLCA will initially recruit volunteers at the group's annual meeting by displaying a map with shorelines of each lake divided into relatively equal sections. Volunteers can then write their names next to a section and provide contact information on a separate form. The

Lake Representatives for each lake will then utilize that list to set up the monitoring program on each lake.

The Lake Representatives from Rock Lake will also work with NLDC staff and riparian property owners to remove pale-yellow iris from the lake's shoreline.

In association with this action and the rapid response plan action below, the TLCA has added an "AIS Alert" section to there website with information on AIS, including pictures and Lake Representative contact information. This feature can be used by lake users if they believe they have located an AIS in the Turtle Lakes Chain.

Action Steps:

1. Board of Directors maintains volunteers to act as Lake Representatives for each of the three lakes.
2. Lake Representatives coordinate to create map and contact form to facilitate initial volunteer recruitment.
3. Lake Representatives introduce program through TLCA website and The Rag, present the program at TLCA annual meeting, and ask for volunteers.
4. Lake Representatives contact volunteers and set up training session with NLDC or other qualified agency, like Vilas County.
5. Lake Representatives coordinate surveys, collect results, and report on those results at annual meeting.

Management Action:	Initiate rapid response plan following detection of new AIS
Timeframe:	If/When Necessary
Facilitator:	Board of Directors
Description:	If volunteers locate a suspected new AIS within the Turtle Lakes Chain, the location would be marked (e.g. GPS, maker buoy) and a specimen would be taken to the NLDC or to the Vilas County Land Conservation Department for verification. If the suspected specimen is indeed a non-native species, the WDNR will fill out an incident form and develop a strategy to determine the population level within the lake. The lake would be professionally surveyed, either by agency personnel or a private consulting firm during that species' peak growth phase. If the AIS is a NR40 prohibited species (i.e. red swamp crayfish, starry stonewort, hydrilla, etc.), the WDNR may take an active role in the response. If the AIS is a NR40 restricted species (i.e. purple loosestrife, curly-leaf pondweed, Eurasian watermilfoil, etc.), the TLCA would need to reach out to a consultant to develop a formal monitoring and/or control strategy. The WDNR would be able to help financially through the AIS Grant Program's Early Detection and Response Grant. This grant

	program is non-competitive and doesn't have a specific application deadline, but is offered on a first-come basis to the sponsor of project waters that contain new infestations (found within less than 5% of the lake and officially documented less than 5 years from grant application date). Currently this program will fund up to 75% percent of monitoring and control costs, up to $20,000.
Action Steps:	
	See description above

Management Goal 3: Increase the TLCA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Promote lake protection and enjoyment through stakeholder education.
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	Education represents an effective tool to address many lake issues. The TLCA distributes a newsletter, The Rag, twice each year to its membership, and has developed a website (www.thetlca.org), which is the official repository of the TLCA information. These mediums allow for communication with association members, but increasing the level of communication is important within a management group because it facilitates the spread of important association news, educational topics, volunteer opportunities, and even social happenings. The TLCA will continue to make the education of lake-related issues a priority. 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* • Specific topics brought forth in other management actions • Aquatic invasive species identification • Basic lake ecology • Boating safety (promote existing guidelines, Lake Use Information handout) • Swimmers itch • Shoreline habitat restoration and protection • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish • Dam operation and water levels • Recreational use of the lakes
Action Steps:	

	See description above.

Management Action:	Continue TLCA's involvement with other entities that have responsibilities in managing (management units) the Turtle Lakes Chain
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	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 TLCA 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 8.9-1
Action Steps:	
	See table guidelines on the next pages.

Table 8.9-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Winchester Lakes Committee	Committee Chair (Rolf Ethun,715.686.2139, rolfappraisals@centurytel.net)	Town resource for lake property owners and lake groups	As needed.	Involved in lake management activities, monitoring, implementation, funding, volunteer recruitment. May be contacted regarding ordinance questions, and for information on community events.
Great Lakes Indian Fish and Wildlife Commission	General (715.682.6619)	Resource management within Ceded Territory	As needed.	Collaborate on lake related studies, AIS management, inform of meetings, etc.
Vilas County Lakes & Rivers Association (VCLRA)	President (Tom Ewing, president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partner in special projects, or networking on other topics pertaining to Vilas Co. waterways.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Wisconsin Department of Natural Resources	Fisheries Biologist (Steve Gilbert, 715.356.5211)	Manages the fish populations and fish habitat enhancement efforts.	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.	As needed.	Information on planning/AIS projects, grant applications or to seek advice on other lake issues.
	Environmental Grant Specialist (Laura MacFarland, 715.365.8920)	Oversees financial aspects of grants.	As needed.	Information on grant financials and reimbursement, CBCW grant applications.
	Conservation Warden (Rich Thole, 715.605.2130)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity, include fishing, boating safety, ordinance violations, etc.
	Water Resources Mgmt Specialist (Sandra Wickman, 715.365.8951, Sandra.Wickman@wisconsin.gov)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Arrange for training as needed, report monitoring activities.
	Trout Lake Station staff (Susan Knight and Carol Warden (715.356.9494)	Conducts lake research on multiple levels	As needed.	Can be contacted for identification or consultation on AIS.
Vilas County Sheriff Dept.	715.479.4441 non-emergency, 911 for emergencies only.	Perform law enforcement duties to protect lakes, especially pertaining to compliance with boating safety rules.	As needed.	Contact regarding suspected violations pertaining to boating safety rules on the lake.
University of Wisconsin Extension Office	Lake Specialist (Pat Goggin, 715.365.8943, Patrick.Goggin@wisconsin.gov)	Provides guidance for lakes, shoreline restoration, and outreach/education.	As needed.	Contact for shoreland remediation/restoration techniques, outreach/education.
North Lakeland Discovery Center	Executive Director (John Heusinkveld, 715.543.2085, john@discoverycenter.net) Water Program Coordinator (Emily Heald, 715.543.2085, water@discoverycenter.net)	Educates and inspires connection to the natural state of the Northwoods	As needed.	Project sponsor. Direct resource for AIS education and monitoring needs, operates aquatic education programs and assists with volunteer recruitment.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Vilas County Land and Water Conservation Department	Lake Conservation Specialist (Cathy Higley, 715.479.3738, cahigl@vilascountywi.gov)	Oversees AIS monitoring and education activities county-wide.	Twice a year or more as issues arise.	AIS training and ID, monitoring techniques, CBCW training, report summer activities.
	Lake Conservation Specialist (Mariquita (Quita) Sheehan, 715.479.3721, mashee@vilascountywi.gov)	Oversees conservation efforts for lake grants and projects.	Twice a year or more as needed.	Contact for shoreland remediation/restoration techniques and cost-share procedures, wildlife damage programs, education and outreach documents.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates	Those interested may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

Management Goal 4: Improve Turtle Lakes Chain Ecological Health and Fishery Resource

Management Action:	Educate stakeholders on the importance of shoreland condition and shoreland restoration on Turtle Lakes Chain.
Timeframe:	Initiate 2019
Facilitator:	Board of Directors
Description:	As discussed in the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. Approximately 11% of Turtle Lakes Chain's shoreline is considered completely urbanized or developed unnatural. This limits shoreland habitat, but it also reduces natural buffering of shoreland runoff and allows nutrients to enter the chain. Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, the TLCA will educate chain property owners regarding shoreland restoration opportunities. This would include inviting Vilas County staff (see Table 8.9-1) to present on the subject at an association meeting. The WDNR's Healthy Lakes Initiative Grant program allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through Vilas County. • 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance • Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap) • Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances • Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide • Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years • Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available
Action Steps:	See description above

Management Action:	Coordinate with WDNR and private landowners to expand coarse woody habitat in Turtle Lakes Chain
Timeframe:	Initiate 2020
Facilitator:	Board of Directors

Description:	Turtle Lakes Chain stakeholders realize the complexities and capabilities of the chain ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation, shore-fishing, or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish. The Shoreland Condition Section and Fisheries Data Integration Section discuss the benefits of coarse woody habitat in detail.
	
	The WDNR's Healthy Lakes Initiative Grant allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.
	• 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
	• Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
	• Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
	• Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
	    o The landowner would need to commit to leaving the area un-mowed
	    o The landowner would need to implement a native planting (also cost share through this grant program available)
	• Coarse woody habitat improvement projects require a general permit from the WDNR
	• Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:	
1.	Board member contacts WDNR Lakes Coordinator and WDNR Fisheries Biologist to gather information on initiating and conducting coarse woody habitat projects. This step is important to

	assure that the action will meet the fisheries goals of the WDNR fisheries management specialists.
2.	The TLCA will encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.