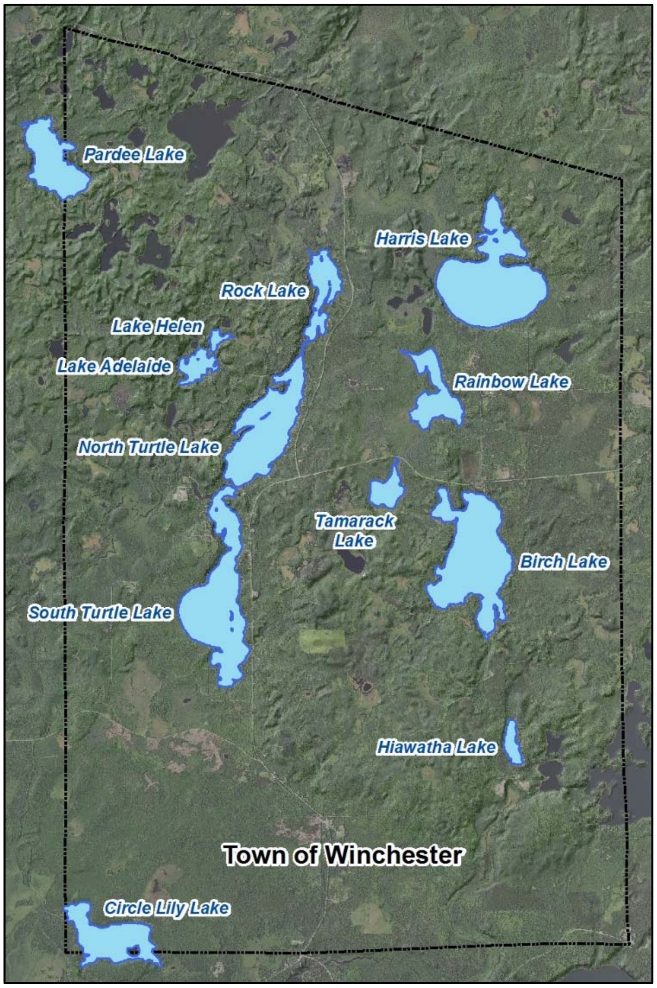
Town of Winchester Lakes

Vilas County, Wisconsin

Comprehensive Management Plan: Phase II

April 2018



Sponsored by:

North Lakeland Discovery Center

Town of Winchester

WDNR Grant Program

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Onterra, LLC
Lake Management Planning

Town of Winchester Lakes
Comprehensive Management Plan – Phase II

Vilas County, Wisconsin
April 2018

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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

North Lakeland Discovery Center
Emily Heald

Wisconsin Dept. of Natural Resources

Kevin Gauthier
Carol Warden

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1.0 INTRODUCTION

Note: This town-wide management plan and individual lake plans will serve as the deliverable for Phase II 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 and II 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	North Turtle Lake	South Turtle Lake	Rock Lake	Circle Lily Lake	Lake Adelaide	Lake Helen	Pardee Lake
Morphometry												
LakeType	DHDL	DHDL	DLDL	DLDL	DLDL							
Surface Area (acres)	536	38	528	63	148							
Max Depth (ft)	57	58	52	27	39							
Mean Depth (ft)	24	32	18	7	9							
Perimeter (miles)	5.8	1.4	6.5	1.7	3.5							
Shoreline Complexity	3.2	2.6	4.1	2.1	4.0							
Watershed Area (acres)	2,348	819	4,178	5,114	6,737							
Watershed to Lake Area Ratio	3:1	21:1	7:1	77:1	43:1							
Water Quality												
Trophic State	OM	M	M	ME	ME							
Limiting Nutrient	P	P	P	P	P							
Avg Summer P (µg/L)	12.2	17.4	18.6	32.2	24.4							
Avg Summer Chl-α (µg/L)	2.4	4.6	5.4	5.6	10.3							
Avg Summer Secchi Depth (ft)	16.1	5.7	7.8	5.9	6.6							
Summer pH	8.1	7.2	7.7	7.3	7.5							
Alkalinity (mg/L as $CaCO_3$)	38.7	14.6	36.8	31.6	30.1							
Vegetation												
Number of Native Species	56	26	37	32	45							
NHI-Listed Species	UTR	None	None	None	PVA							
Exotic Species	CLP	None	None	None	None							
Average Conservatism	7.0	7.2	7.1	7.3	7.2							
Floristic Quality	44.3	25.8	31.8	34.1	40.7							
Simpson's Diversity (1-D)	0.91	0.87	0.80	0.83	0.93							

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

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 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 is scheduled for the spring of 2017.

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 first official draft of the Phase II report will be provided to the WDNR in the fall of 2017.

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

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.

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.

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.

Harris Lake and Hiawatha Lake, the Phase I project lakes, are classified as deep, headwater drainage lakes under this classification system as both lakes possess a perennial tributary outlet (Class 3 in Figure 3.1-1). Both Harris and Hiawatha lakes are technically *spring lakes*, or lakes that do not possess perennial tributary inlets but to maintain a perennial tributary outlet. Spring lakes receive the majority of their water from groundwater sources, and are a common lake type in northern Wisconsin. However, for this water quality analysis, any lake possessing a perennial tributary inlet and/or outlet is classified as a drainage lake. Birch Lake, Tamarack, and Rainbow Lake, the Phase II project lakes, are all classified as deep, lowland drainage lakes (Class 5 in Figure 3.1-1). All three of these lakes have watersheds greater than four square miles and possess perennial inlets and outlets. The community classification for the Town of Winchester project lakes can be found in Table 3.1-1.

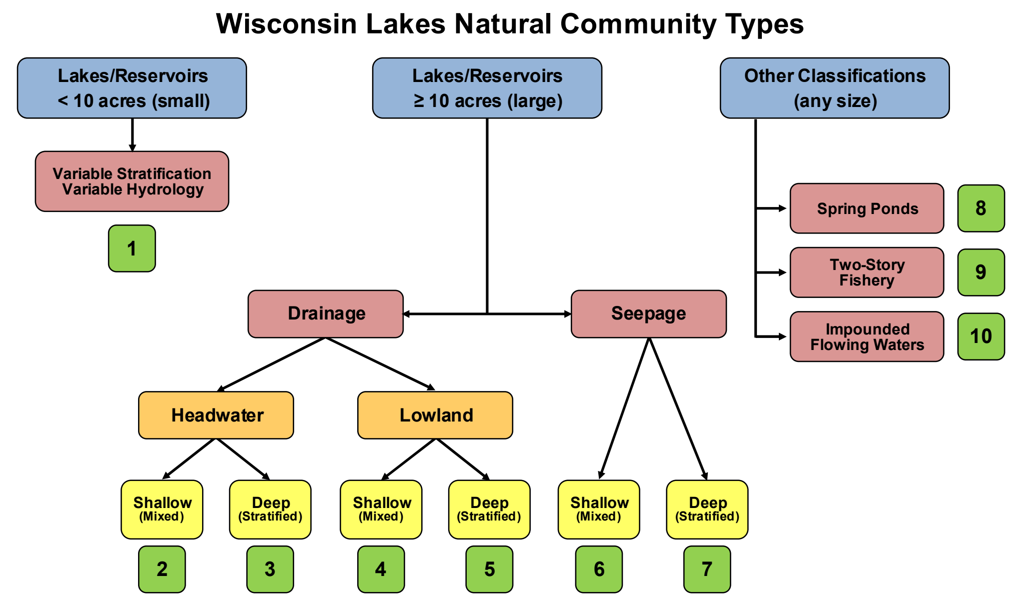


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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	Available in Phase III
	South Turtle Lake	Available in Phase III
	Rock Lake	Available in Phase III
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.

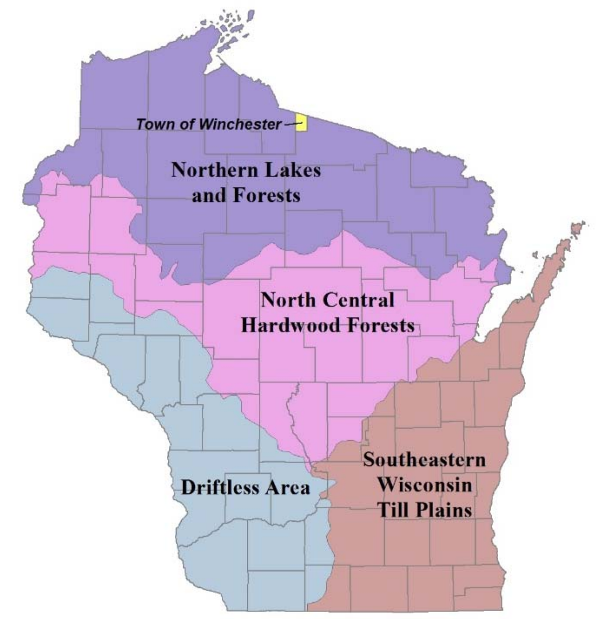


Figure 3.1-2. Location of the Town of Winchester within the ecoregions of Wisconsin. After Nichols 1999.

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 and Phase II project lakes. Monitoring occurred during the summer and winter of each respective phase. The Phase III lakes are scheduled to be sampled in 2017/18 and Phase IV lakes 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 differences 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 five 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 27:1 in Harris Lake. These ratios indicate that all five lakes within Phase I and II are phosphorus-limited, and that increases in phosphorus inputs would likely result in increased phytoplankton production.

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). The summer total phosphorus concentrations for Harris and Hiawatha lakes fall within the *excellent* category for deep headwater drainage lakes in Wisconsin.

Most often, deep headwater lakes most often have lower phosphorus concentrations when compared to deep lowland lakes. The watersheds of deep headwater lakes are smaller, and these lakes generally receive less phosphorus. In contrast, deep lowland lakes have larger watersheds and as a result, receive a higher amount of phosphorus. The median summer near-surface total phosphorus concentration for Wisconsin's deep headwater drainage lakes is 17.0 µg/L compared to 23.0 µg/L for deep lowland drainage lakes (Figure 3.1-4).

Summer near-surface total phosphorus concentrations measured from the Phase I and II project lakes ranged from 12.2 µg/L in Harris Lake to 32.2 µg/L in Tamarack Lake (Figure 3.1-4). The deep headwater drainage lakes of Harris and Hiawatha lakes had lower total phosphorus concentrations when compared to the deep lowland drainage lakes of Birch, Tamarack, and Rainbow Lakes. Pearson correlation analysis indicated that total phosphorus concentrations in the Phase I and II lakes were most strongly correlated with watershed to lake area ratio. The lakes with the largest watershed area relative to the lake area, like Tamarack and Rainbow lakes, had the highest phosphorus concentrations. These lakes have more land per unit of lake area draining to them, and as mentioned previously, receive more phosphorus. The primary driver of differences in phosphorus concentrations among the Phase I and Phase II lakes is a combination of morphometry (lake area, depth, etc.) and watershed size. The influence of these lakes' watersheds on water quality is discussed further within the Watershed Assessment Section (section 3.2).

The total phosphorus concentrations for Harris and Hiawatha lakes fall within the *excellent* category for deep headwater drainage lakes. Birch Lake's total phosphorus concentrations fall within the *excellent* category for deep lowland drainage lakes, Tamarack Lake's total phosphorus concentrations straddle the threshold between *good* and *fair*, and Rainbow Lake's total phosphorus concentrations fall within the *good* category. The measured total phosphorus concentrations in Harris, Hiawatha, and Birch, lakes aligned with Wisconsin Lake Modeling Suite (WiLMS) predicted total phosphorus concentrations based upon each lakes' watershed size and land cover composition.

However, the measured total phosphorus concentrations in Tamarack Lake was 37% higher than compared to predicted concentrations. As is discussed further in the Watershed Assessment Section, the higher concentrations of phosphorus measured in Tamarack Lake are believed to be the result of higher external inputs from its direct watershed than the model predicts. While *internal nutrient loading*, a process where phosphorus and other nutrients are released from bottom sediments into the overlying water under anoxic (devoid of oxygen) conditions, is often the reason behind higher than predicted phosphorus concentrations, the data do not indicate internal loading is a significant source of phosphorus in Tamarack Lake. Phosphorus concentrations were slightly higher than predicted in Rainbow Lake, and this is largely a result of phosphorus originating from upstream in the Tamarack subwatershed. While phosphorus concentrations are higher in Tamarack and Rainbow lakes, chlorophyll-*a* concentrations were relatively low. The reasons why chlorophyll-*a* concentrations were lower in these lakes despite higher phosphorus concentrations is discussed in the subsequent Chlorophyll-*a* subsection.

Chlorophyll-α

Summer average chlorophyll-*a* concentrations measured within the five Phase I and II project lakes ranged from 2.4 µg/L in Harris Lake to 10.3 µg/L in Rainbow Lake (Figure 3.1-5). Chlorophyll-*a* concentrations were positively correlated with total phosphorus concentrations, and chlorophyll-*a* concentrations were lower in the deep headwater drainage lakes when compared to the deep lowland drainage lakes. Summer average chlorophyll-*a* concentrations for Harris and Hiawatha lakes fall within the *excellent* category for deep headwater drainage lakes in Wisconsin. Chlorophyll-*a* concentrations for Birch and Tamarack lakes straddle the line between the *excellent* and *good* category for deep lowland drainage lakes in Wisconsin, while concentrations in Rainbow Lake fall into the *good* category.

Chlorophyll-*a* concentrations for both Harris and Hiawatha lakes fall below the median concentrations for Wisconsin's deep headwater drainage lakes and for all lake types within the NLF ecoregion. Chlorophyll-*a* concentrations for Birch and Tamarack lakes fall below the median concentration for Wisconsin's deep lowland drainage lakes and are similar to the median concentrations for all lake types within the NLF ecoregion. Chlorophyll-*a* concentrations in Rainbow Lake are higher than the median concentrations for Wisconsin's deep lowland drainage lakes and for all lake types within the NLF ecoregion.

Measured chlorophyll-*a* concentrations in Harris, Hiawatha, Birch, and Rainbow lakes align with predicted chlorophyll-*a* concentrations based upon total phosphorus concentrations (Carlson 1977). However, as mentioned previously, the measured chlorophyll-*a* concentrations in Tamarack Lake are approximately 80% lower than predicted concentrations based on measured total phosphorus concentrations. As is discussed in the subsequent Water Clarity Subsection, Tamarack Lake along with Hiawatha, Birch, and Rainbow lakes have higher concentrations of humic substances and organic acids in the water which result in brown- or tea-colored water. This natural staining of the water reduces clarity, and the reduced light availability likely limits phytoplankton production in these lakes. While sufficient phosphorus is available in Tamarack Lake to produce higher phytoplankton abundance, their growth is likely light-limited due to the dark color of the lake's water.

Water Clarity

Average summer Secchi disk depth measured within the five Phase I and II study lakes ranged from 5.7 feet in Hiawatha Lake to 16.1 in Harris Lake (Figure 3.1-6). The Secchi disk depth for Harris Lake falls within the *excellent* category for deep headwater drainage lakes, and exceeds the median values for other deep headwater drainage lakes in Wisconsin and all lake types within the NLF ecoregion. Secchi disk depth for Hiawatha Lake falls within the *good* category for Wisconsin's deep headwater drainage lakes, while Secchi disk depth in Birch, Tamarack, and Rainbow lakes fall within the *good* category for Wisconsin's deep lowland drainage lakes.

Predicted Secchi disk depths based on measured chlorophyll-*a* concentrations (Carlson 1977) in Hiawatha, Birch, Tamarack, and Rainbow lakes were on average 13% lower than measured depths. The fact that measured Secchi disk depths were lower than predicted based upon measured chlorophyll-*a* concentrations is an indication that a factor(s) other than phytoplankton abundance is influencing water clarity in these 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 these four lakes indicating minimal amounts of suspended material within the water.

Apart from suspended material within the water, water clarity in Wisconsin's lakes 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 3.1-7). Birch, Tamarack, and Rainbow lakes had similar true color values indicating *tea-colored* water. The combination of low chlorophyll-*a* concentrations and low concentration of dissolved compounds in Harris Lake results in the lake's high water clarity. While chlorophyll-*a* concentrations are relatively low in Hiawatha, Birch, Tamarack, and Rainbow lakes, the higher concentrations of dissolved compounds reduce water clarity.

Like total phosphorus concentrations, the differences in true color values between these lakes is a result of a combination of each lakes morphometry and watershed size/composition. The lakes with higher true color values is an indication they receive a larger proportion of surface water which has passed through forests and 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 indicative of degraded water quality.

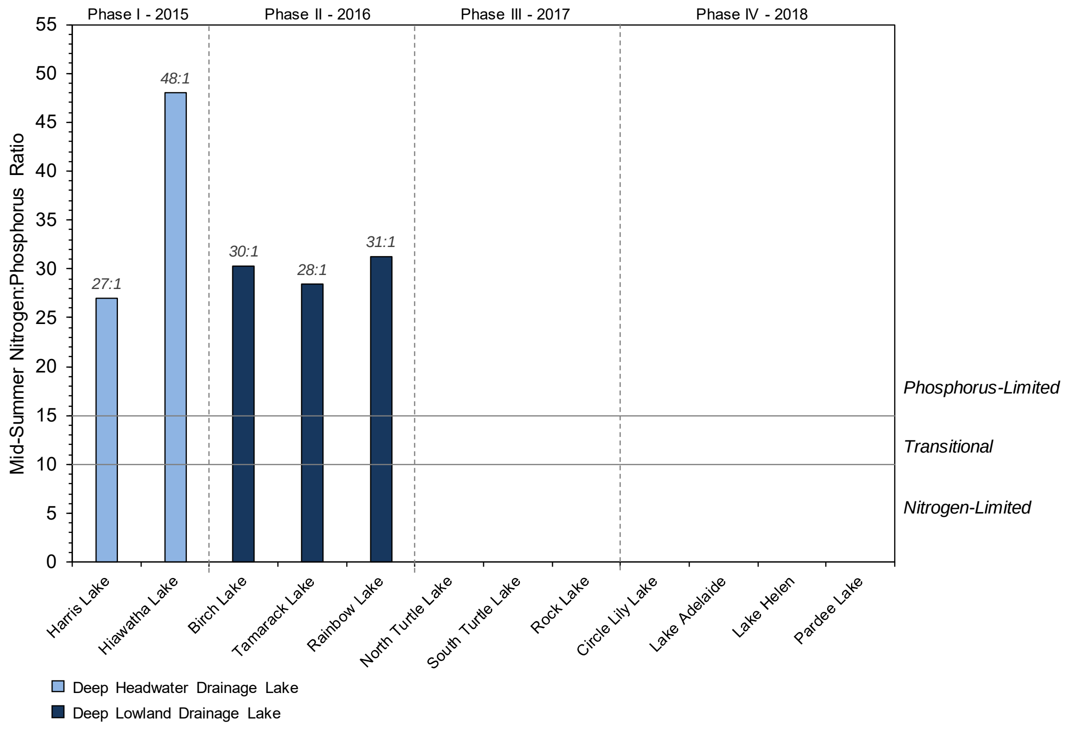


Figure 3.1-3. Town of Winchester project lakes mid-summer total nitrogen to total phosphorus ratios. Data represent surface samples collected during mid-summer during each respective project phase.

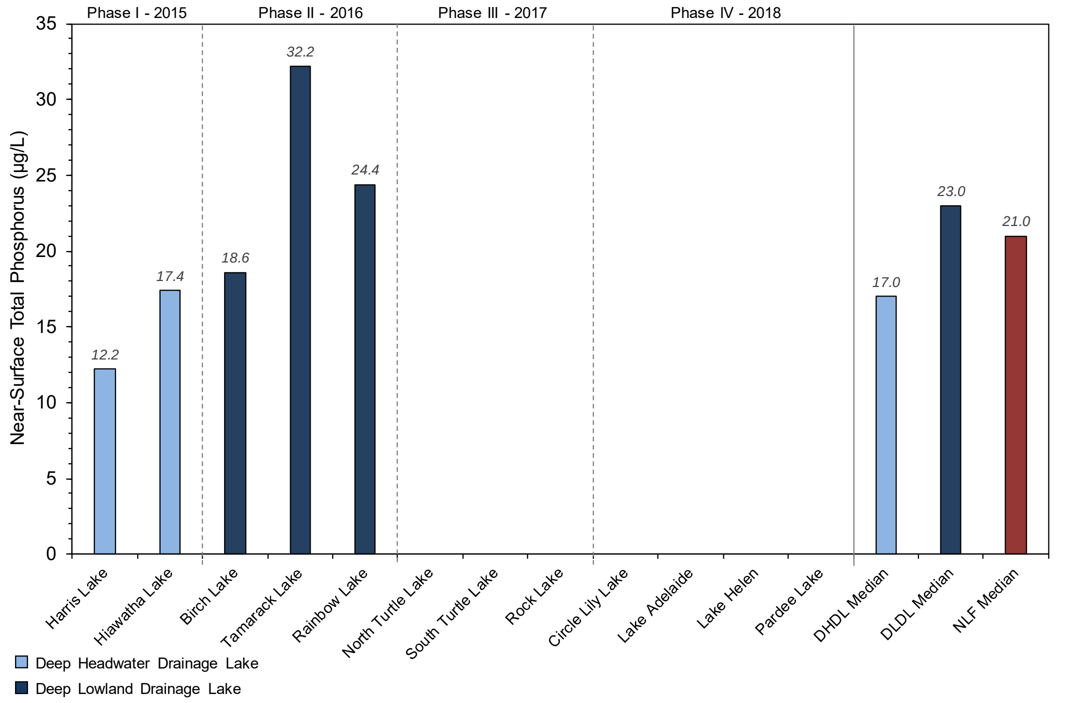


Figure 3.1-4. Town of Winchester project lakes summer average near-surface total phosphorus concentrations and median summer near-surface total phosphorus concentrations from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion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

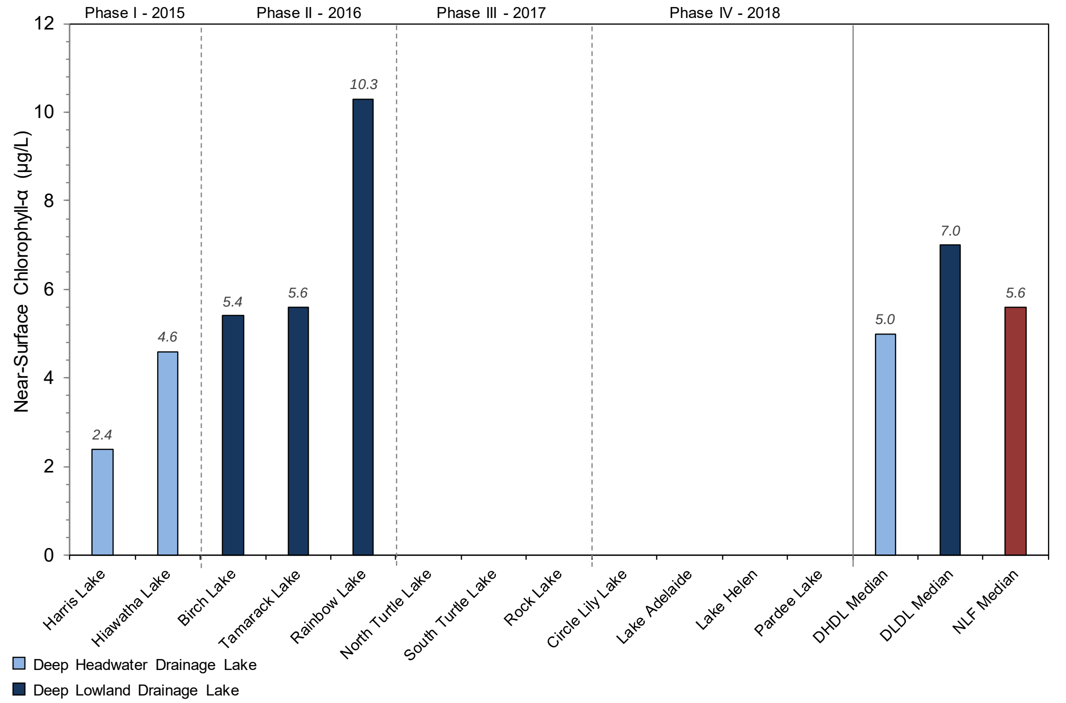


Figure 3.1-5. Town of Winchester project lakes summer average chlorophyll-α concentrations and median summer chlorophyll-α concentrations from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion Lakes.

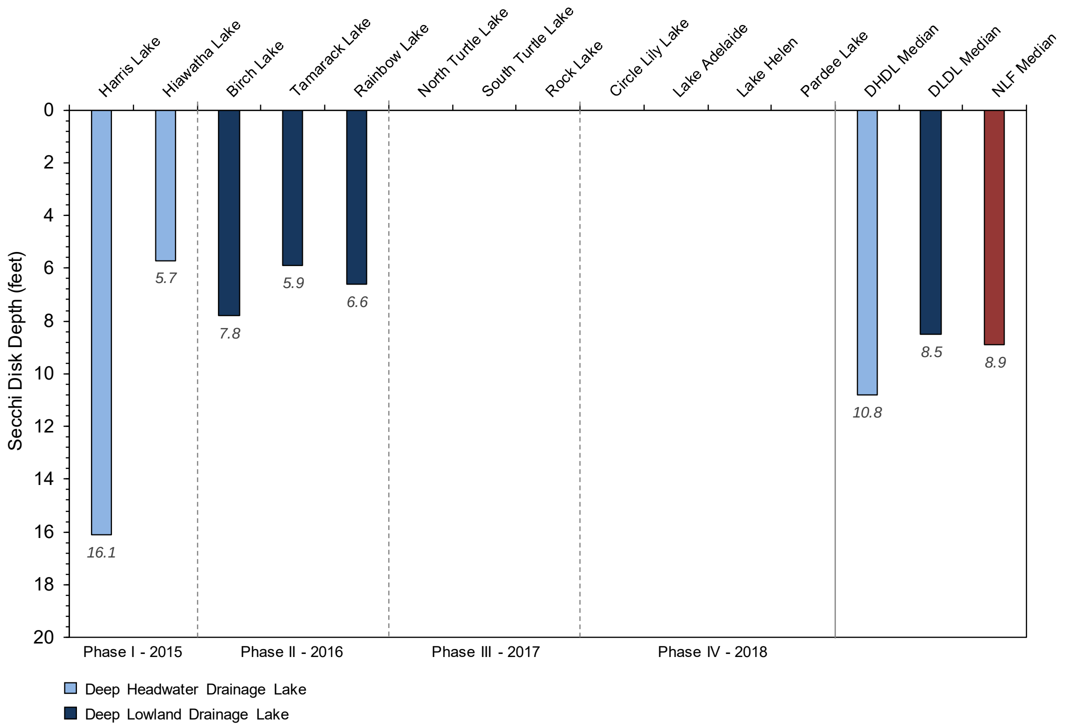


Figure 3.1-6. Town of Winchester project lakes summer average Secchi disk transparency and median summer Secchi disk transparency from comparable lakes. DHDL = Deep Headwater Drainage Lakes; DLDL = Deep Lowland Drainage Lakes; NLF = Northern Lakes and Forests Ecoregion Lakes.

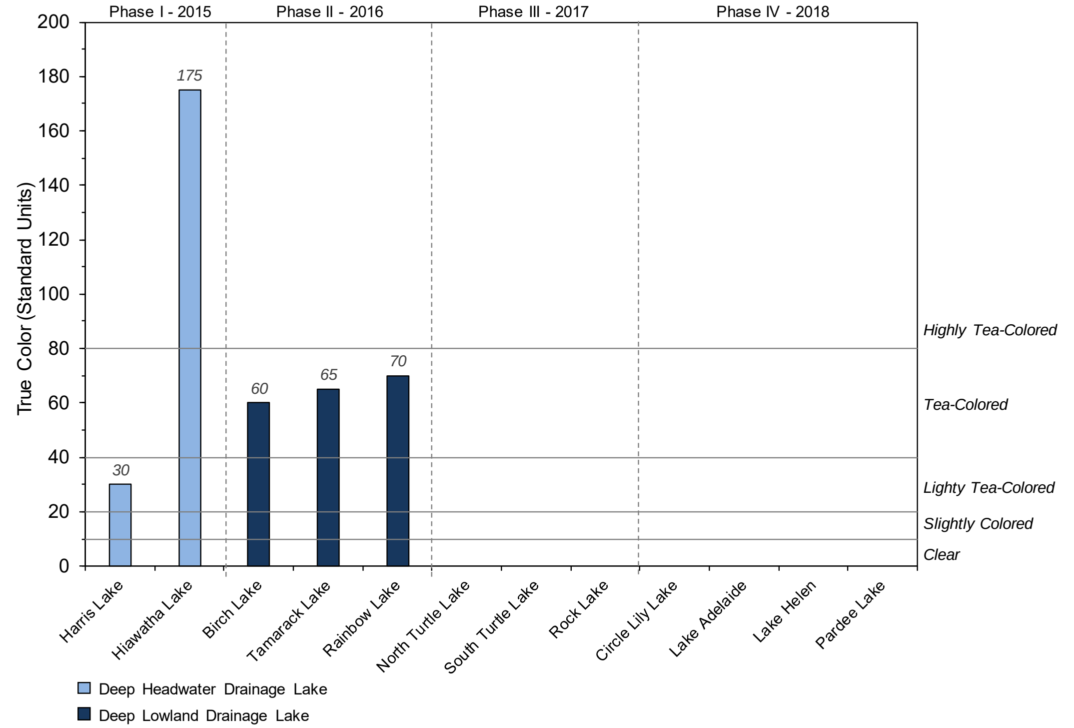


Figure 3.1-7. Town of Winchester project lakes average growing season true color values. Samples collected from the near-surface. Color range adapted from UNH Center for Freshwater Biology (2014).

Town of Winchester Lakes Trophic State

Figure 3.1-8 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 other 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.

The weighted TSI values for total phosphorus and chlorophyll-*a* in the five Phase I and II project lakes range from oligo-mesotrophic in Harris Lake to lower eutrophic in Tamarack and Rainbow lakes (Figure 3.1-8). Overall, Harris Lake is of lower productivity when compared to other deep headwater drainage lakes in Wisconsin while Hiawatha Lake is of similar productivity. When compared to other deep lowland drainage lakes in Wisconsin, Birch and Tamarack lakes are of lower productivity, while Rainbow Lake's productivity is slightly higher.

The TSI values for all three parameters in Harris, Birch, and Rainbow Lakes were relatively similar, indicating phytoplankton production is largely regulated by phosphorus availability and water clarity is largely influenced by phytoplankton abundance. In Hiawatha Lake, the TSI values for total phosphorus and chlorophyll-*a* were similar indicating phosphorus availability regulates phosphorus availability. However, Hiawatha Lake's TSI value for Secchi disk depth is higher, and indicates a factor (dissolved organic compounds) other than phytoplankton abundance influence water clarity.

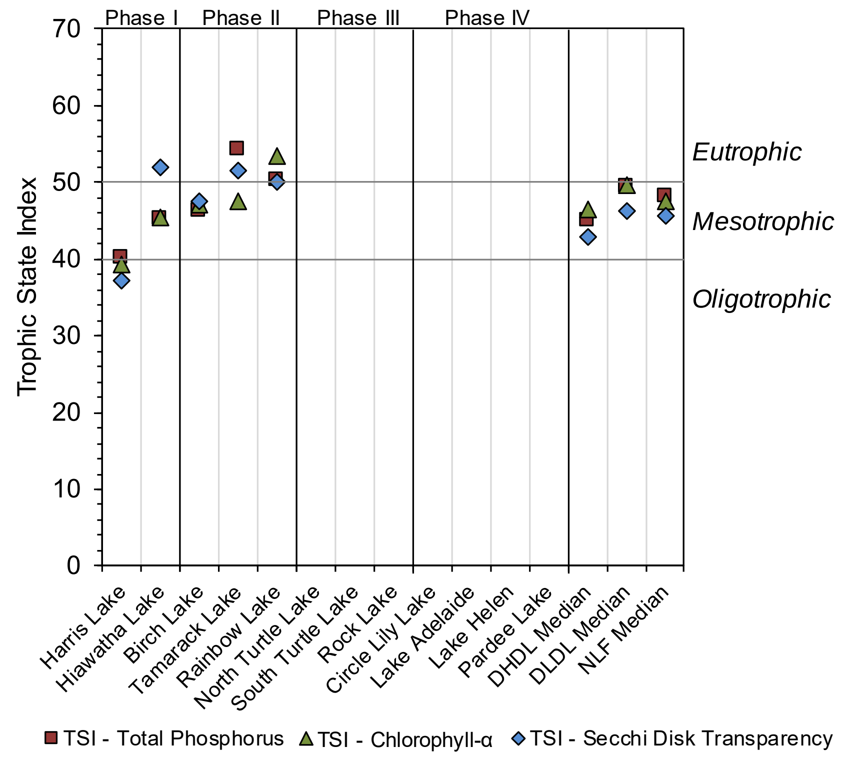


Figure 3.1-8. Town of Winchester project lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193. DHDL = Deep Headwater Drainage Lake; DLDL = Deep Lowland Drainage Lake.

In Tamarack Lake, the TSI value for chlorophyll-*a* was lower than both the TSI values for total phosphorus and Secchi disk depth. This indicates that phytoplankton production is regulated by a factor other than phosphorus concentrations (presumably light) and that water clarity is influenced by a factor (dissolved organic compounds) other than phytoplankton abundance. Given the higher content of humic organic matter in Hiawatha, Birch, Tamarack, and Rainbow lakes, these lakes are also termed *dystrophic* lakes. Dystrophic lakes are a subset of lakes that fall within the range from oligotrophic to eutrophic lakes but are characterized by having larger external inputs of organic matter and brown-colored water. While productivity in these lakes can be high, they are generally lower due to limited light availability and lower concentrations of calcium and other minerals.

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 and II project lakes, summer near-surface pH values ranged from 7.2 in Hiawatha Lake to 8.1 in Harris Lake (Figure 3.1-9). The pH values for Birch, Tamarack, and Rainbow lakes ranged between 7.3 and 7.7. All of these values indicate these five lakes are slightly alkaline, and all fall within the normal range for Wisconsin's lakes.

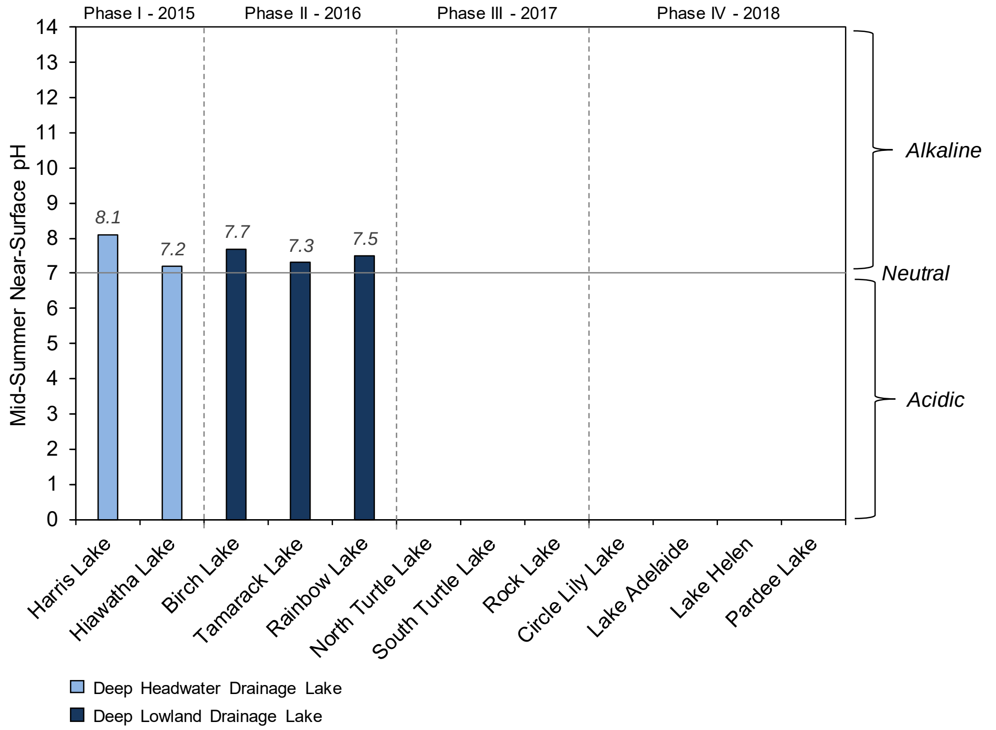


Figure 3.1-9. Town of Winchester project lakes mid-summer near-surface pH values. Data for each lake collected during the respective project phase.

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 and II 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 3.1-10). Alkalinity within Birch, Tamarack, and Rainbow lakes decreased from upstream to downstream. This is likely the result of dilution with low-alkalinity water originating from wetlands within the Tamarack and Rainbow lakes' subwatersheds. Given the alkalinity in these five lakes, none are sensitive to inputs from acid rain.

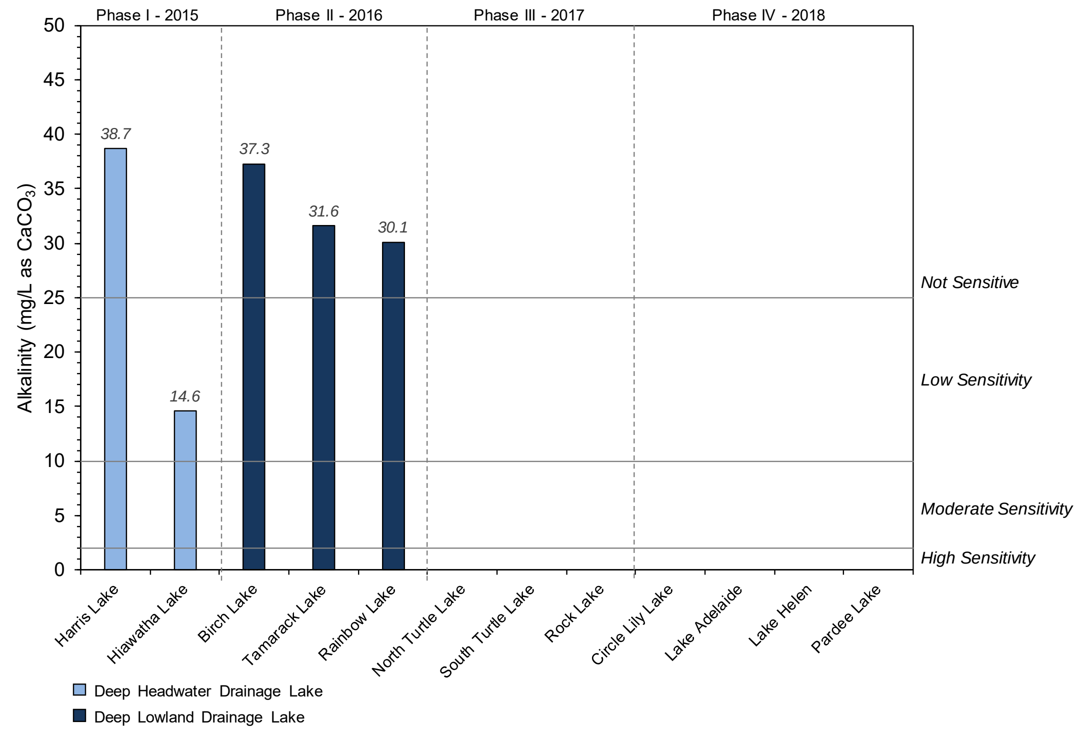


Figure 3.1-10. Town of Winchester project lakes average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 and II project lakes ranged from 12.2 in Harris Lake to 6.1 in Hiawatha Lake (Figure 3.1-11). Calcium concentrations in Hiawatha, Birch, Tamarack, and Rainbow lakes all fall within the *very low susceptibility* category for zebra mussel establishment, while Harris Lake falls in the *low susceptibility* category. The calcium concentrations in these lakes indicate zebra mussels have a low probability of establishing if they were to be accidentally introduced.

Onterra ecologists collected three plankton tows from three different locations within each project lake 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 Phase I and II project lakes, and no adult zebra mussels were observed during the surveys completed. It is believed that zebra mussels are currently not present in any of the Phase I or II project lakes.

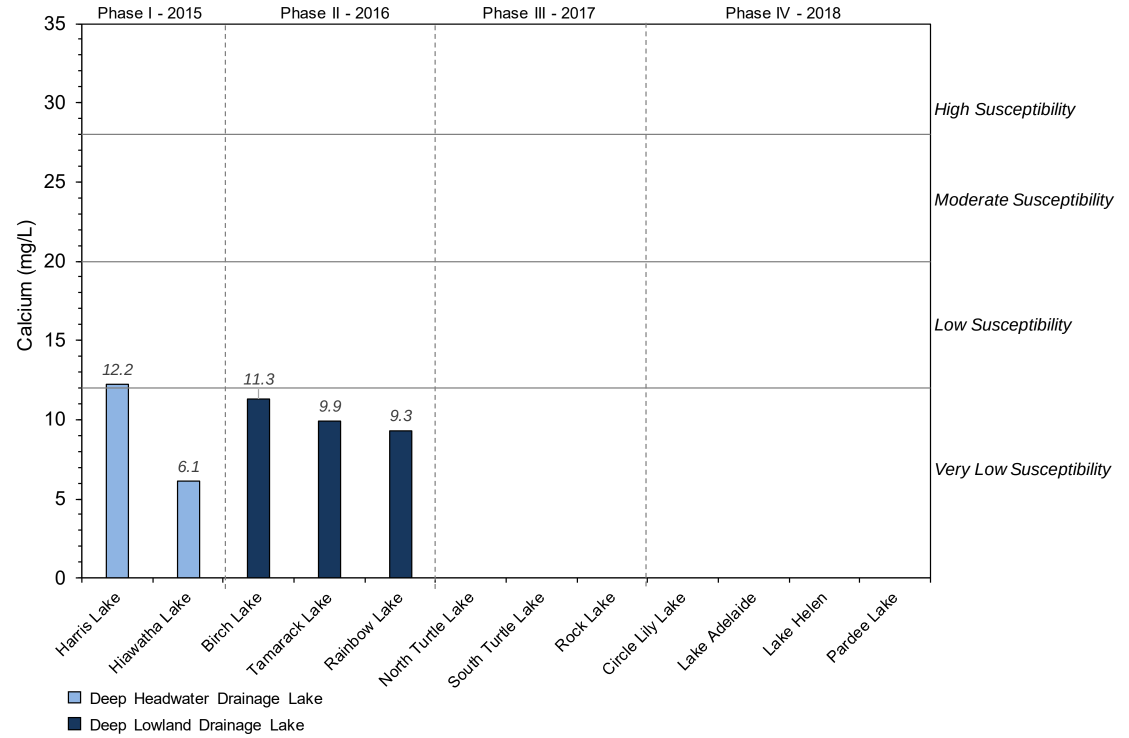


Figure 3.1-11. Town of Winchester project lakes average growing season calcium concentrations and susceptibility to zebra mussel establishment. Samples collected from the near-surface.

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

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 and II project lakes are largely the result of differences in lake morphometry and watershed size. The watershed sizes among the five Phase I and II project lakes range in size of 819 acres for Hiawatha Lake to 6,737 acres for Rainbow 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 largest portion of land cover within each of the five lakes' watersheds is forests followed by wetlands (Figure 3.2-2). Smaller portions of their watersheds include areas of pasture/grass, rural residential areas, and the lake surfaces themselves. No agricultural land cover or medium- or high-density urban areas are located within the Phase I and II project lakes' watersheds. The high proportion of natural land cover types within these watersheds results in minimal amounts of phosphorus being delivered to these lakes and is the primary reason for the high-grade water quality found in these lakes. Maintaining these minimally-developed watersheds is essential for maintaining the excellent water quality currently found in these waterbodies.

Watershed modeling indicated that the estimated annual phosphorus loading delivered to these lakes varies widely, ranging from 76 lbs/year in Hiawatha Lake to 629 lbs/year in Rainbow 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-feet 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, that 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 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-feet/year in Tamarack Lake.

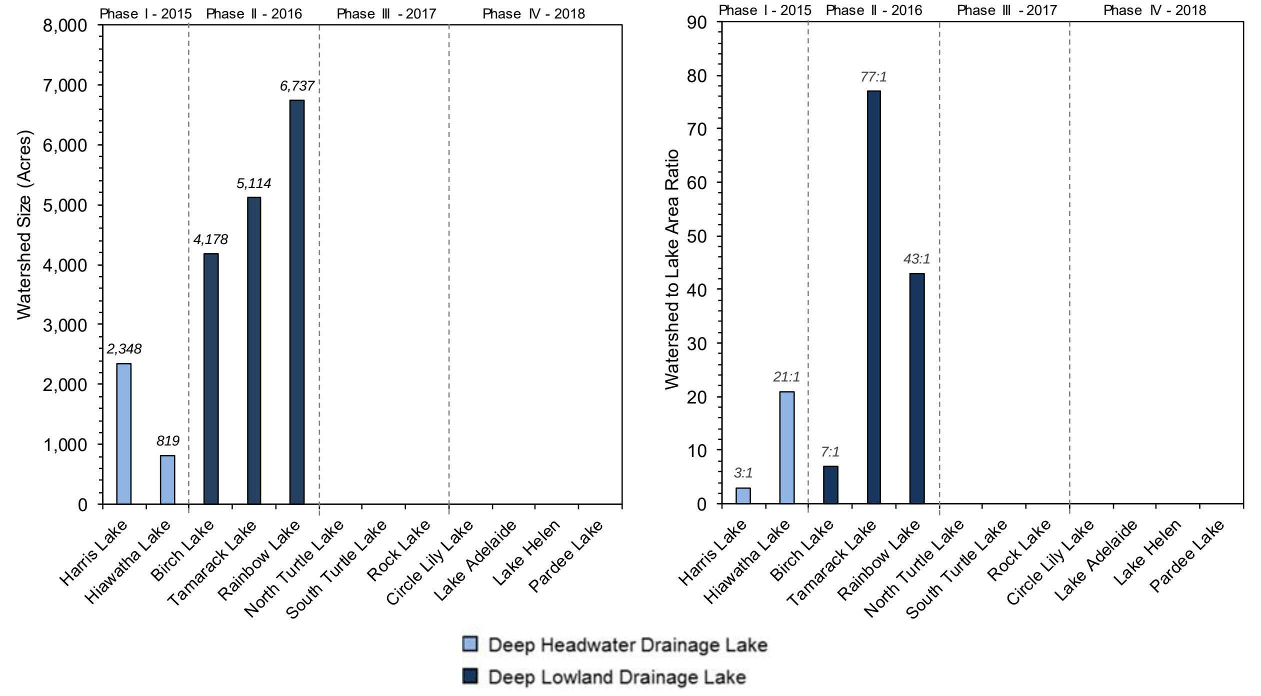


Figure 3.2-1. Town of Winchester lakes watershed size (left) and watershed to lake area ratios (right). Maps displaying watershed boundaries can be found within the individual lake report sections.

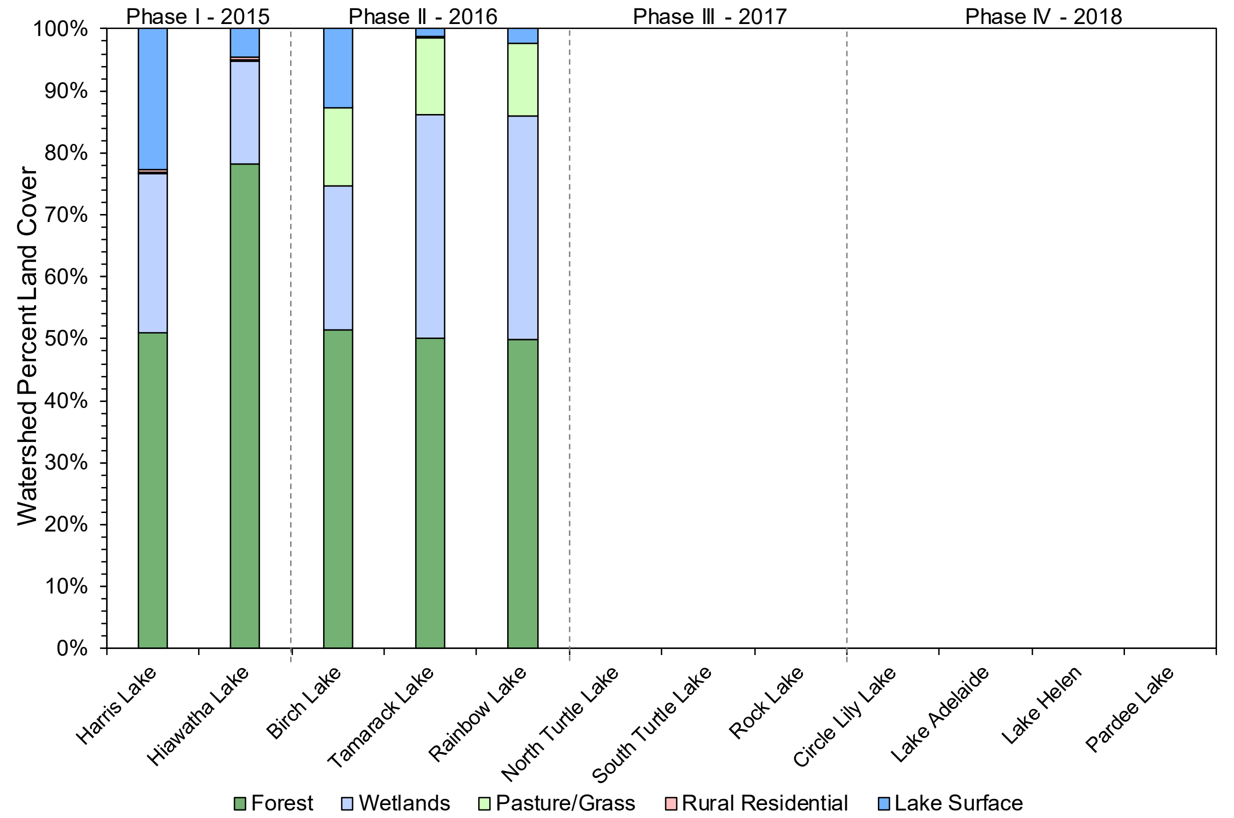


Figure 3.2-2. Town of Winchester lakes watershed land cover composition. Maps displaying watershed boundaries can be found within the individual lake report sections.

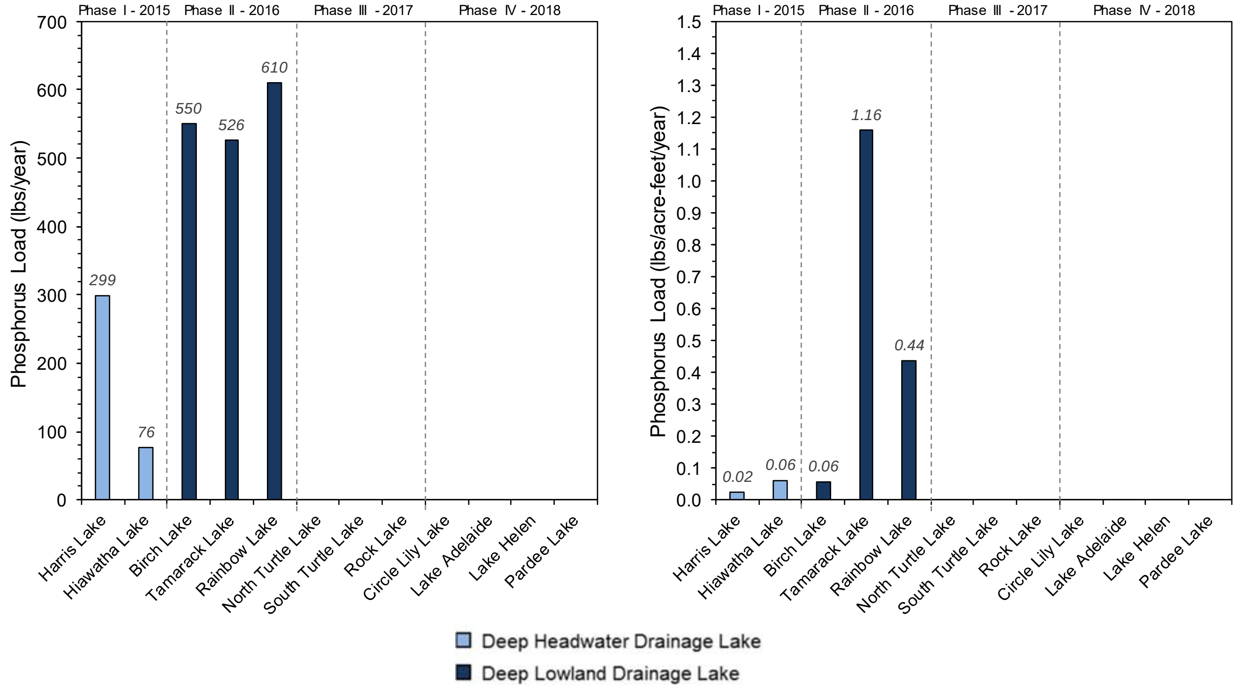


Figure 3.2-3. Town of Winchester lakes WiLMS estimated annual phosphorus loading in pounds (right) and calculated annual phosphorus loading in pounds/acre-feet/year. Maps displaying watershed boundaries can be found within the individual lake report sections.

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 Phase I and II project lakes' measured growing season (April-October) near-surface total phosphorus concentrations compared to WiLMS predicted concentrations. Measured and predicted phosphorus concentrations in Harris, Hiawatha, and Birch lakes were relatively similar, indicating that no significant sources of unaccounted phosphorus are being loaded to these lakes. However, measured total phosphorus concentrations in Tamarack Lake were approximately 37% higher than the concentration predicted by WiLMS, indicating that approximately 200 lbs of additional phosphorus are being loaded to Tamarack Lake on an annual basis from an unaccounted source.

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.

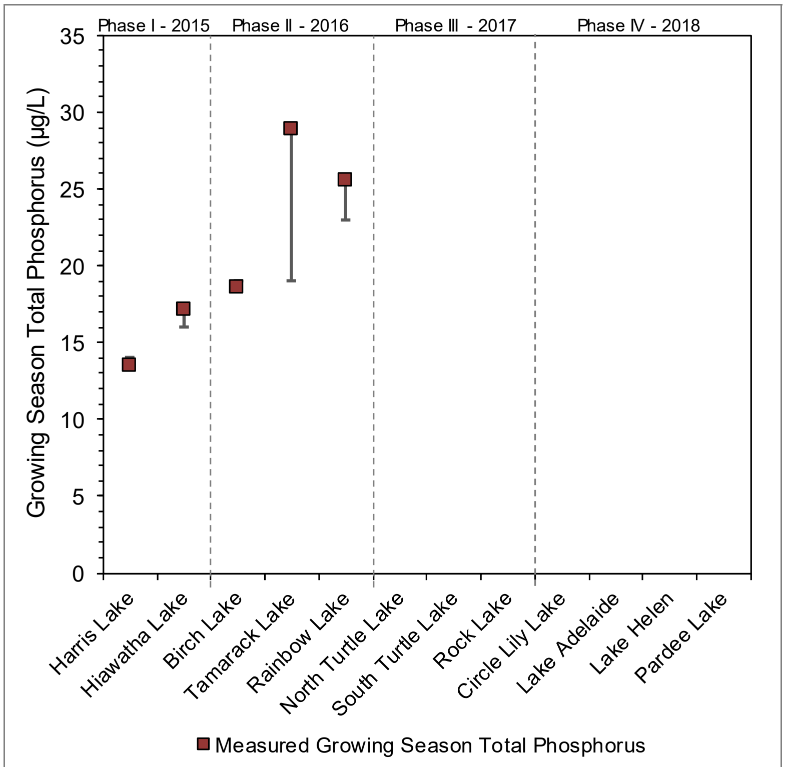


Figure 3.2-4. Town of Winchester lakes measured versus WiLMS-predicted growing season total phosphorus concentrations. Error bar represents WiLMS-predicted concentration.

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 increase 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 natural conditions, resulting in higher than predicted phosphorus concentrations within the lake. While phosphorus concentrations are higher in Tamarack Lake, it is not a concern as phytoplankton production remains low due to light limitation from the lake's dark-stained water.

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 Phase I and II lakes is negligible, ranging from 0% of the annual load in Tamarack Lake to 2% of the annual load in Birch Lake. Please see the individual lake report sections to see estimated phosphorus loading from shoreline septic systems for each lake. Overall, the watersheds for the Phase I and II 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 protective 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 protective than the state's minimum standards contained in NR 115. Counties that had shoreland zoning ordinances that were more protective than state standards are no longer able to enforce those more protective 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:

- Vegetation Removal: 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 Wisconsin Forest Management Guidelines (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.

- Impervious surface standards: 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.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion.

New language in NR-115 allows 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

- <u>Mitigation requirements</u>: 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.

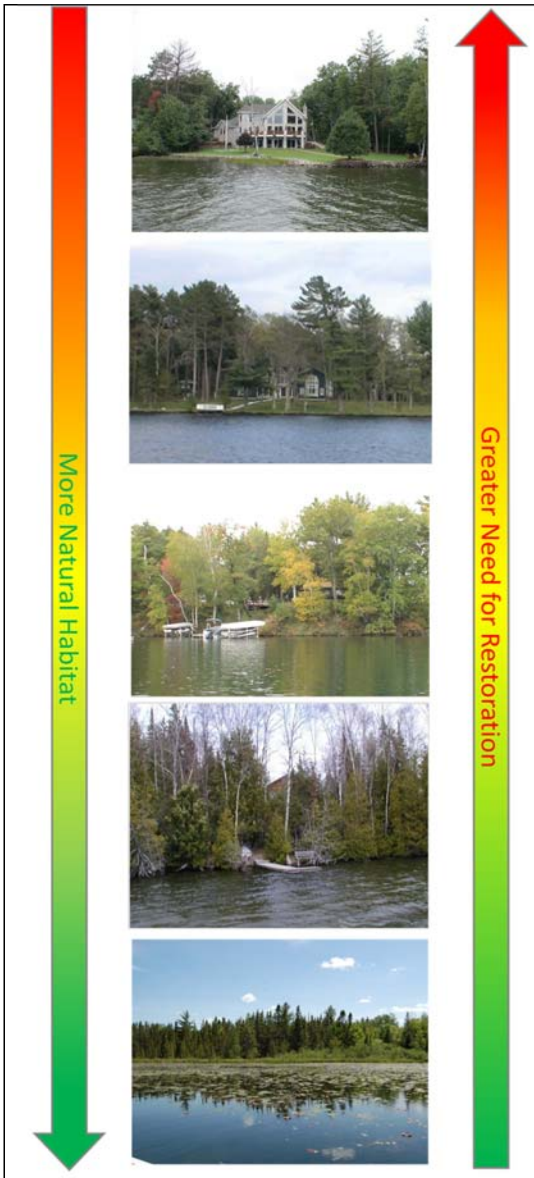
  - 100’ of shoreline.
  - An upland buffer zone depth of 35’.
  - An access and viewing corridor 30’ x 35’ free of planting (recreation area).
  - Planting area of upland buffer zones: two 35’ x 35’ areas
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has only 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 and II 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 70% in Birch 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 Lake to 14% in Hiawatha Lake (Figure 3.3-3). Overall, the shoreland conditions assessment of the Phase I and II 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.

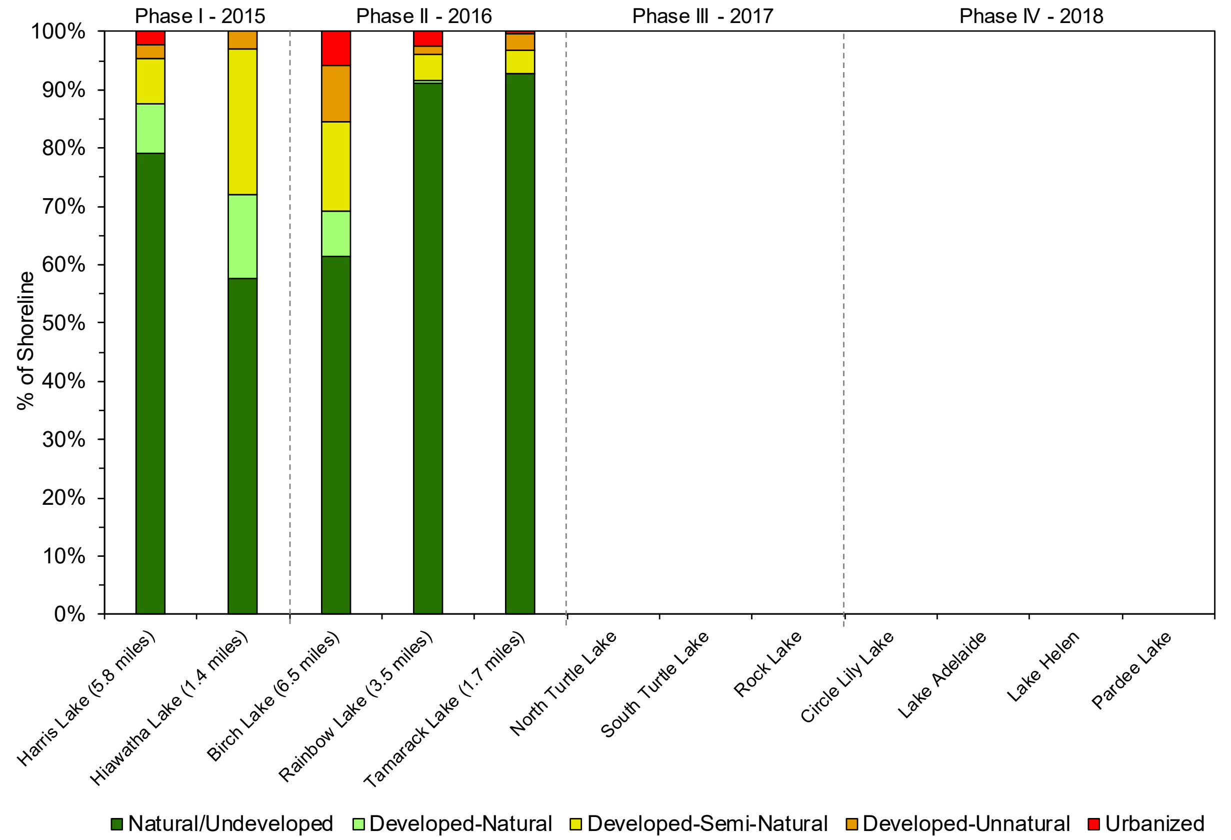


Figure 3.3-2. Town of Winchester lakes shoreland condition. Maps displaying the locations of these categorized shorelands can be found in the individual report sections.

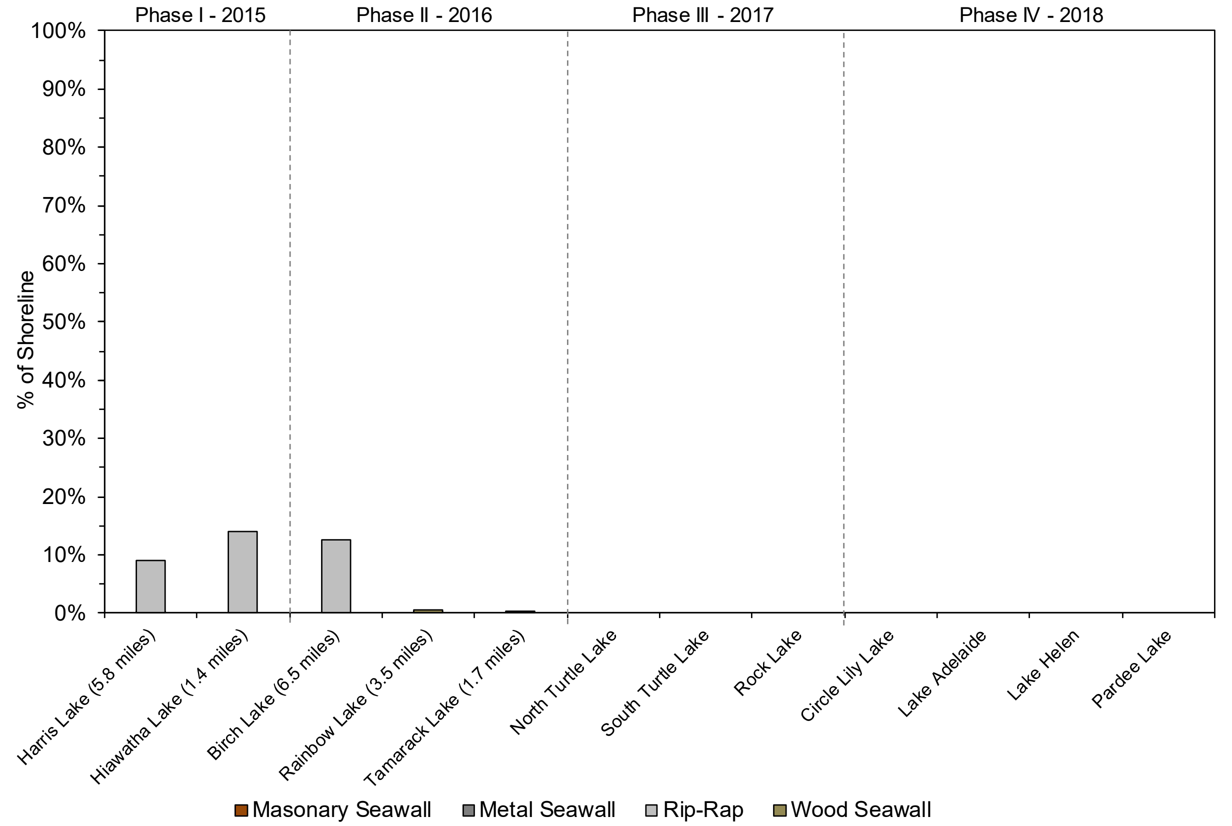


Figure 3.3-3. Town of Winchester lakes proportion of shoreline comprised of seawalls. Maps displaying the locations of these seawalls can be found in the individual report sections.

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).

Onterra has completed coarse woody habitat surveys on 75 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 75 lakes surveyed. The number of coarse woody habitat pieces per mile ranged from 108 in Harris Lake to 11 in Tamarack Lake. The number of coarse woody habitat pieces per shoreline mile in Harris, Hiawatha, and Birch Lakes fall well above the 75th percentile of these 75 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 Tamarack and Rainbow lakes fell below the median value for these 75 lakes. 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 Harris, Hiawatha, and Birch lakes 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.

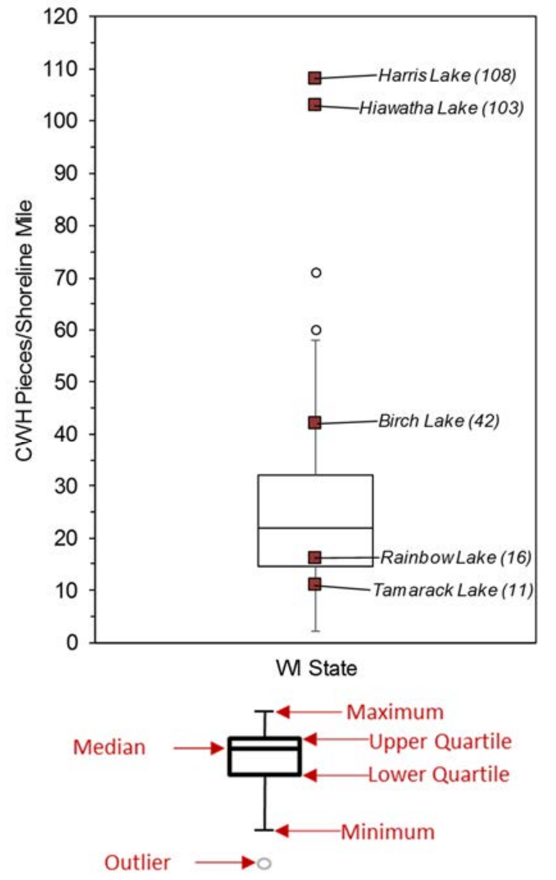


Figure 3.3-4. Town of Winchester lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. State-wide comparative data available from 75 lakes surveyed by Onterra since 2012. Maps displaying the locations of these coarse woody habitat pieces can be found in the individual report sections.

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.

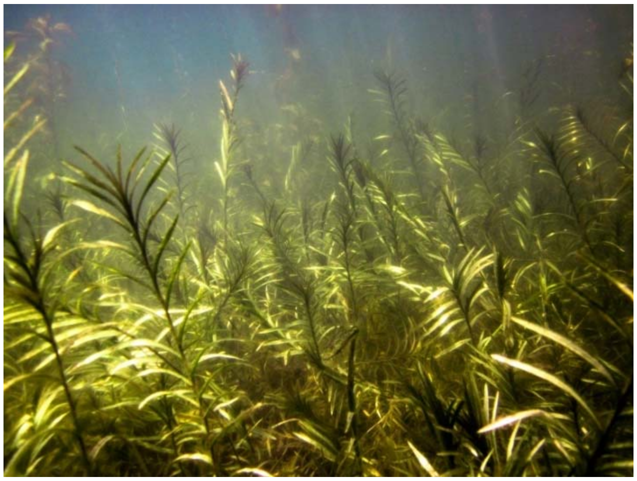


Photo 3.4-1. Native aquatic plant community. Fern pondweed (*Potamogeton robbinsii*). Photo credit Onterra.

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

Photo 3.4-3. Aquatic plant mechanical harvester.

limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor. Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the latter route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Cost

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

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

Herbicide Treatment

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers (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)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; Eurasian water milfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance natives species including duckweeds, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for Eurasian water milfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for Eurasian water milfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

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

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

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

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

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.

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.

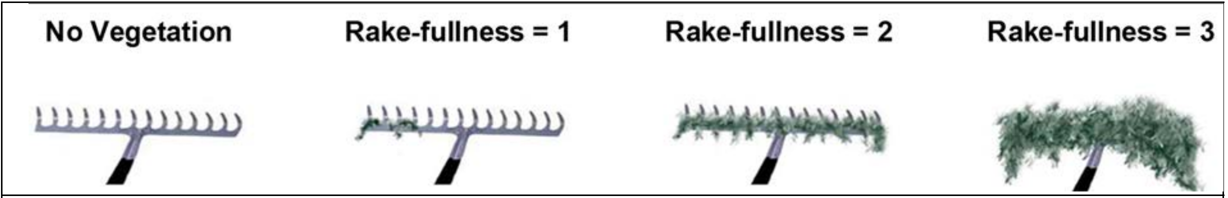


Figure 3.4-1. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

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.

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

The FQI components 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 both the Town-Wide Report and individual lake report sections.

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

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

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

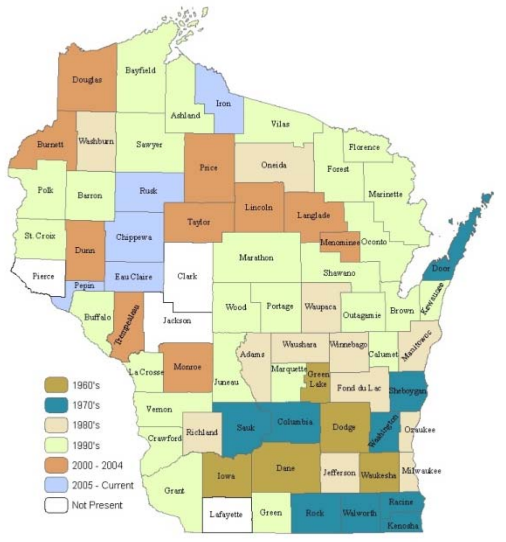


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data mapped by Onterra (2011).

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.

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 five Phase I and II lakes that have been studied to date, a total of 84 aquatic plant species representing 26 families have been documented, collected, and verified by the UW-Stevens Point Herbarium (Table 3.3-2 and Table 3.3-3). Thirty-five of these plant species (45%) belong to two families, the *Potamogetonaceae* (the pondweeds) and *Cyperaceae* (the sedges). Eight plant species were located in all five lakes, and include creeping spikerush, three-way sedge, spatterdock, floating-leaf bur-reed, muskgrasses, quillworts, slender naiad, and variable-leaf pondweed Growth forms include 43 submergent species, 28 emergent species, six floating-leaf species, four submergent/emergent species, two floating-leaf/emergent species, and two free-floating species. The number of native aquatic plant species ranged from 57 in Harris Lake to 26 in Hiawatha, with an average of 39 native species per lake. Of the 84 species located to date, only one is considered to be a non-native, invasive species: curly-leaf pondweed (Harris Lake). Because of its importance, the small curly-leaf pondweed population present in Harris Lake is discussed in detail in the subsequent Non-Native Aquatic Plants Subsection.

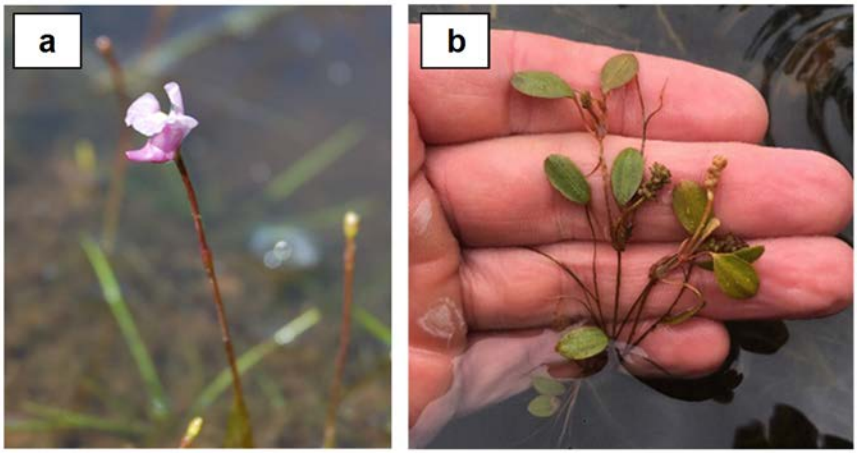


Photo 3.4-5. Native plant species listed as special concern in Wisconsin. a. Flower of northeastern bladderwort. b. Flowers and floating-leaves of Vasey's pondweed. Photo credit Onterra.

Two native aquatic plant species, northeastern bladderwort and Vasey's pondweed, located during these studies 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 Lake (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.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, and substrate composition, and all of these factors 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 Town of Winchester 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.

Table 3.4-2. List of emergent and floating-leaf 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							
	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									
	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 stricta	Common tussock sedge	7					I							
	Carex utriculata	Common yellow lake sedge	7	I	I	I		I							
	Cladium mariscoides	Smooth sawgrass	10	I		I									
	Dulichium arundinaceum	Three-way sedge	9	X	I	I	I	I							
	Eleocharis palustris	Creeping spikerush	6	X	X	I	I	X							
	Equisetum fluviatile	Water horsetail	7	X	X	I									
	Glyceria canadensis	Rattlesnake grass	7		I										
	Iris versicolor	Northern blue flag	5			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							
	Sagittaria latifolia	Common arrowhead	3	I		I									
	Sagittaria rigida	Stiff arrowhead	8	I											
	Schoenoplectus acutus	Hardstem bulrush	5	X		X	I	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								
	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									
FL	*Brasenia schreberi*	Watershield	7	X			X	X							
	Nuphar variegata	Spatterdock	6	X	X	X	X	X							
	Nymphaea odorata	White water lily	6	X		X	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							

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

Table 3.4-3. List of submergent 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**
Submergent	*Bidens beckii*	Water marigold	8	X		X	X	X							
	Callitriche palustris	Common water starwort	8		I										
	Ceratophyllum demersum	Coontail	3				X								
	Ceratophyllum echinatum	Spiny hornwort	10			X		X							
	Chara spp.	Muskgrasses	7	X	X	X	X	X							
	Elodea canadensis	Common waterweed	3	X		X	I	X							
	Elodea nuttallii	Slender waterweed	7					X							
	Eriocaulon aquaticum	Pipewort	9	X	X		X								
	Fontinalis sphagnifolia	Rolled water moss	N/A		X										
	Heteranthera dubia	Water stargrass	6	X				X							
	Isoetes spp.	Quillwort spp.	8	X	X	X	X	X							
	Lobelia dortmanna	Water lobelia	10	X											
	Myriophyllum alterniflorum	Alternate-flowered watermilfoil	10	X											
	Myriophyllum sibiricum	Northern watermilfoil	7	X		X	X	X							
	Myriophyllum tenellum	Dwarf watermilfoil	10	X		X									
	Najas flexilis	Slender naiad	6	X	X	X	X	X							
	Nitella spp.	Stoneworts	7		X	X		X							
	Potamogeton amplifolius	Large-leaf pondweed	7	X		X	X	X							
	Potamogeton berchtoldii	Slender pondweed	7		X		X	X							
	Potamogeton crispus	Curly-leaf pondweed	Exotic	I											
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X		X	I							
	Potamogeton foliosus	Leafy pondweed	6												
	Potamogeton friesii	Fries' pondweed	8	X											
	Potamogeton gramineus	Variable-leaf pondweed	7	X	X	X	X	X							
	Potamogeton illinoensis	Illinois pondweed	6	X											
	Potamogeton natans	Floating-leaf pondweed	5		I			X							
	Potamogeton obtusifolius	Blunt-leaved pondweed	9					I							
	Potamogeton praelongus	White-stem pondweed	8	X			I	X							
	Potamogeton pusillus	Small pondweed	7	X											
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X		X	I	X							
	Potamogeton robbinsii	Fern-leaf pondweed	8	X		X	X	X							
	Potamogeton spirillus	Spiral-fruited pondweed	8		X	I	X	X							
	Potamogeton strictifolius	Stiff pondweed	8	X											
	*Potamogeton vaseyi**	Vasey's pondweed	10					X							
	Potamogeton zosteriformis	Flat-stem pondweed	6	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							
	Vallisneria americana	Wild celery	6	X		X		X							
S/E	*Eleocharis acicularis*	Needle spikerush	5	X			I								
	Juncus pelocarpus	Brown-fruited rush	8	X											
	Sagittaria cristata	Crested arrowhead	9	I											
	Schoenoplectus subterminalis	Water bulrush	9					X							

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*

The Phase I and II studies lake 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.

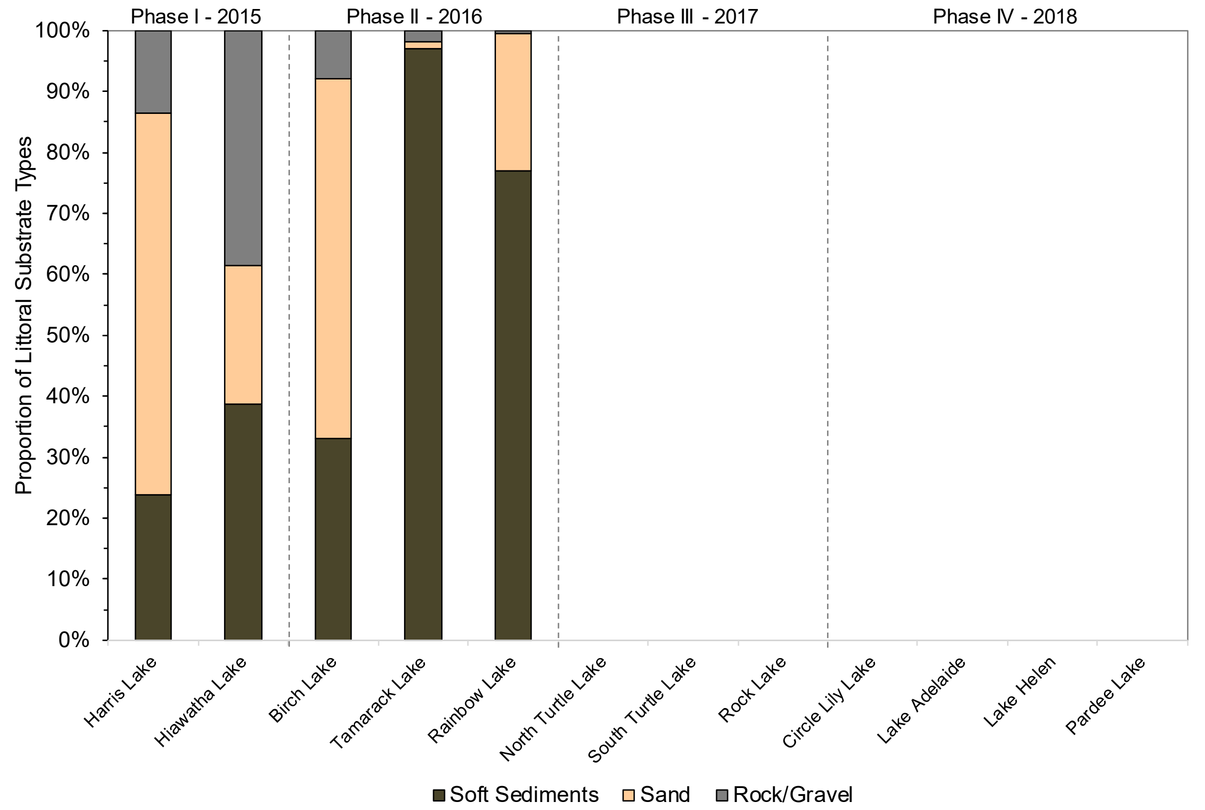


Figure 3.4-3. Town of Winchester project lakes proportion of substrate types. Created using data collected during the whole-lake point-intercept survey.

The maximum depth of aquatic plant growth within the Phase I and II lakes ranged from 28 feet in Harris Lake to 7 feet in Hiawatha Lake. Maximum depth of aquatic plant growth was highly correlated with average summer Secchi disk depth. The lakes with higher average Secchi disk depth indicating higher water clarity had aquatic plants growing deeper. 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.

The littoral frequency of occurrence of aquatic vegetation in the Phase I and II lakes ranged from 79% in Tamarack Lake to 48% in Harris Lake with an average of 66% (Figure 3.4-5). The proportion of aquatic plant total rake fullness (TRF) ratings varied among the five lakes. Of the sampling locations that contained aquatic vegetation in Harris, Hiawatha, and Birch lakes, the majority had TRF ratings of 1, indicating that where plant growth occurs it is relatively sparse. In contrast, of the sampling locations that contained aquatic vegetation in Tamarack and Rainbow lakes, the majority had TRF ratings of 2 or 3, indicating that the growth of aquatic plants in these lakes is relatively dense. The substrate within littoral areas of Tamarack and Rainbow lakes was largely comprised of soft, organic sediments which are conducive for supporting larger plant species. The littoral areas Harris, Hiawatha, and Birch lakes were largely comprised of sand and/or rock, which support smaller, less-dense growing plant species.

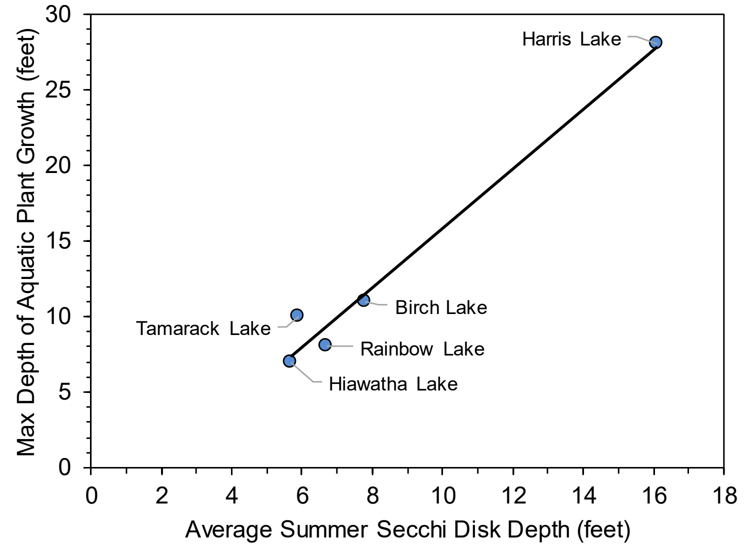


Figure 3.4-4. Town of Winchester project lakes maximum depth of aquatic plant growth plotted against average summer Secchi disk depth.

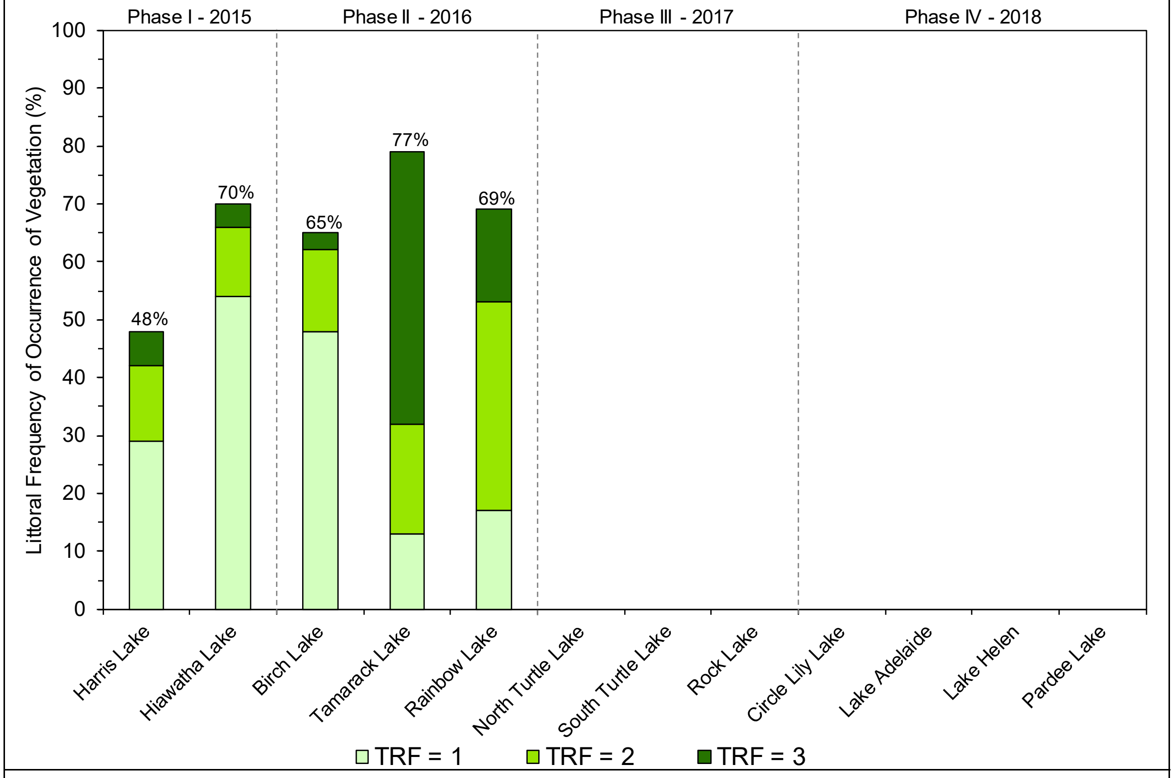


Figure 3.4-5. Town of Winchester lakes littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings. Created using data collected during the whole-lake point-intercept surveys.

Of the five Town of Winchester lakes that have been studied in Phase I and II, the number of native aquatic plant species (species richness) per lake ranged from 56 in Harris Lake to 26 in Hiawatha Lake with an average of 39 species per lake (median of 37) (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 57 native aquatic plant species were located in Harris Lake in 2015, 41 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.

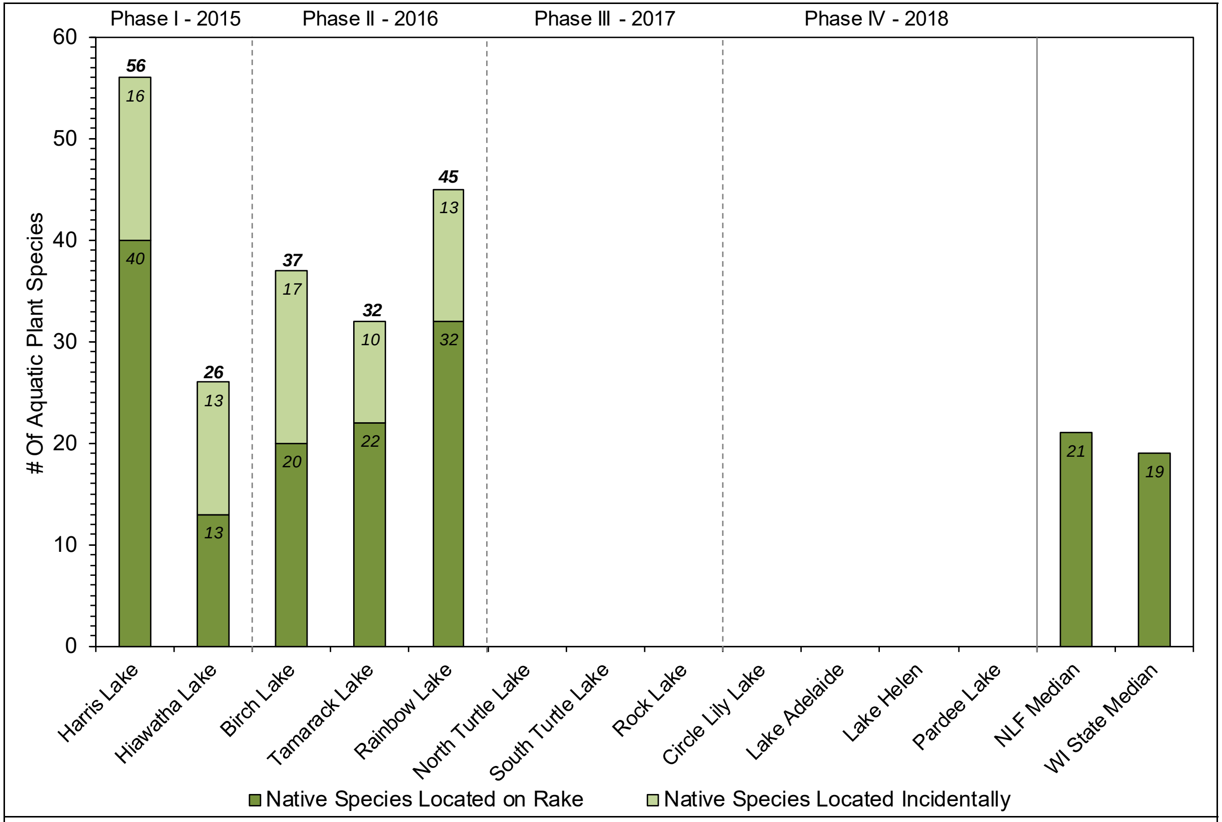


Figure 3.4-6. Town of Winchester lakes native aquatic plant species richness and median species richness for Northern Lakes and Forests (NLF) ecoregion lakes and Wisconsin lakes. Includes species located on rake during point-intercept surveys and incidentally-located species.

The native aquatic plant species richness in Harris, Tamarack, and Rainbow 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 Lake fell below both median values. Studies have shown that aquatic plant species richness increases with littoral area (Vestergaard and Sand-Jensen 2000). Species richness in the Phase I and II lakes was highly correlated with littoral area.

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 five Phase I and II lakes, with values ranging from 2.1 in Tamarack Lake to 4.1 in Birch Lake. There was no significant relationship between shoreline complexity and native aquatic plant species richness in the Phase I and II lakes, indicating that littoral area and water chemistry are likely primary parameters driving the differences in species richness among these lakes. Littoral area within a lake is going to be determined by both the lake's morphometry and water clarity. For example, Harris Lake's littoral zone extends to a depth of 28 feet, and the lake contains approximately 300 acres of littoral area that are shallower than 28 feet. In contrast, the combination of both low water clarity and steep contours in Hiawatha Lake create a small littoral area of approximately 5 acres.

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, Harris, Birch, Tamarack, and Rainbow lakes 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 four 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. All five lakes which have been studied to data have average conservatism values of 7.0 or higher, exceeding the median conservatism values for lakes within NLF ecoregion and for lakes throughout Wisconsin. The average conservatism values for these lakes means they harbor a higher number of aquatic plant species that are considered sensitive to environmental disturbance (higher C-values) and indicate minimally-disturbed 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 does 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 value were relatively similar among all five lakes, the FQI values are more variable and range from 25.8 in Hiawatha Lake to 45.1 in Harris Lake with an average of 35.5.

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, and Rainbow lakes exceed the median values for lakes within the NLF ecoregion and lakes throughout Wisconsin. The FQI value for Hiawatha Lake falls below the median values for lakes within the ecoregion and the state; however, this is not an indication of a degraded aquatic plant community but the result of the natural conditions present in this lake as discussed previously.

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.

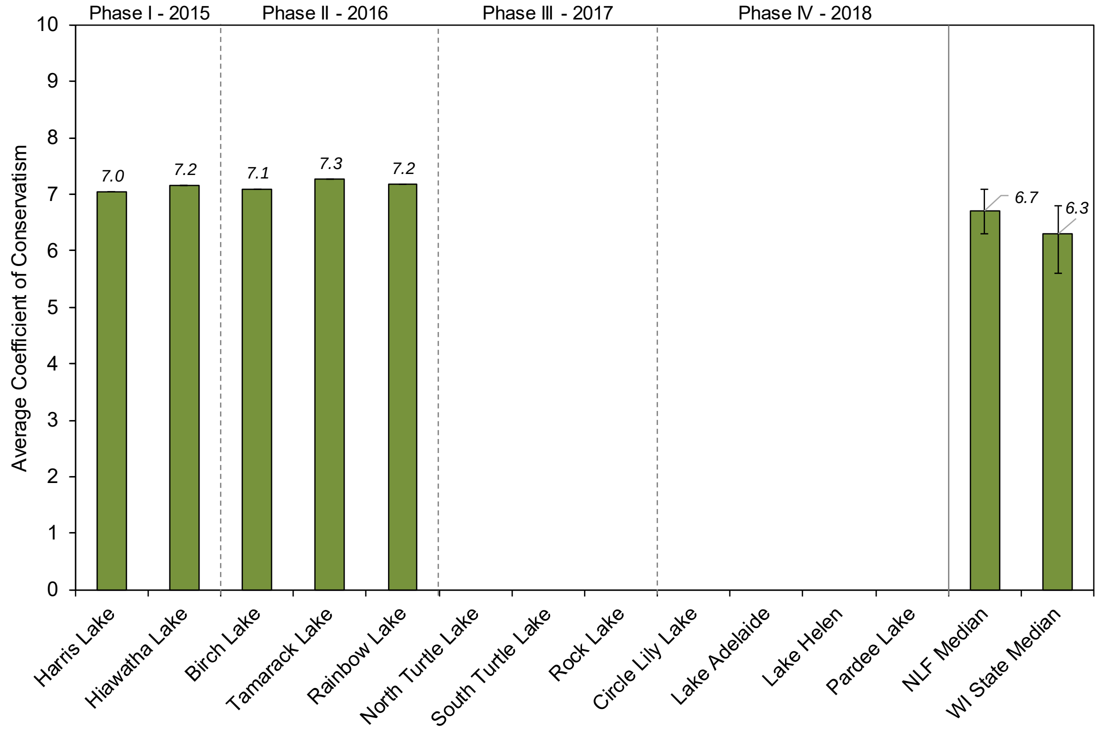


Figure 3.4-7. Town of Winchester lakes native aquatic plant average coefficients of conservatism. Error bars represent interquartile range. Created using conservatism values of native aquatic plant species located on the rake during the whole-lake point-intercept surveys. Analysis follows Nichols (1999).

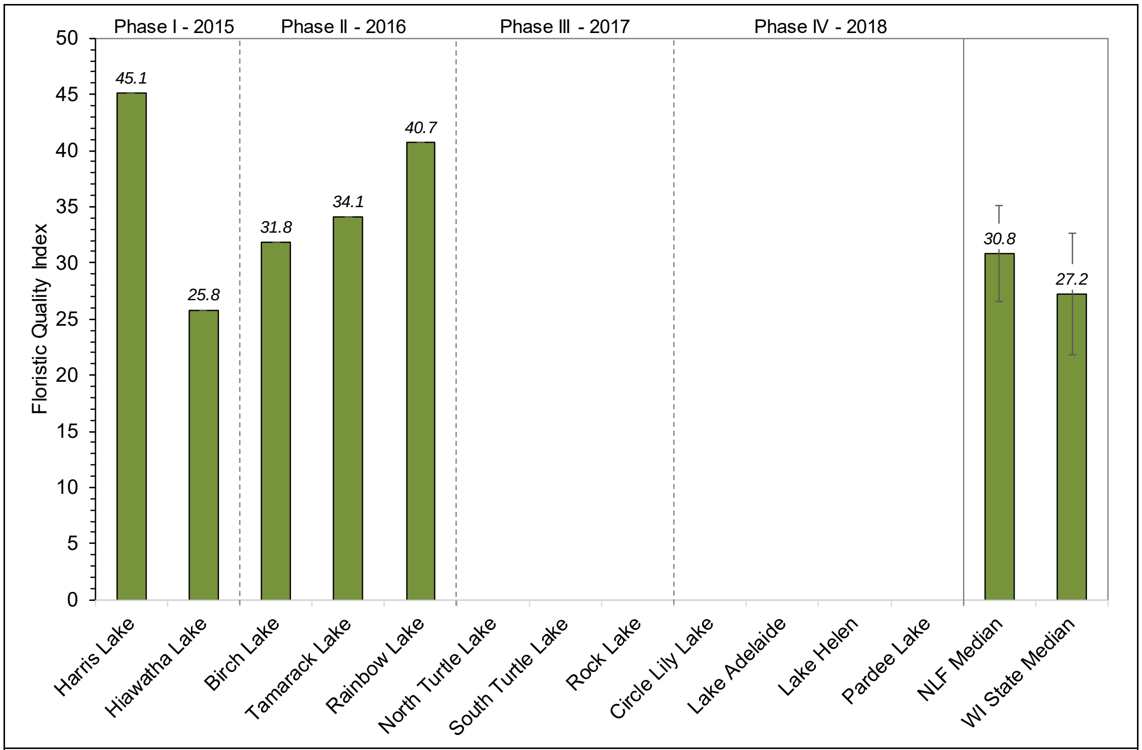


Figure 3.4-8. Town of Winchester lakes Floristic Quality Index values. Created using conservatism values and number of native aquatic plant species located on the rake during the whole-lake point-intercept surveys. Analysis follows Nichols (1999).

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 Lake and Rainbow Lake exceed the median value for lakes within the NLF ecoregion, the diversity value for Hiawatha Lake falls near the median value, and the diversity values for 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 Phase I and II 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 Phase I and II lakes found that the acreage of these communities range from 0.8 acres in Hiawatha Lake to 91.9 acres in Harris Lake, with the percentage of lake area

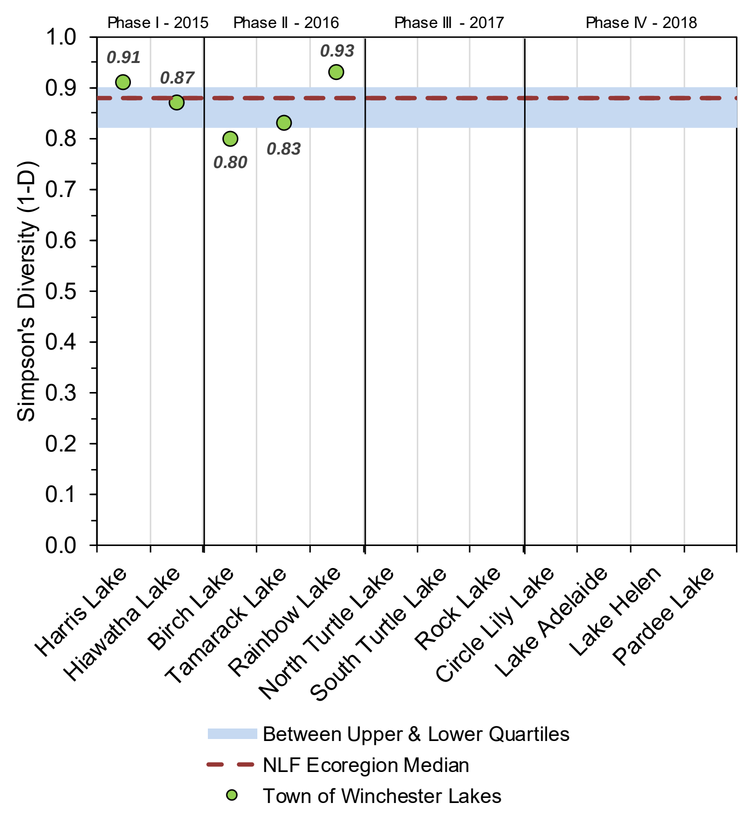


Figure 3.4-9. Town of Winchester lakes Simpson's Diversity Index. Created using data collected from whole-lake point-intercept surveys. Ecoregion data calculated using Onterra and WDNR science services point-intercept survey data.

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 36 emergent and floating-leaf aquatic plant species were located within these five lakes (Table 3.4-2).

Figure 3.4-10 illustrates the composition of emergent and floating-leaf aquatic plant communities in the Town of Winchester Lakes. The composition of these communities varied among lakes. Harris Lake's communities were mainly comprised of emergent plants while Tamarack Lake's was primarily comprised of floating-leaf plants. Hiawatha, Birch, and Rainbow lakes had communities largely comprised of both emergent and floating-leaf plants. 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**	**Rainbow Lake**	**Tamarack 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	3.0	7.8							
Floating-leaf Acres	0.1	0.2	3.7	22.5	12.3							
Mixed Emergent & Floating-leaf Acres	2.9	0.4	40.8	21.6	0.0							
Total Acres	**91.9**	**0.8**	**69.1**	**47.1**	**20.0**							
% Lake Area	**17.1**	**2.0**	**13.2**	**30.6**	**30.6**							

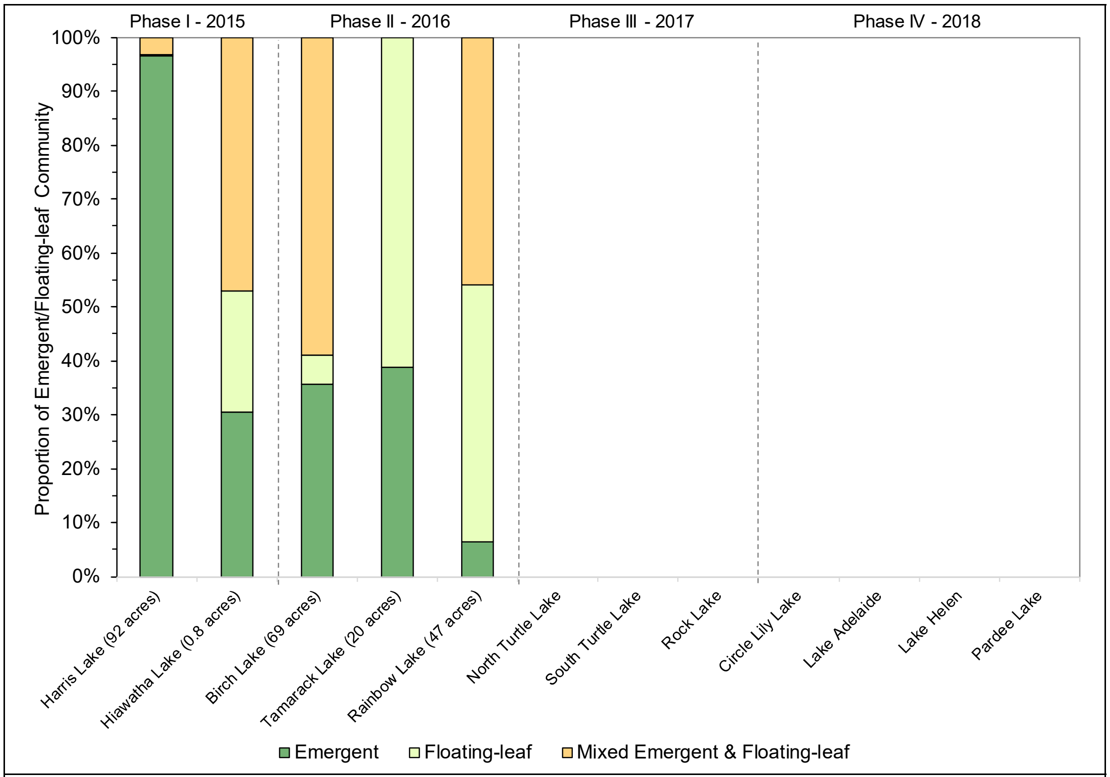


Figure 3.4-10. Town of Winchester lakes emergent and floating-leaf aquatic plant community composition. Locations of these aquatic plant communities are displayed on maps within the individual lake report sections.

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.

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

Of the five lakes studied to date under Phase I and II, 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 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 five years (Johnson et al. 2012), 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 not 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).

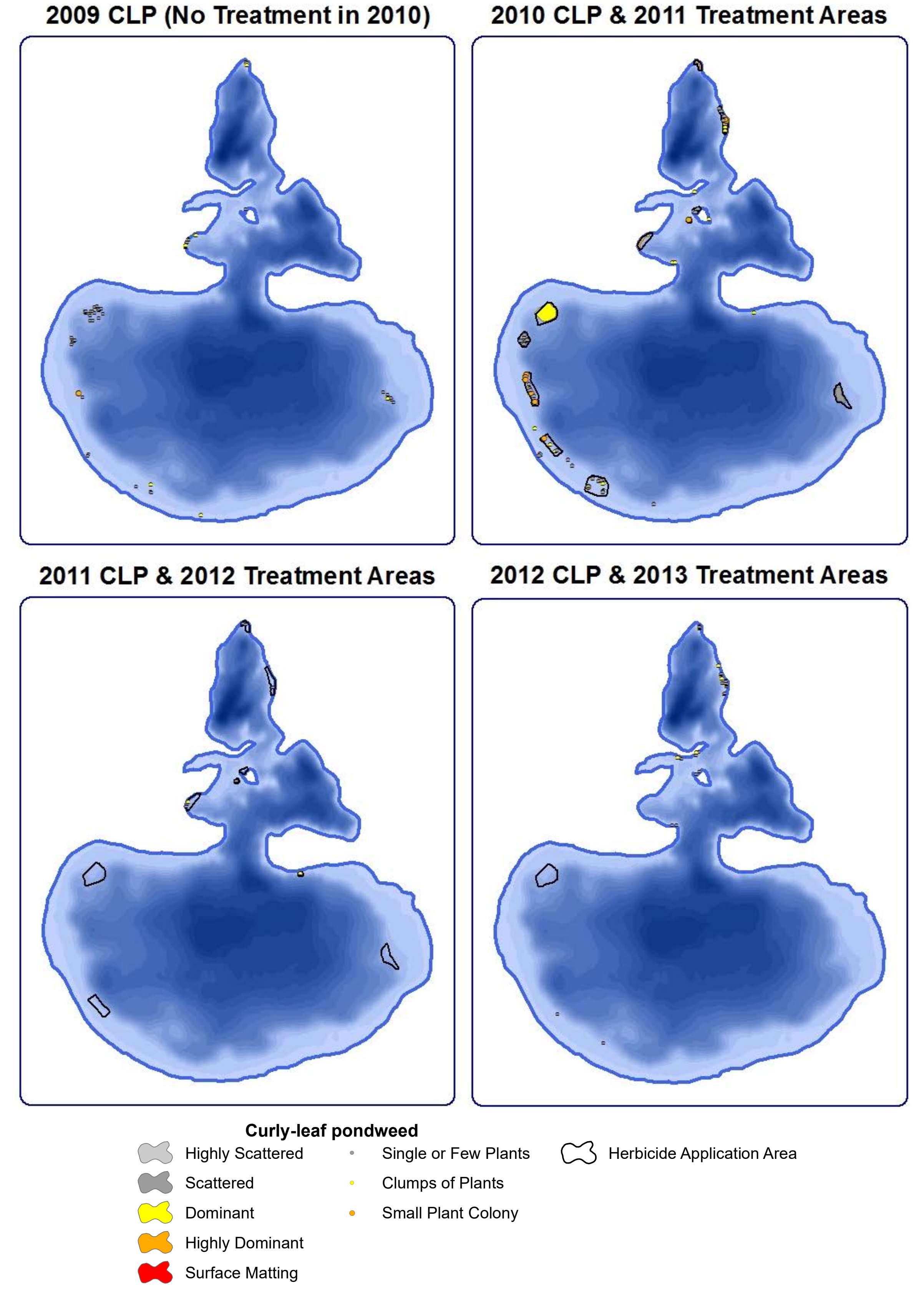


Figure 3.4-11. Locations of CLP and herbicide application areas in Harris Lake from 2009-2012.

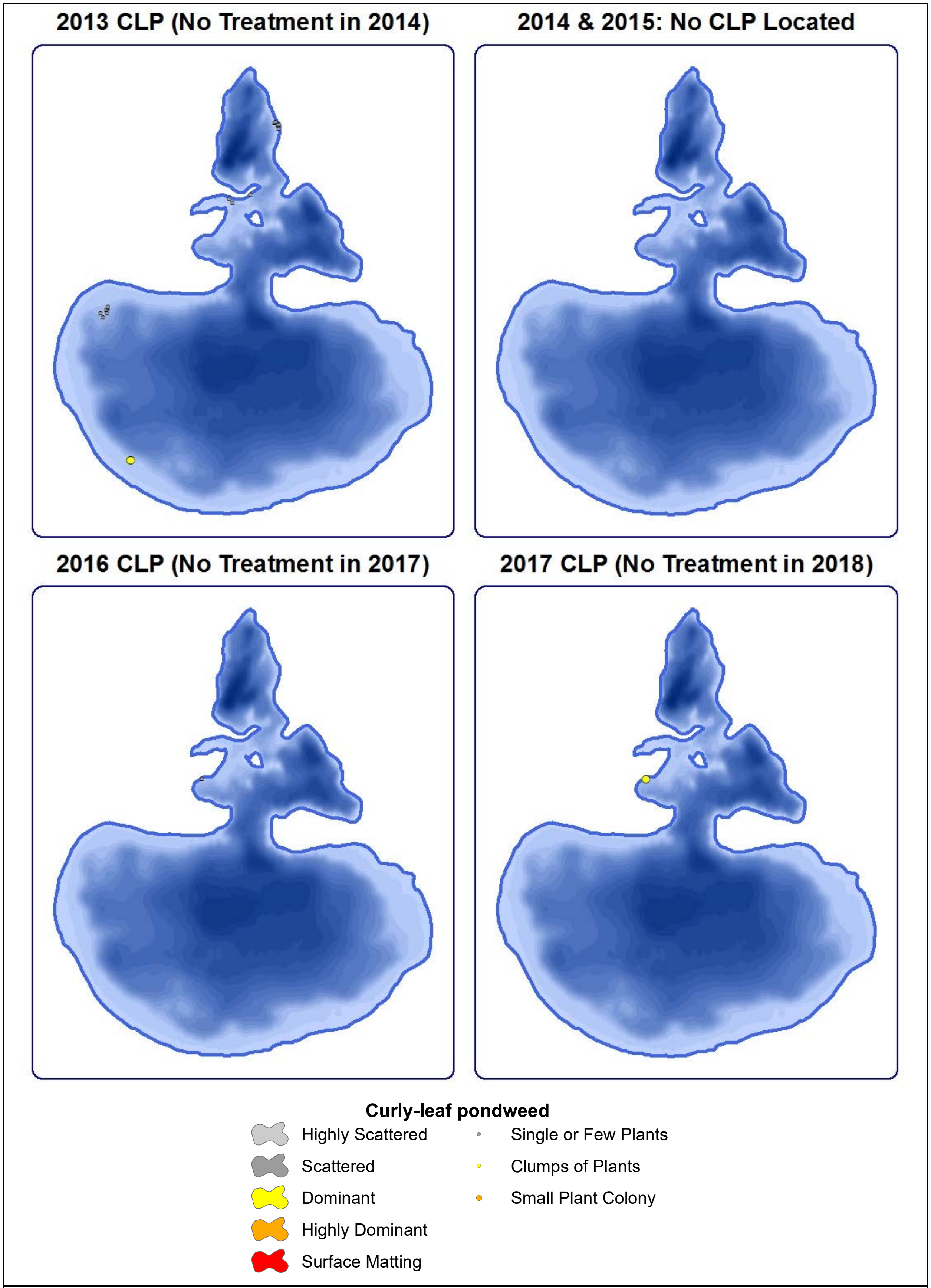


Figure 3.4-12. Locations of CLP in Harris Lake from 2013-2016.

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 the Phase I and II study results show that 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 thus far on the Phase I and II 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 five 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 2016 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 more phases are completed and common challenges between the lakes become more evident.

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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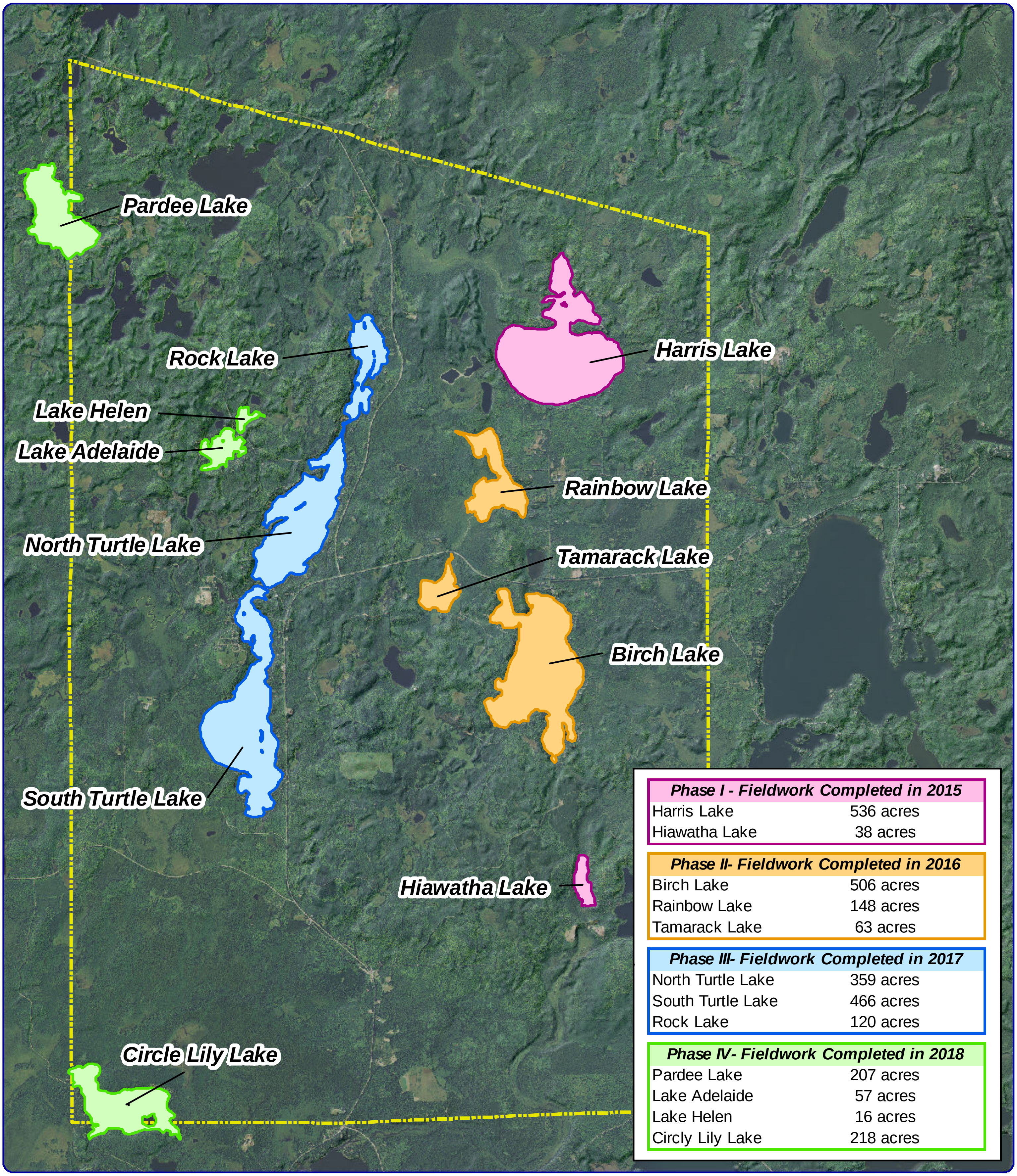
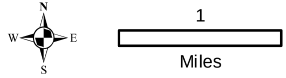


Phase I - Fieldwork Completed in 2015	
Harris Lake	536 acres
Hiawatha Lake	38 acres

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



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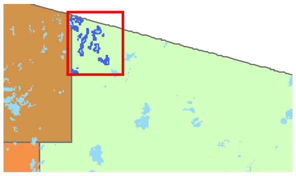
www.onterra-eco.com

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