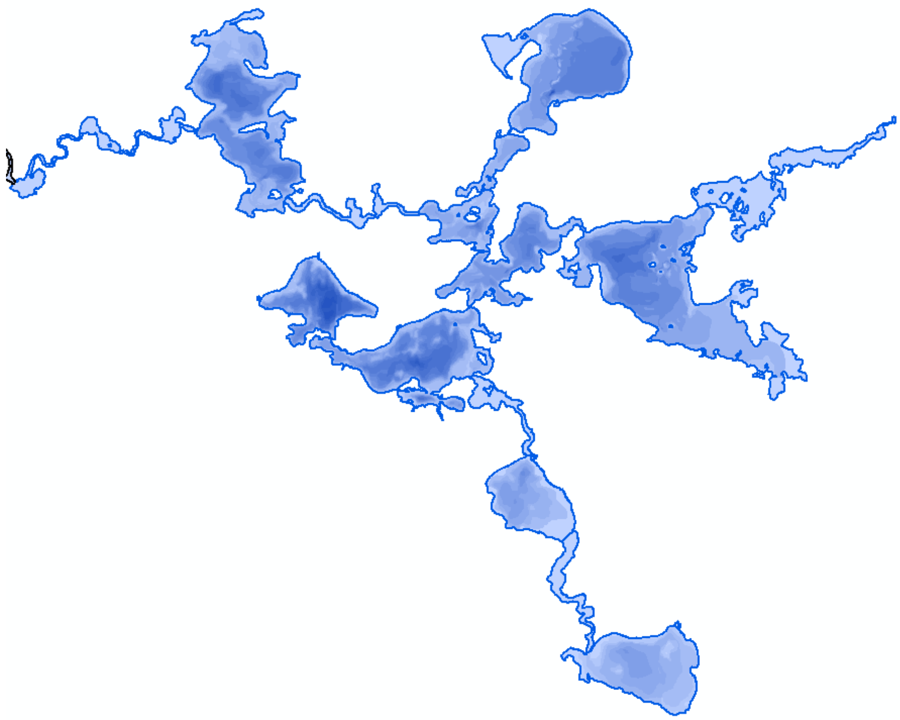
Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Comprehensive Management Plan

December 2019



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Onterra, LLC
Lake Management Planning

Manitowish Waters Chain of Lakes Comprehensive Management Plan

Phase I – Phase V

Vilas County, Wisconsin

December 2019

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Manitowish Waters Chain of Lakes Planning Committee

The Planning Committee was comprised of Board members from the NLDC, MWLA as well as riparian property owners from chain lakes. Additionally, several individuals of the committee were crucial in much of the planning process:

Tom Joseph　　Karen Dixon

Organization

Town of Manitowish Waters　　Town of Boulder Junction

North Lakeland Discovery Center　　Emily Heald

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APPENDICES

1.0 INTRODUCTION

The Manitowish Waters Chain of Lakes consists of 10 lakes totaling over 4,200 acres located in and just east of the Town of Manitowish Waters in Vilas County, and three additional lakes located below the Rest Lake Dam (Map 1). The chain is fed by a series of streams, including Papoose Creek, Rice Creek, Island Creek, the Manitowish River and Trout River. Downstream of the Rest Lake Dam, the Manitowish River runs into Iron County where it becomes one of two main tributaries to the 13,500+ acre Turtle Flambeau Flowage. The Rest Lake Dam was first constructed in 1887 by the Chippewa Lumber and Boom Company. Its construction was implemented then to store water for the purpose of floating logs downstream. Eventually, other purposes were recognized (flood control, recreation, hydropower, etc.). In 1939, the Public Service Commission of Wisconsin approved an operating order that allowed for a winter (November 1 to spring thaw) drawdown to a minimum of 5’0” (Public Service Commission, 1939). Summer water levels were raised to between 7’3”-8’6”, while downstream flows were to be maintained at 40 cfs (cubic feet per second). At the time of this writing, the Wisconsin Department of Natural Resources (WDNR) is considering alterations of this order to a more natural flow regime. In 2016, the Wisconsin Department of Natural Resources (WDNR) updated this plan stating that from November 1 to spring that the dam will be set to run of the river and during the summer the dam should not have less than 45 cubic feet per second (cfs) flow except in times of drought (WDNR 2016).

The chain is a major attraction for this area of Vilas County, providing angling, sightseeing, recreational boating, wildlife viewing, and a relaxing setting for residents and visitors from nearby and far away. Realizing the chain’s uniqueness as a natural resource as well as its potential for economic opportunity, several groups have spear-headed campaigns for its protection and management. They include:

- The North Lakeland Discovery Center (NLDC – http://www.discoverycenter.net), a non-profit environmental education center founded in 1996 that connects people with nature in Wisconsin’s Northwoods. Their mission is to enrich lives and inspire an ethic of care for Wisconsin’s Northwoods, through the facilitation of communications among people, nature and community. The NLDC and North Lakeland School District co-lease the expansive property from the WDNR within the Northern Highland American Legion State Forest. The grounds and facilities are a former Youth Conservation Corps camp, originally opened in 1962. The facility is located on the shores of the 25-acre Statehouse Lake and offers 20 km of trails traversing 66 acres for recreationalists to enjoy year-round. Among their many year-round educational offerings, the NLDC conducts citizen-based monitoring programs and offers on-going life-long learning opportunities. The NLDC serves as sponsor for this lake management planning project.

- The Manitowish Waters Lake Association (MWLA - http://www.mwlakes.com/) is a non-profit organization advocating for clean, healthy lake and river environments within the Township of Manitowish Waters. The MWLA is highly involved in lake monitoring programs, education of lake and area residents, enhancing lake safety and recreation and improving the Manitowish Waters Chain of Lakes’ ecology through hands-on volunteer based projects.

- The Town of Manitowish Waters and Town of Boulder Junction oversee many matters pertaining to the Manitowish Waters Chain of Lakes. The towns commit funds every year for aquatic invasive species education, prevention, and control efforts. The towns also provide other support such as facility use, annual feedback to partners, volunteer recruitment aid, and dissemination of aquatic invasive species information at town-owned facilities, boat landings, and appropriate venues.

These management entities have collaborated very effectively. The NLDC serves as the primary contact for aquatic invasive species collaboration in the Manitowish Waters area and serves as technical advisor to the towns and MWLA through the hiring of an invasive species coordinator and a water education intern. The NLDC provides services including administration, education, monitoring, control, volunteer training, and coordination. The MWLA aids in recruiting volunteers and integrates aquatic invasive species information into public education materials, meetings, and other venues. In 2010, solidifying past partnerships, the MWLA, NLDC, and the Town of Manitowish Waters formed the Town Aquatic Invasive Species Partnership (TAISP) consisting of the three entities in order to effectively address aquatic invasive species in area waters and wetlands through education, prevention and control. A 2018 annual report highlighting these projects can be viewed within Appendix A.

Curly-leaf pondweed was first documented on the Manitowish Waters Chain of Lakes in Island Lake on June 18, 2010 by a volunteer who had attended a training session the previous day. In July of that year, subsequent monitoring turned up the presence of curly-leaf pondweed in Rice Creek. With the discovery of curly-leaf pondweed, the TAISP began discussing the need for management plans in order to address this looming threat as well as document the health of the chain lakes. The TAISP contracted with Onterra, LLC in late 2010/early 2011 to steer this process

Beginning in 2011, a phased approach was developed to address each lake within the chain over the course of several years. Developing management plans for small clusters of lakes within the chain allow 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 lake's 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 chain as a whole. Financial assistance was obtained through the Wisconsin Department of Natural Resources' (WDNR) Lake Management and AIS Grant Program for each phase of the project. While the planning project was being conducted, three AIS-Early Detection and Response Grants and a single AIS-Established Population Control Grant were also sponsored by the NLDC to provide partial funding for curly-leaf pondweed management activities. Annual reports were produced from 2012 to 2018 regarding the activities and results of those grants. A summary of the discussions contained in those reports can be found in Section 3.4, below.

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, the completion of a stakeholder survey, and updates within the lake group's newsletter.

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

Project Planning Process

Table 2.0-1. Project-related meeting information

Date	Meeting	Audience	Discussion
7/28/2012	Project Kick-off Meeting	General Membership	Chain-wide management planning project discussion and explanation of studies to be completed
7/27/2013	Project Update Meeting	General Membership	Update on management planning project and discussion of future grants
10/21/2013	Planning Meeting - Phase I	MWLA Board of Directors	Results of Phase I lakes surveys and CLP management
6/15/2015	Planning Meeting - Phase II & III	MWLA Board of Directors	Results of Phase II & III lakes surveys and CLP management
7/25/2015	MWLA 2015 Annual Meeting	General Membership	NLCD staff conducted discussion regarding CLP management and CLP/wild rice monitoring with a presentation supplied by Onterra
6/30/2016	Kick-off Meeting - Phase IV	General Membership	New and future project lakes and CLP management
7/7/2017	Planning Meeting - Phase IV	MWLA Board of Directors	Results of Phase IV lakes surveys and CLP management
8/22/2018	Planning Meeting - Phase V	MWLA Board of Directors	Results of Phase V lakes surveys and CLP management

Management Plan Review and Adoption Process

Prior to the first Planning Meeting, the Results Section of this document (Section 3.0) as well as the individual lake sections were sent to all Planning Meeting attendees for their review and preparation for the meeting. Following discussions at the meeting, Onterra staff drafted this report's Implementation Plan and sent it to NLDC and MWLA board members for review. Their comments were integrated to the plan, and a first official draft was sent to the WDNR for review in August of 2014. As each phase was completed, the Implementation Plan Section 5.0 was updated, approved by the NLDC and MWLA Board of Directors. The final draft of the implementation plan was accepted by the WDNR in 2019.

Stakeholder Survey

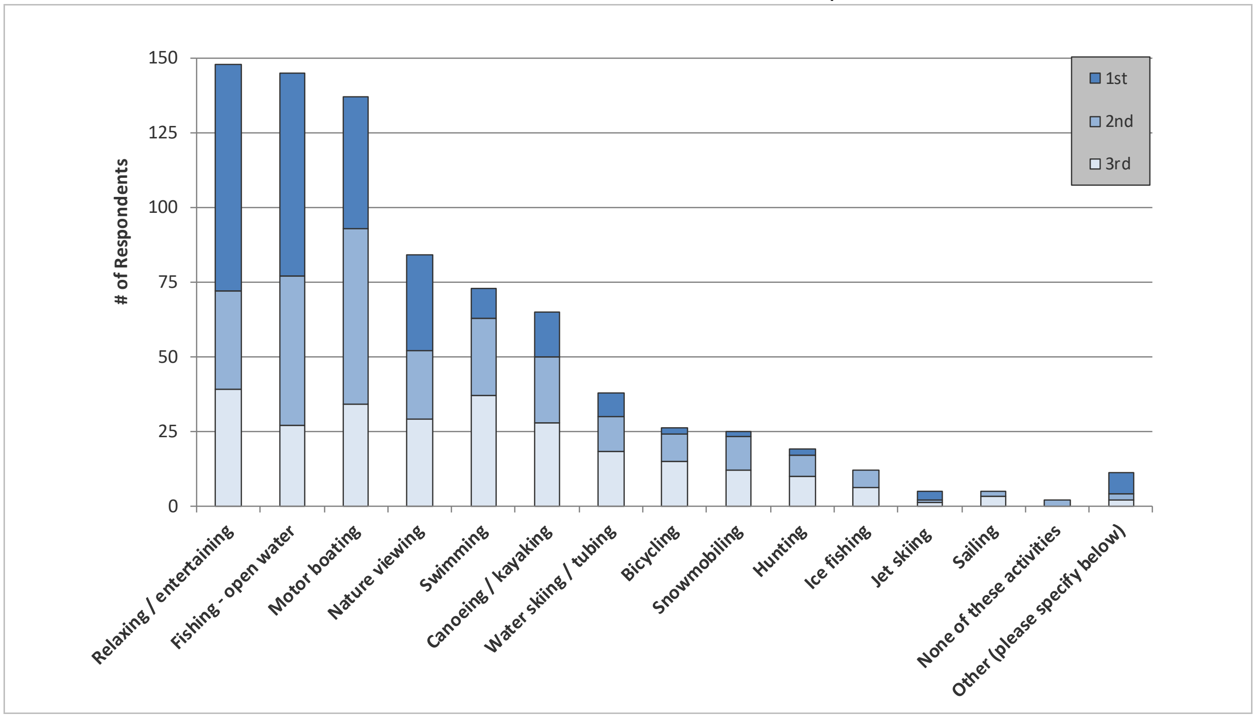
As a part of this project, a stakeholder survey was distributed to MWLA members and non-member riparian property owners. This survey was designed by Onterra staff and the MWLA / NLDC planning committee in winter of 2015-2016. The draft survey was sent to a WDNR social scientist for review during that time frame as well. During February 2016, the eight-page, 33-question survey was mailed to 1,381 riparian property owners in the Manitowish Waters Chain of Lakes watershed. Twenty percent of the surveys were returned. The data were summarized and analyzed by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Because of a relatively low response rate (20%), the results may not statistically represent the opinions of the stakeholder population. The results may however represent stakeholders holding the strongest opinions, thereby identifying issues and concerns of the larger population. Survey results will be shared within this report; however, caution was used in interpreting their results due to the low level of participation. Based upon the results of the Stakeholder Survey, much was learned about the people that use and care for Manitowish Waters Chain of Lakes. Thirty-eight percent of survey respondents are year-round residents, while 29% live on the chain seasonally and 22% visit on weekends throughout the year (Appendix B – Question #2). Seventy-three percent of stakeholders have owned their property for over 15 years, and 44% have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect to these particular topics. Figure 2.0-1 highlights several other questions found within this survey. Relaxing / entertaining was the highest ranked option respondents indicated when asked, “What are the top activities that are important reasons for owning / renting your property on or near the Manitowish Waters Chain of Lakes?” (Question #7). Fishing and motor boating were also highly ranked options.

Several concerns noted throughout the stakeholder survey include AIS introduction, excessive fish harvesting, and watercraft traffic (Question #15). AIS discussion and fish harvesting are discussed within the Aquatic Plant portion and Fisheries Data Integration portions of this report, respectively.

Question #7: What are the top activities that are important reasons for owning / renting your property on or near the Manitowish Waters Chain of Lakes?



Question #15: Please rank your top three concerns regarding the Manitowish Waters Chain of Lakes.

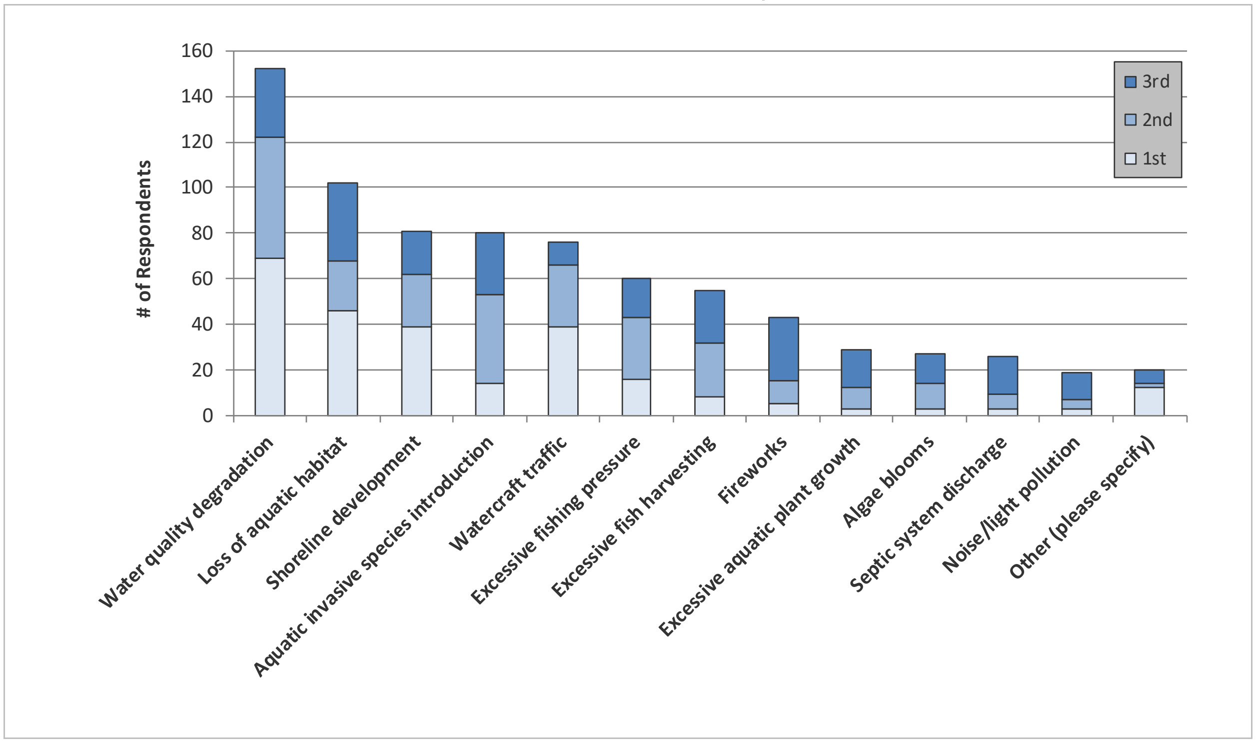


Figure 2.0-1. Select survey responses from the Manitowish Waters Chain of Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

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

Chlorophyll-*a* is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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.

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.

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

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

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

Non-Candidate Lakes

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

Candidate Lakes

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

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

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

Comparisons with Other Datasets

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

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

The Manitowish Waters Chain of Lakes, though all connected, differ in their morphological and hydrologic characteristics and thus are classified differently. For example, Island Lake is quite deep and holds a large drainage basin, or watershed. It is then classified as a deep, lowland drainage lake (category 5 on Figure 3.1-1). Clear Lake is also deep, but has a small drainage area and thus may respond to in-lake watershed variables differently. Clear Lake is a deep seepage lake (category 7 on Figure 3.1-1).

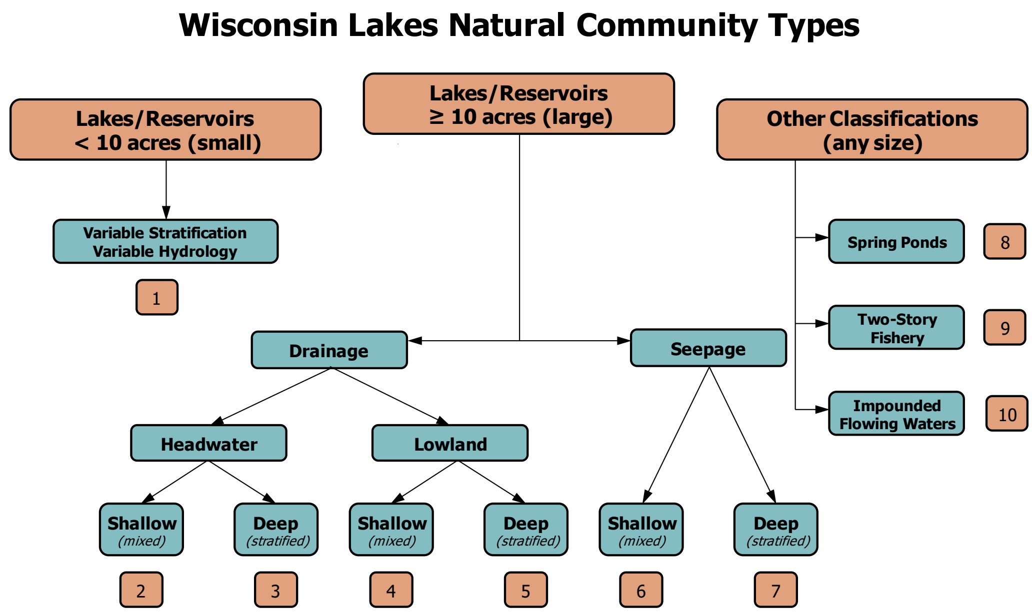


Figure 3.1-1. Wisconsin Lake Natural Community classifications. Adapted from WDNR 2013.

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

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

Manitowish Waters Chain of Lakes Water Quality Analysis

Manitowish Waters Chain of Lakes Nutrient Content and Clarity

The amount of historical water quality data existing on the Manitowish Waters Chain of Lakes varies by lake. Several lakes have volunteers that are actively monitoring their lake through the WDNR's Citizens Lake Monitoring Network (CLMN), collecting nutrient samples or Secchi disk clarity data several times each summer. Many lakes do not have active CLMN volunteers and because of this, there is little historic data to compare against the data that were collected as a part of this project. The importance of consistent, reliable data cannot be stressed enough; just as a person continuously monitors their weight or other health parameters, the water quality of a lake should be monitored in order to understand the system better and make sounder management decisions.

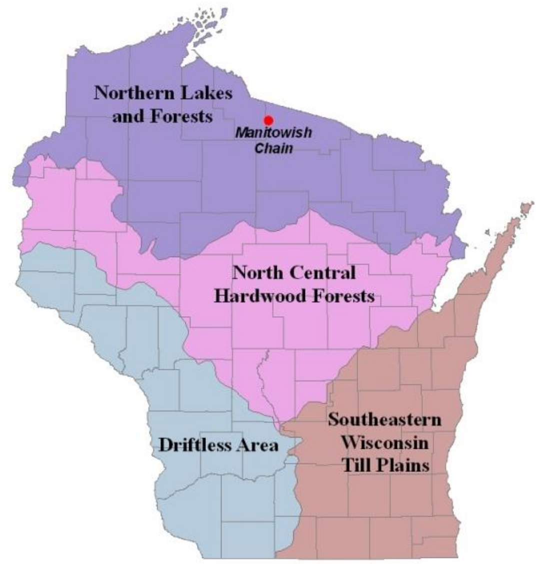


Figure 3.1-2. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Within this project's stakeholder survey, residents were polled on their perceptions of water quality. The plurality of respondents indicated that the water quality in the chain was "Good" (161 of 263 respondents). 112 of 263 respondents indicated they believed the water quality had "Remained the Same" since they first visited the chain, while 113 of 263 respondents indicated they believed the water to be "Somewhat Degraded".

Onterra staff collected water quality samples and monitored Secchi disk clarity on each Manitowish Waters Chain of Lakes lake during the course of this project. Monitoring occurred during the summer and following winter of each project phase (Phase I lakes sampled in 2012/2013, Phase II lakes sampled in 2013/2014, etc.). While each individual lake section provides in-depth discussion of that lake's water quality monitoring, the data presented in this section will serve to compare lakes within the chain and also characterize the water quality of the chain as a whole.

Note that unless otherwise indicated, the data displayed in this section occurs from samples collected during either mid-summer or average summer (June, July and August) periods. Furthermore, the data displayed in this section is derived from sub-surface locations in the deep hole location of each lake. Near surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Lakes in the Chain belong to one of three categories. The most numerous category is deep, lowland drainage lakes where there are eight lakes. There is one deep, headwater lake and four shallow, lowland lakes. The depth of the lake as well the size of the lake compared with its watershed can impact the nutrient levels of a lake. Shallow lakes tend to have higher phosphorus concentrations, while lakes with a small watershed to lake ratio tend to naturally have lower phosphorus levels.

Onterra staff feel that comparisons are best made across lakes of similar classification (deep, lowland drainage lakes in dark blue, shallow, lowland drainage lakes in light blue, etc.). Unless otherwise indicated, parameters represent samples collected from the sub-surface of each lake. Data presented are weighted averages for the years since the early 1980s where data are available. For most of the lakes this will consist of only one year, e.g. Island Lake, while for Little Star and Clear lakes there is data available for multiple years. Most lakes have a longer record for Secchi disc transparency than for other chemical parameters. The exception for the longer Secchi disc records are the small lakes that are more like a wide spot in the river, e.g. Fawn, Sturgeon lakes.

For the entire Manitowish Waters Chain, the summer mean phosphorus concentrations for the lakes ranged from a low of 11 µg/L in Little Star Lake to a high of 23 µg/L in Benson and Stone lakes with the average for the Manitowish Waters Chain being 17 µg/L (Figure 3.1-3). All of the lakes had phosphorus concentrations that were less than or the same as the median value for lakes statewide of the same lake classification. Most of the lakes had phosphorus concentrations that were less than the median value for all lakes in the Northern Lakes and Forest Ecoregion.

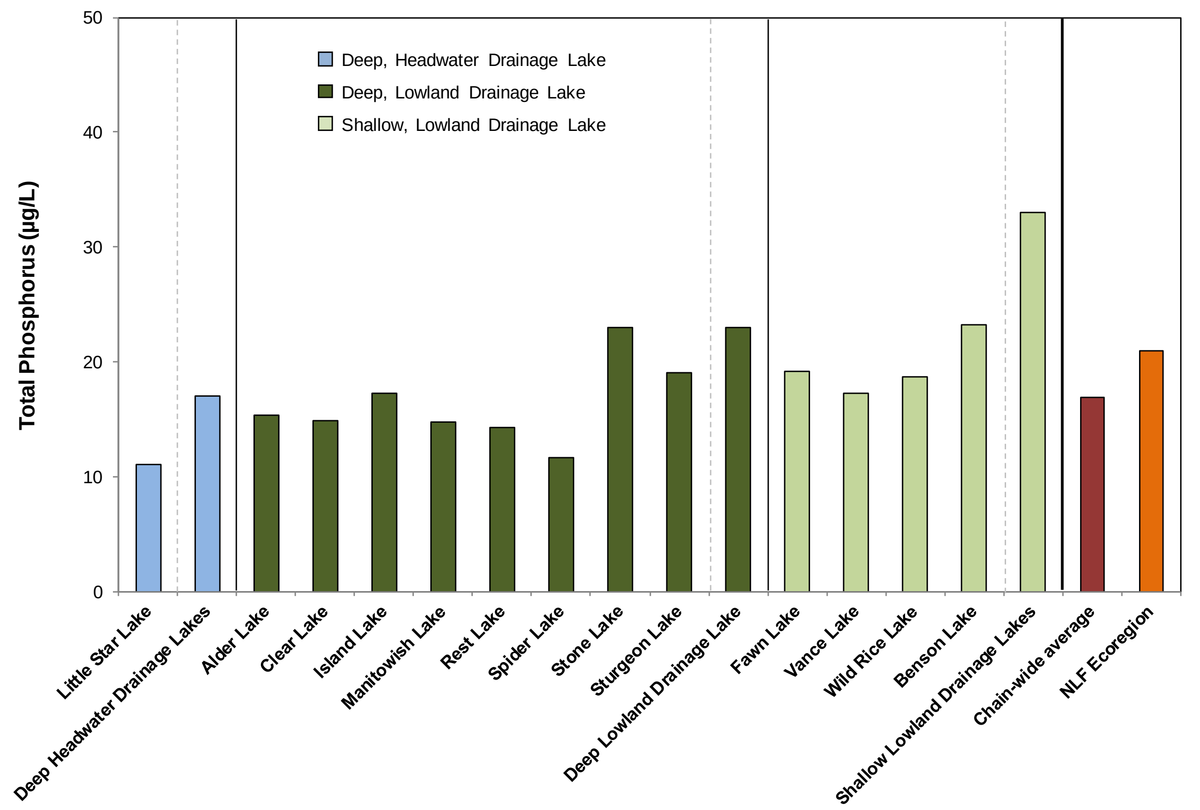


Figure 3.1-3. Manitowish Waters Chain of Lakes weighted means over available time periods and comparable lakes total phosphorus concentrations. Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests Lakes ecoregion median.

Summer average chlorophyll-*a* ranged from 0.6 µg/L in Little Star Lake to 6.4 µg/L in Island Lake (Figure 3.1-4). Chlorophyll-*a* concentrations for all thirteen lakes are considered to be *excellent* for their respective lake type, and no lakes were found to have concentrations approaching 20 µg/L, the concentration which is considered to create *nuisance algal blooms*. All of the lakes had chlorophyll-*a* concentrations that were less than the median value for lakes statewide of the same lake classification. Most of the lakes had phosphorus concentrations that were less than the median value for all lakes in the Northern Lakes and Forest Ecoregion.

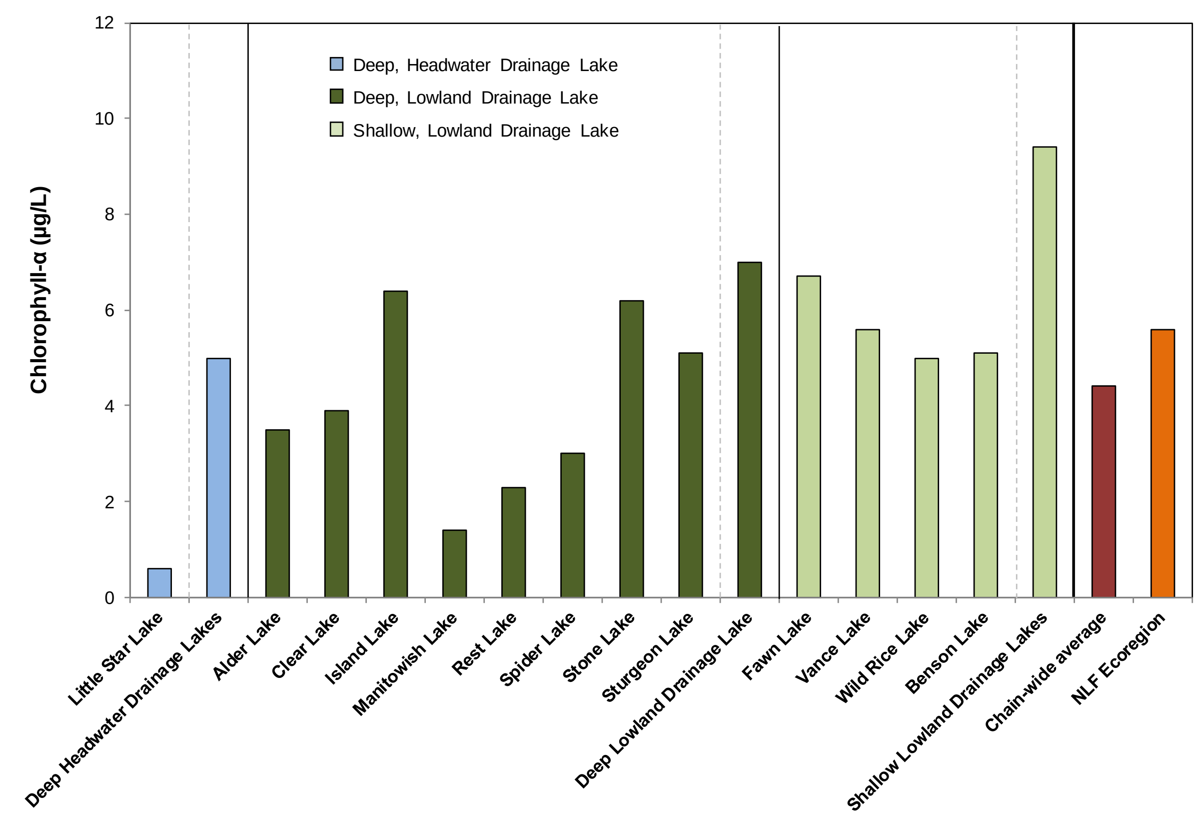


Figure 3.1-4. Manitowish Waters Chain of Lakes summer average chlorophyll-α concentrations and median summer chlorophyll-α concentrations from comparable lakes. NLF = Northern Lakes and Forests Ecoregion Lakes.

Average summer Secchi disk depth ranged from 7.0 feet in Benson Lake to 16.8 feet in Little Star Lake (Figure 3.1-5). These Secchi disk values fall within the *excellent* to *good* categories for their respective lake types. Many of the lakes had Secchi disc depths that were better than the median value for lakes statewide of the same lake classification. Exceptions to this were Alder, Benson, Island, Stone, and Sturgeon lakes. The chain-wide average was better than the median value for all lakes in the Northern Lakes and Forest Ecoregion.

While the amount of algae within the water largely regulates water clarity in Wisconsin's lakes, analysis of the data from the Manitowish Waters Chain of Lakes indicates that chlorophyll-*a* concentrations explain only 48% of the variation in water clarity among these lakes. This is an indication that another factor(s) other than algal levels is influencing water clarity in the Manitowish Waters Chain of Lakes.

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

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

A measure of water clarity, once all of the suspended material (i.e. phytoplankton and sediments) have been removed, is termed *true color*, and indicates the level of dissolved material within the water. Average true color values ranged from 3 SU (standard units), or *clear* in Little Star Lake to 50 SU or *tea-colored* in Wild Rice Lake (Figure 3.1-10). Alder and Stone lakes were *lightly tea-colored* while the rest of the lakes were either *clear* or *slightly colored*.

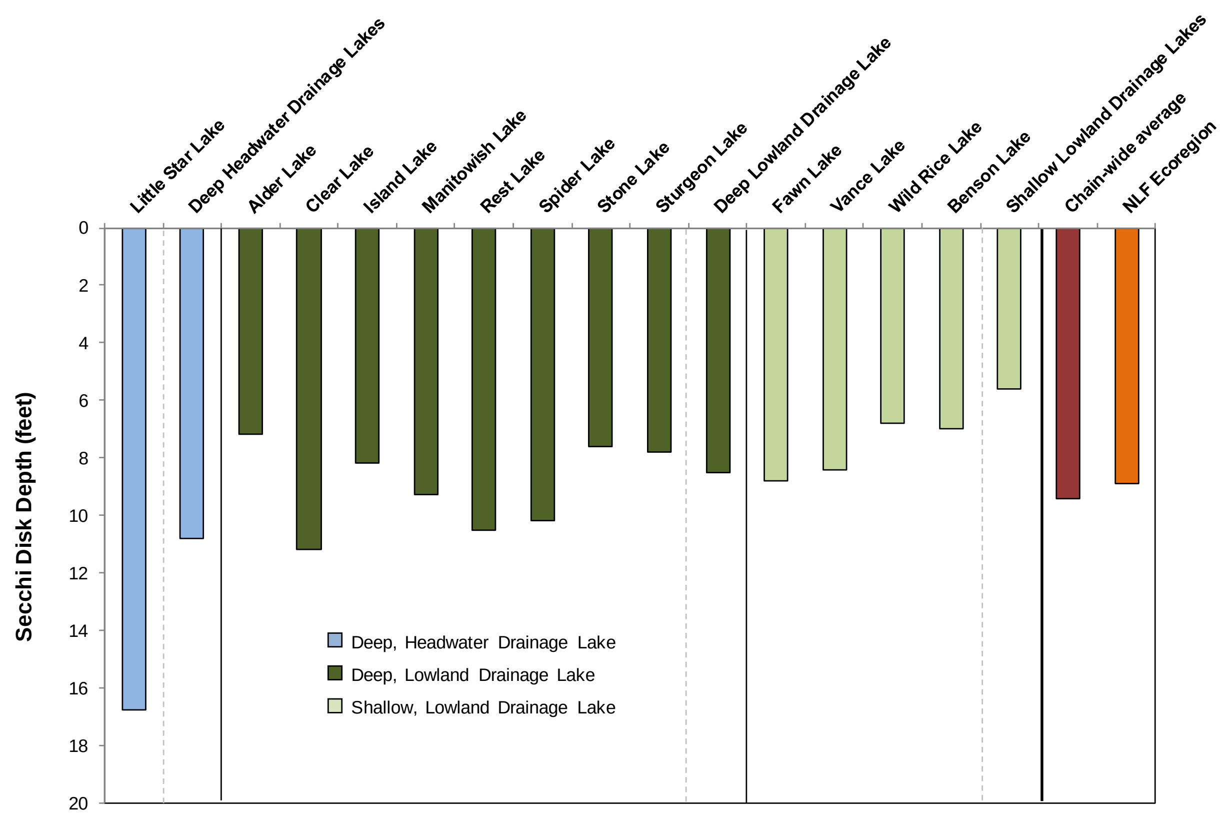


Figure 3.1-5. Manitowish Waters Chain of Lakes summer average Secchi disk transparency and median summer Secchi disk transparency from comparable lakes. NLF = Northern Lakes and Forests Ecoregion Lakes.

Limiting Plant Nutrient of Manitowish Waters Chain of Lakes

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 Manitowish Waters Chain of Lakes indicates that all the lakes studied are phosphorus-limited with the exception of Stone Lake (Figure 3.1-6). The mid-summer nitrogen to phosphorus ratios ranged from 41:1 in Clear Lake to 9:1 in Stone Lake. These ratios indicate that in all but Stone Lake are phosphorus-limited, and that increases in phosphorus inputs would likely result in increased phytoplankton production.

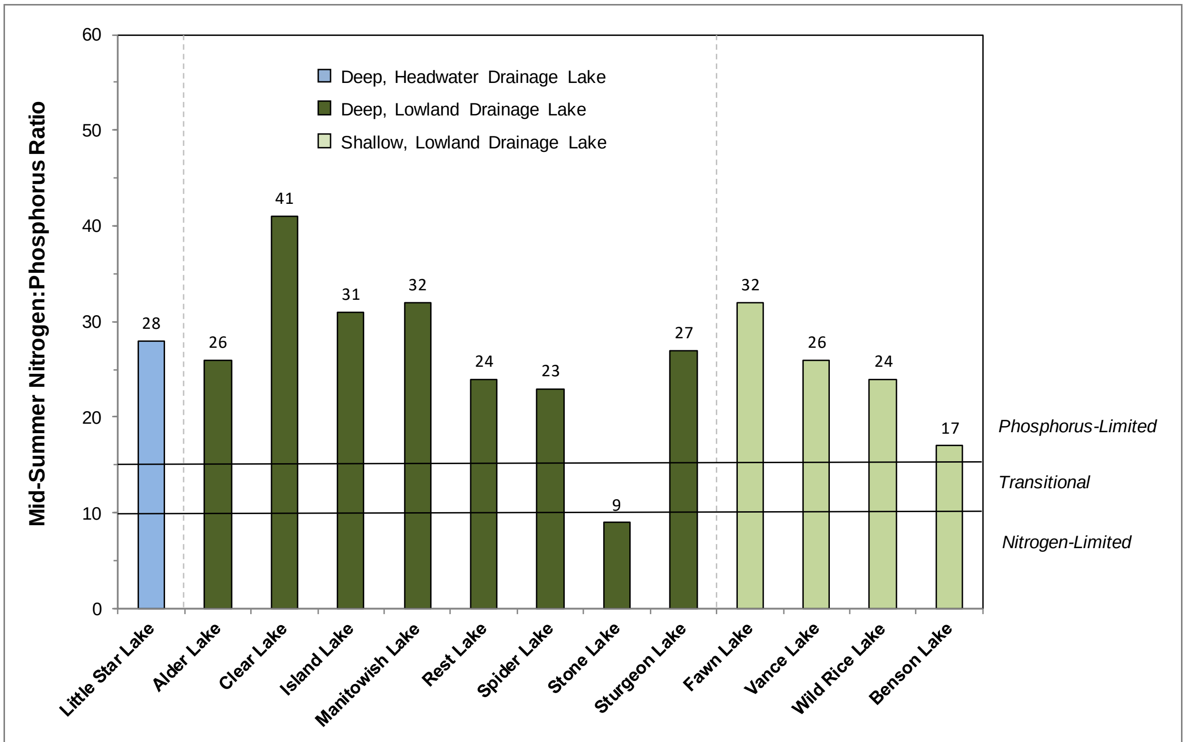


Figure 3.1-6. Manitowish Waters Chain of Lakes mid-summer total nitrogen to total phosphorus ratios. Data represent surface samples collected during mid-summer during each respective project phase.

Manitowish Waters Chain of Lakes Trophic State

Figure 3.1-7 contains the weighted average Trophic State Index (TSI) values for each of the Manitowish Waters Chain of Lakes. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds within the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* range in productivity from oligotrophic for Little Star Lake while the rest of the lakes are mesotrophic (Figure 3.1-8). Most lakes have better TSI values than the median value for comparable lake types and the Chain-wide average is better than the median value for lakes in the Northern Lakes and Forests Ecoregion.

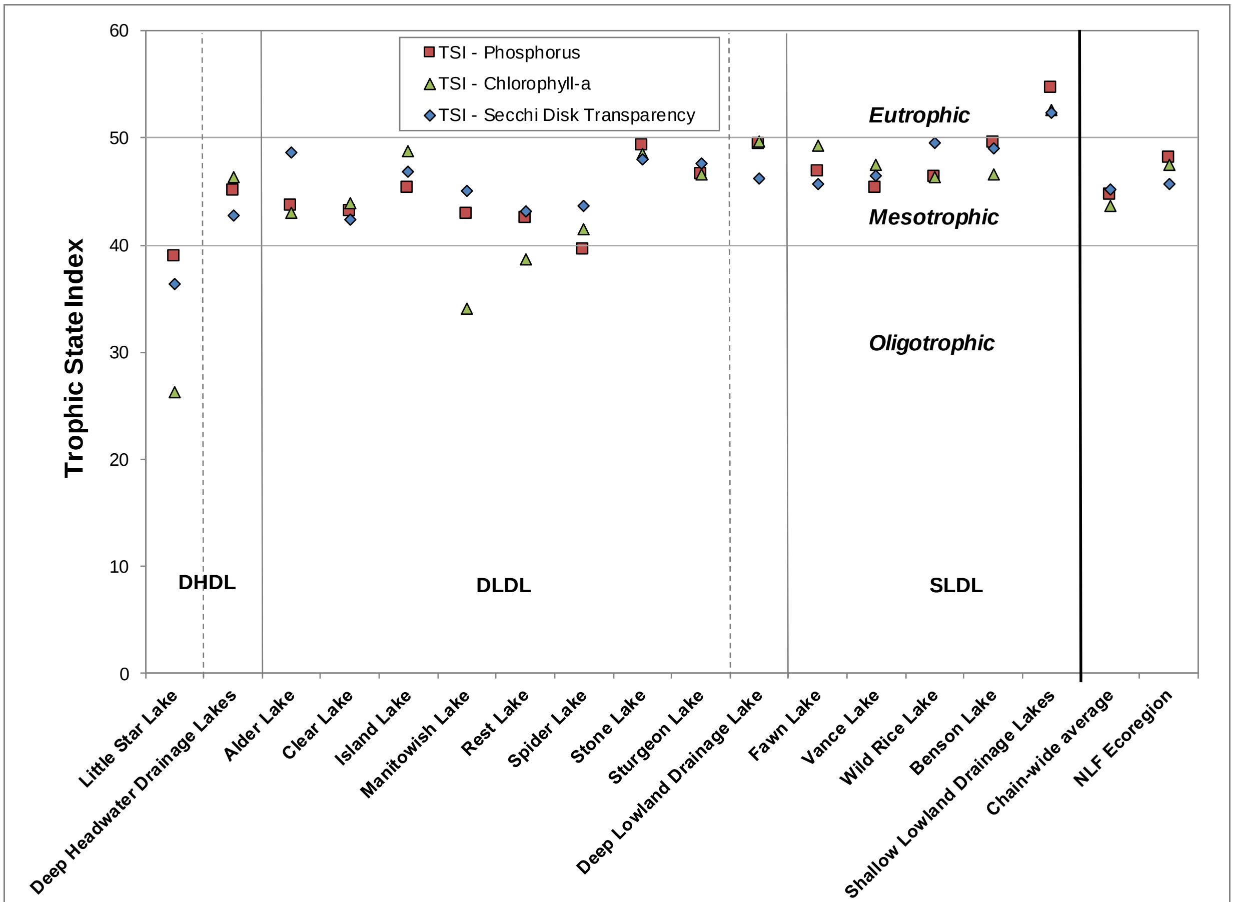


Figure 3.1-7. Manitowish Waters Chain of Lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193. NLF = Northern Lakes and Forests Ecoregion.

Additional Water Quality Data Collected on the Manitowish Waters Chain of 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 Manitowish Waters Chain Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

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. Summer near-surface pH values ranged from 7.2 in Rest Lake to 9.1 in Fawn Lake indicating the pH of all the project lakes are slightly alkaline (Figure 3.1-8). The pH values of the Manitowish Waters Chain Lakes fall within the normal range for Wisconsin's lakes.

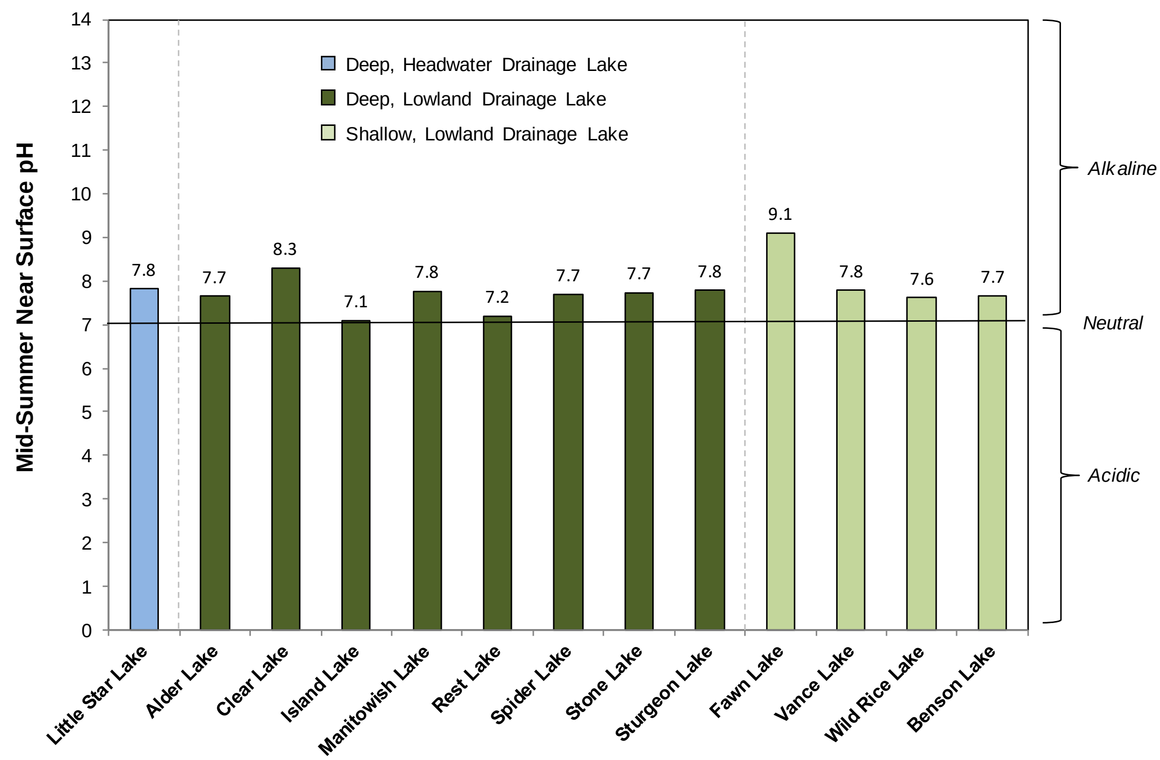


Figure 3.1-8. Manitowish Waters Chain Lakes mid-summer near-surface pH values. Data for each lake collected during the respective project phase.

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. Alkalinity values ranged from 37 mg/L as $CaCO_3$ in Manitowish and Stone lakes to 47 mg/L as $CaCO_3$ in Rest Lake (Figure 3.1-9). Given the alkalinity in these lakes, none are sensitive to inputs from acid rain.

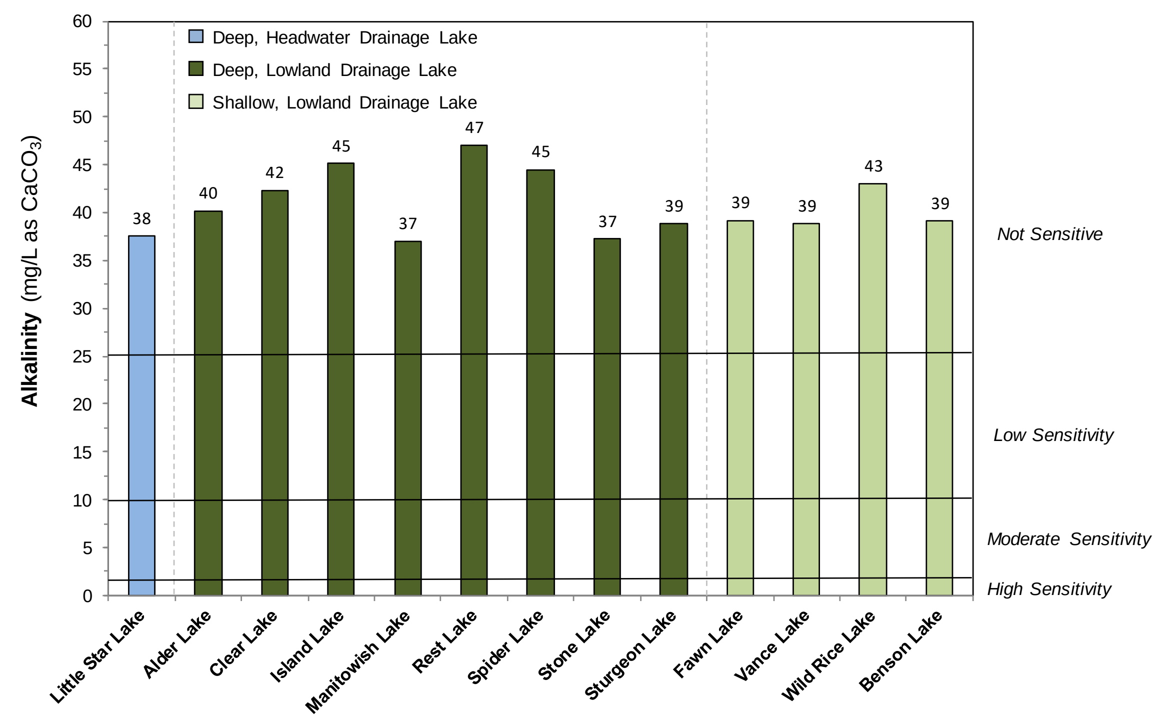


Figure 3.1-9. Manitowish Waters Chain Lakes average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface.

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 ranged from 9.9 mg/L in Fawn Lake to 12.7 mg/L in Rest Lake (Figure 3.1-10). Beson, Sturgeon, and Vance lakes were not sampled for calcium as a part of the Phase V project because the receive their waters primarily from upstream lakes, meaning that their calcium content would be similar to Rest and Stone lakes. Calcium concentrations for all the lakes fall within the *very low* or *low susceptibility* category for zebra mussel establishment. The calcium concentrations in these lakes indicate zebra mussels have a low probability of establishment if they were to be accidentally introduced.

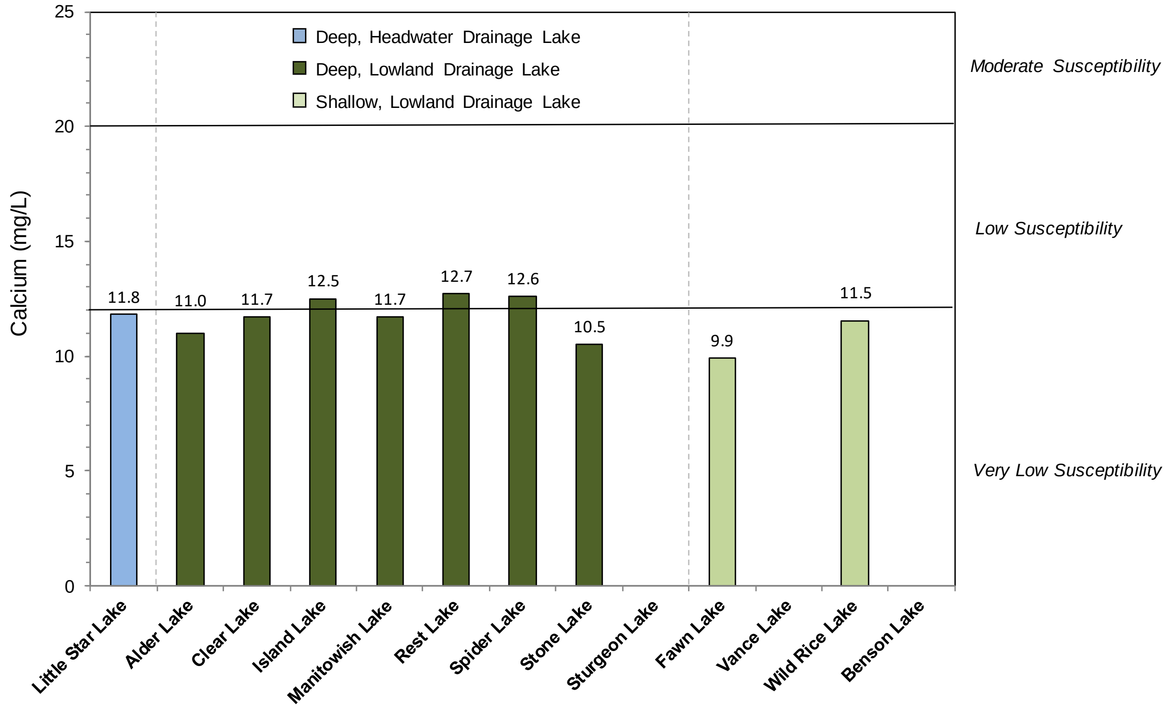


Figure 3.1-10. Manitowish Waters Chain Lakes average growing season calcium concentrations and susceptibility to zebra mussel establishment. Samples collected from the near-surface.

Stakeholder Survey Responses to The Manitowish Waters Chain of Lakes Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figure 3.1-7 and 3.1-8 display responses of Manitowish Waters Chain of Lakes stakeholders to questions regarding the current water quality of the chain and how it has changed since they first visited the lake.

When asked how they could describe the current water quality of the Manitowish Waters Chain of Lakes, the majority (61%) of respondents answered *good*, 25% indicated *excellent*, 12% indicated *fair*, and 2% indicated they were unsure. (Figure 3.1-7). No one answered that they believe the water quality is anything less than fair. When asked how water quality in the Manitowish Waters Chain of Lakes has changed since they first visited the lake, 43% indicated that the water quality has *somewhat degraded*, 43% indicated that the water quality has *remained the same*, 10% indicated they were unsure, and 5% indicated that the water quality has either *severely degraded* or *somewhat improved* (Figure 3.1-8). Due to the natural staining of the water in the Manitowish Waters Chain of Lakes, it can be assumed that stakeholders believe that the dark water may be a sign of water quality degradation. As seen throughout the Water Quality Section, the Manitowish Waters Chain of Lakes is generally classified as a mesotrophic lake. A decrease in perception of water quality can also occur if more aquatic plants are found near or at the surface, for example duckweed or wild celery.

Figure 3.1-7. Stakeholder survey response Question #16. How would you describe the current water quality of the Manitowish Waters Chain of Lakes?

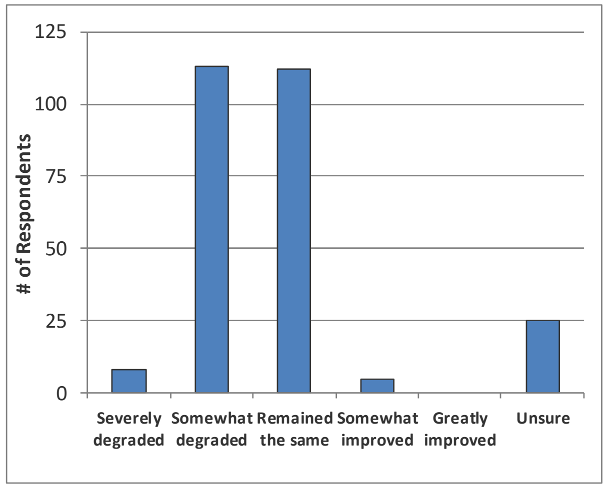


Figure 3.1-8. Stakeholder survey response Question #17. How has the water quality changed in the Manitowish Waters Chain of Lakes since you first visited the chain?

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

A reliable and cost-efficient method of creating a general picture of a watershed's 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 and Kreider 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

As discussed above, the size of the watershed in relation to the size of the lake can have a considerable impact on the lake's water quality. There is high variation in the amount of land draining to each of the Manitowish Waters Chain of Lakes (Figure 3.2-1 and Map 2). The watershed to lake area ratios of the lakes in the Manitowish Waters Chain of Lakes range from 2:1 for Little Star Lake to 5,283:1 for Benson Lake. In total, approximately 147,947 acres of land drains to the Manitowish Waters Chain of Lakes, the majority (49% or 71,999 acres) of which is classified as forest (Figure 3.2-2). Wetlands account for the second largest land cover type in the watershed (28% or 41,362 acres), while open water is the third largest cover type at 24,502 acres (17%). Areas of rural open space (5%), pasture/grass (1.3%), row crops (0.3%), rural residential (0.1%), urban – medium density (0.01%), and urban – high density (0.01%), account for the remaining land cover types within the Manitowish Waters Chain of Lakes' watershed.

Manitowish Waters Chain Lakes Watershed Assessment

The overall watershed of the Manitowish Waters Chain Lakes encompasses parts of the Manitowish and Trout rivers. The Trout River enters Wild Rice Lake which discharges into Alder Lake and then Manitowish Lake before the waters enter the Manitowish River system. Little Star Lake is the only headwater lake in the Chain and it discharges into Manitowish Lake. Island and Spider lakes are upstream of where the discharge from Manitowish Lake enters. The rest of the lakes are downstream of where the Manitowish and Trout rivers join.

The watershed size of the lakes exhibits a wide range from Little Star Lake at 859 acres to Benson Lake at 147,950 acres (Figure 3.2-1). A more detailed description of the watersheds of individual lakes will be discussed in the section that discusses the lake ecology of each individual lake. As described in the Water Quality section, it is generally thought that lakes with a watershed to lake area ratio of less than 10:1 are in better shape and lakes with a much higher ratio tend to have poorer water quality. The lake with the largest ratio is Vance Lake at 4,946:1 but Benson and Sturgeon lakes have ratios over 4,000:1 (Table 3.1-1). Even though these three lakes have extraordinarily large ratios, they are more like wide areas in the Manitowish River than true lakes.

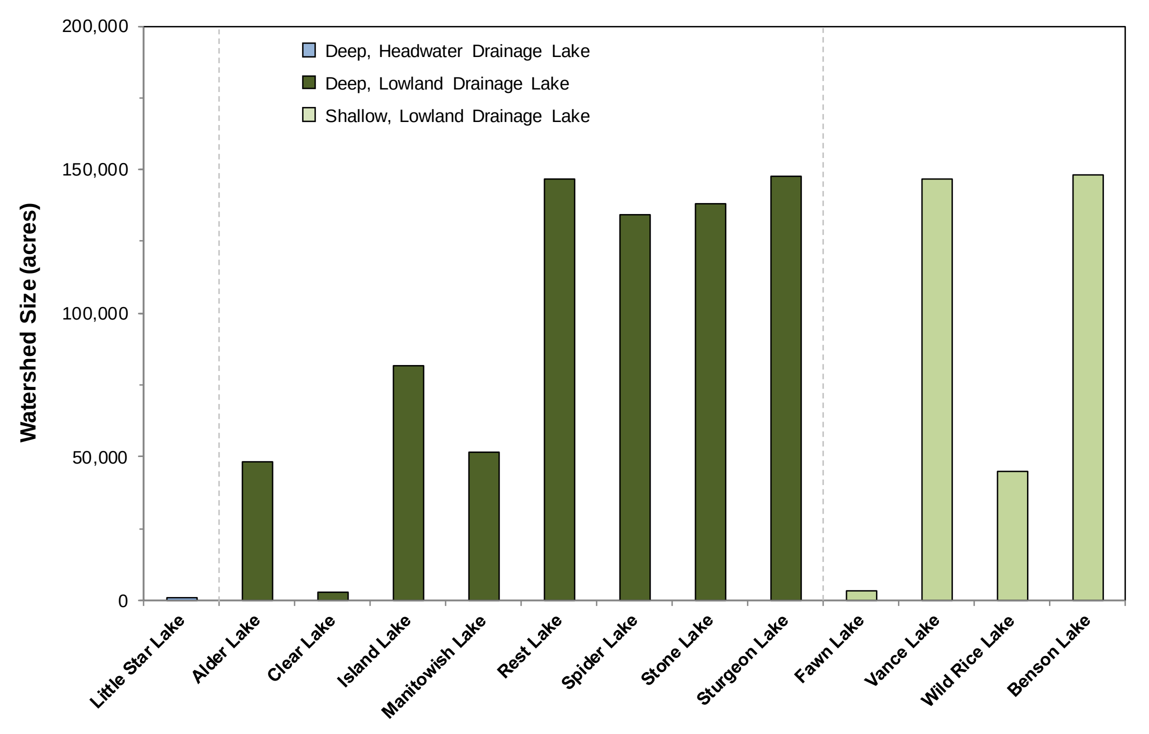


Figure 3.3-1. Manitowish Waters Chain Lakes watershed size, in acres.

When considering the entire watershed of the Manitowish Waters Chain Lakes, the dominant landuses are forest (47%) followed by wetlands (41%), and pasture grass (9%) (Figure 3.3-2). Residential, agriculture, and urban make up a small part of the landuse in the watershed.

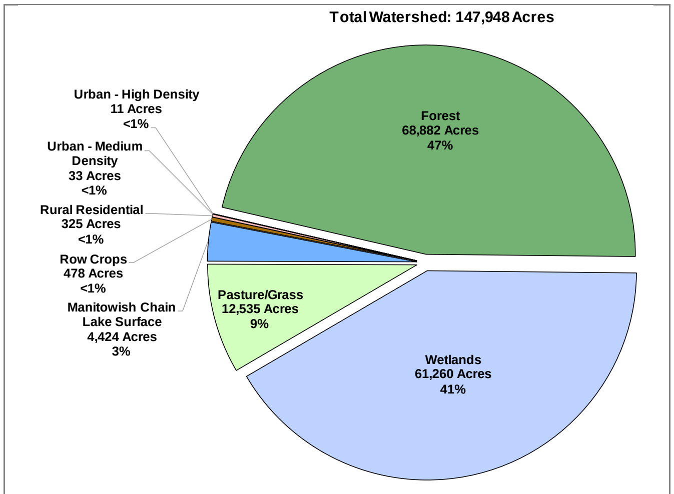


Figure 3.3-2. Manitowish Waters Chain Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Watershed modeling indicated that the estimated annual phosphorus loading delivered to these lakes varies widely, ranging from 146 pounds/year in the headwater lake, Little Star Lake to 9,220 pounds/year in the main channel lake, Rest Lake (Figure 3.3-3). Clear and Fawn lakes also have relatively low phosphorus loading rates. However, as discussed, besides the phosphorus loading, the lake size and volume help determine what the phosphorus concentration will be in the lake, as well as the lake's flushing rate. Using the estimated annual phosphorus loads and the estimated volume of each lake, the annual phosphorus load per acre-foot of the lake was calculated (Figure 3.3-4). Benson, Sturgeon, and Vance lakes have exceedingly high loading rates at over 30 pounds/acre-foot/year but this is because they are more like wide areas in the Manitowish River than true lakes. Of the traditional lakes, Stone Lake has the highest phosphorus loading rate at 3.6 pounds/acre-foot/year while Little Star Lake is the lowest at 0.02 pounds/acre-foot/year.

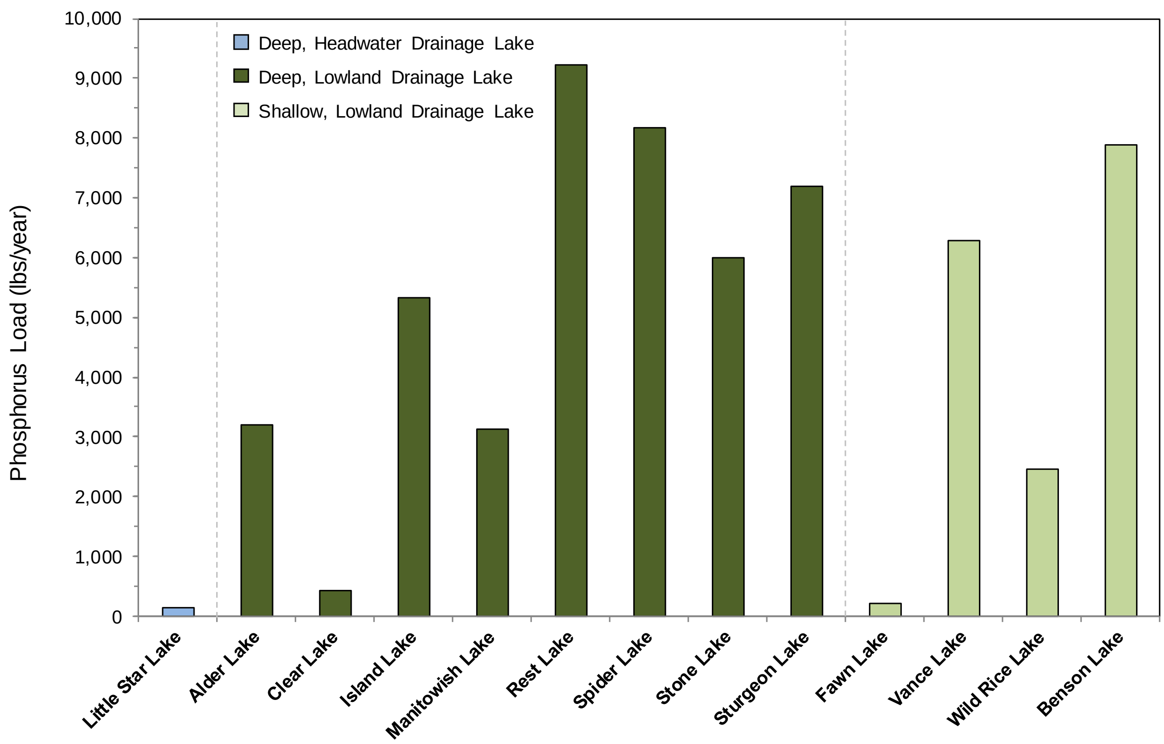


Figure 3.3-3. Manitowish Waters Chain Lakes annual phosphorus load in pounds.

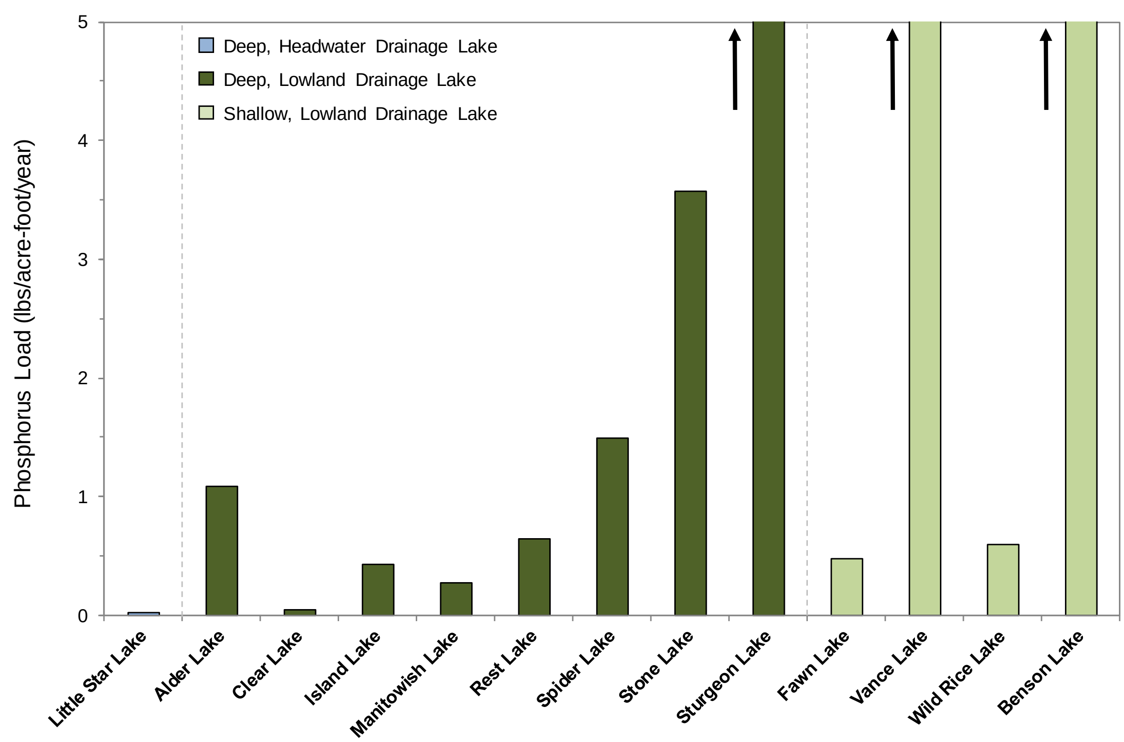


Figure 3.3-4. Manitowish Waters Chain Lakes annual phosphorus load in pounds/acre-feet/year. The loading rate for Benson, Sturgeon, and Vance lakes is exceptionally high, over 30 pounds/acre-foot/year, because of their small size.

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 3.3-5 displays the measured growing season (April-October) near-surface total phosphorus concentrations compared to WiLMS predicted concentrations from all the lakes in the chain. For most of the lakes the predicted phosphorus concentration is greater than the measured value. Only in Rest and Spider lakes was the predicted less than the measured phosphorus value. The differences are likely a reflection of the error in the model. Overall the model seems to work fairly well for these lakes. It is important to note that the model indicates that none of the lakes experience significant internal loading; however, the internal loading is not great enough to warrant management actions as it is a natural occurrence.

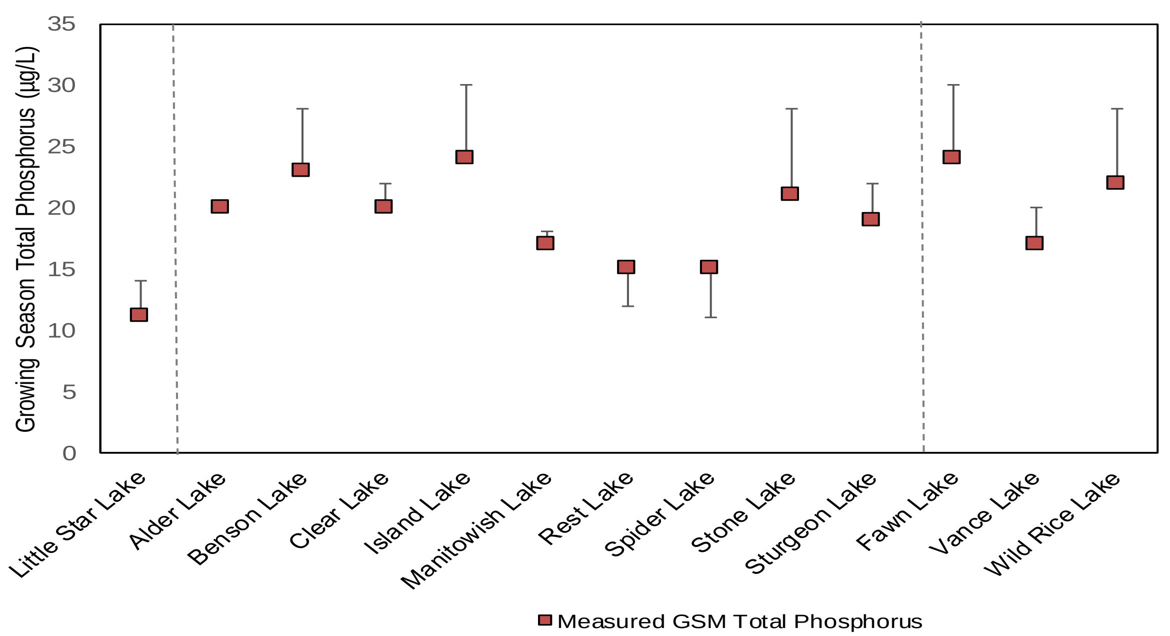


Figure 3.3-5. Manitowish Waters Chain Lakes measured versus WiLMS-predicted growing season total phosphorus concentrations. Error bar represents WiLMS-predicted concentration.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

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

Shoreland Zone Regulations

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

<u>Wisconsin-NR 115: Wisconsin's Shoreland Protection Program</u>

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, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

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

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

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

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

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.

Wisconsin Act 55

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 finished its session in November of 2015 and did not take any action on repealing Act 55 despite these objections. At the time of this writing Act 55 is still a state law.

Shoreland Research

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

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

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

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody debris 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 impacts these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

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

Cost

The cost of native aquatic and shoreland plant restorations is highly variable and depends on the size of the restoration area, depth of buffer zone required to be restored, 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. Some 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. Protective measures may be used to guard newly planted area from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting and using mulch to help retain moisture. Most restoration work can be completed by the landowner themselves. To decrease costs further, bare-root form of trees and shrubs should be purchased in early spring. If additional assistance is needed, the 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 about $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 site used for the estimate indicated above has the following characteristics:

- Spring planting timeframe.
- 100' of shoreline.
- An upland buffer zone depth of 35'.
- An access and viewing corridor 30' x 35' free of planting (recreation area).

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

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

Manitowish Waters Chain of Lakes Shoreland Zone Condition

Shoreland Development

The lakes within the Manitowish Waters Chain of Lakes were surveyed as a part of this project to determine the extent of their degree of development. Lakes were visited during each appropriate phase, generally during the late summer to conduct this survey.

A lake's shoreland zone can be classified based upon the amount of human disturbance (vegetation removal, construction of rip-rap or seawalls, etc.). In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.3-1 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state. On each of Manitowish Waters Chain of Lakes, the development stage of the entire shoreline was surveyed during field studies using a GPS unit to map the shoreline. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreline on a property-by-property basis. During the survey, Onterra staff examined the shoreline for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.3-1.

The Manitowish Waters Chain of Lakes has stretches of shoreland that fit all of the five shoreland assessment categories. Some of the lakes surveyed had more areas of natural shoreline than others. In all, the Phase I-V Manitowish Waters Chain of Lakes contain approximately 44.2 miles of natural/undeveloped and developed-natural shoreline – 58% of the total shoreline (Figure 3.3-2). These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. Approximately 14.2 miles (19%) of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each Phase I-V lake's shoreland condition, while each individual lake section discusses the shoreline condition further. Maps of each lake and the location of these categorized shorelands are included within each individual lake section as well.

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.

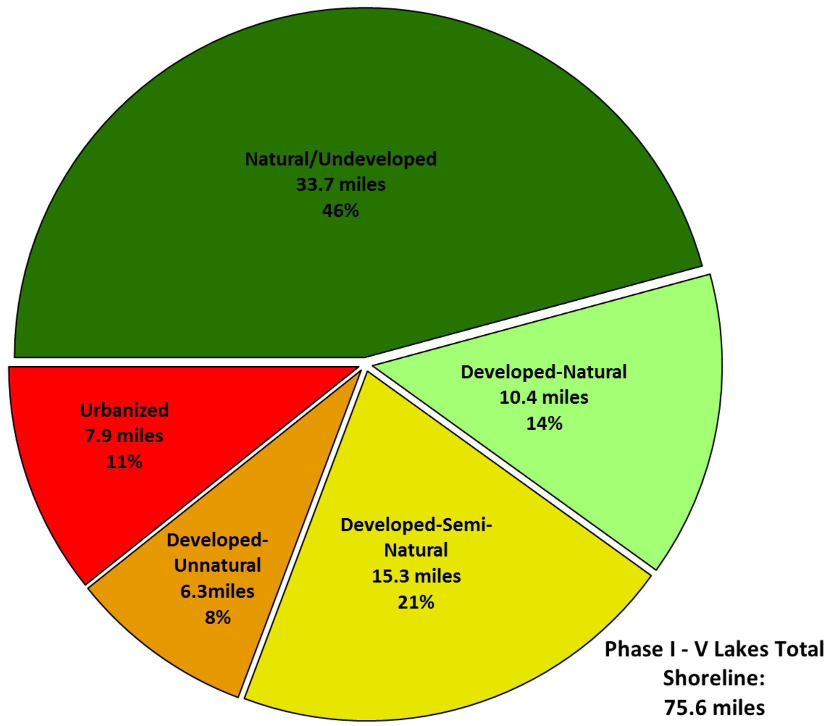


Figure 3.3-2. Phase I-V Manitowish Waters Chain of Lakes total shoreland category classification. Based upon field surveys conducted in late summer. Locations of these categorized shorelands can be found on maps within each individual lake section.

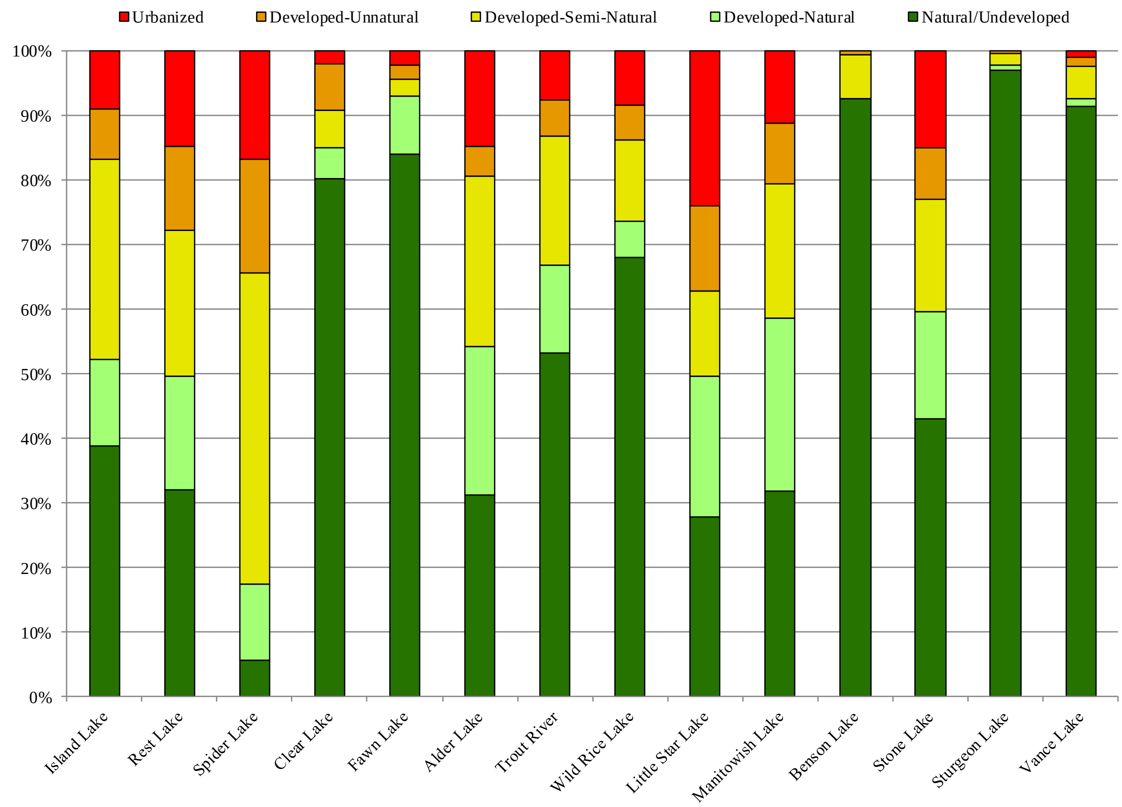


Figure 3.3-3. Phase I-V Manitowish Waters Chain of Lakes shoreline condition breakdown. Based upon late summer field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

While producing a completely natural shoreline is ideal for a lake ecosystem, it is not always practical from a human's perspective. However, riparian property owners can take small steps in ensuring their property's impact upon the lake is minimal. Choosing an appropriate landscape position for lawns is one option to consider. Placing lawns on flat, unsloped areas or in areas that do not terminate at the lake's edge is one way to reduce the amount of runoff a lake receives from a developed site.

One factor that influences the diversity and species richness of the aquatic plant community of a lake is the "development factor" of the shoreline. This is not the degree of human development or disturbance, but rather it is a value that attempts to describe the nature of the habitat a particular shoreline may hold. This value is referred to as the shoreline complexity. It specifically analyzes the characteristics of the shoreline and describes to what degree the lake shape deviates from a perfect circle. It is calculated as the ratio of lake perimeter to the circumference of a circle of area equal to that of the lake. A shoreline complexity value of 1.0 would indicate that the lake is a perfect circle. The further away the value gets from 1.0, the more the lake deviates from a perfect circle. As shoreline complexity increases, species richness increases, mainly because there are more habitat types, bays and back water areas sheltered from wind. The shoreline complexity value for each lake within the Manitowish Waters Chain of Lakes is reported within its respective individual lake section.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey on each of the Manitowish Waters Chain of Lakes. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed 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.

To date, Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012. Figure 3.3-4 displays the number of coarse woody habitat pieces per shoreline mile from the Manitowish Waters Chain of Lakes and how they compare with data from the 98 lakes surveyed. The number of coarse woody habitat pieces per mile ranged from 5 in Spider Lake to 56 in Stone Lake. Clear, Fawn, Vance, and Stone lakes have coarse woody habitat per shoreline mile values that fall at or above the 75th percentile for these 98 lakes. The number of coarse woody habitat pieces per shoreline mile in Benson, Sturgeon, Manitowish, and Little Star lakes fell near the median value. The number of coarse woody habitat pieces per shoreline mile in Wild Rice, Alder, Rest, Island, and Spider lakes fell below the median value.

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.

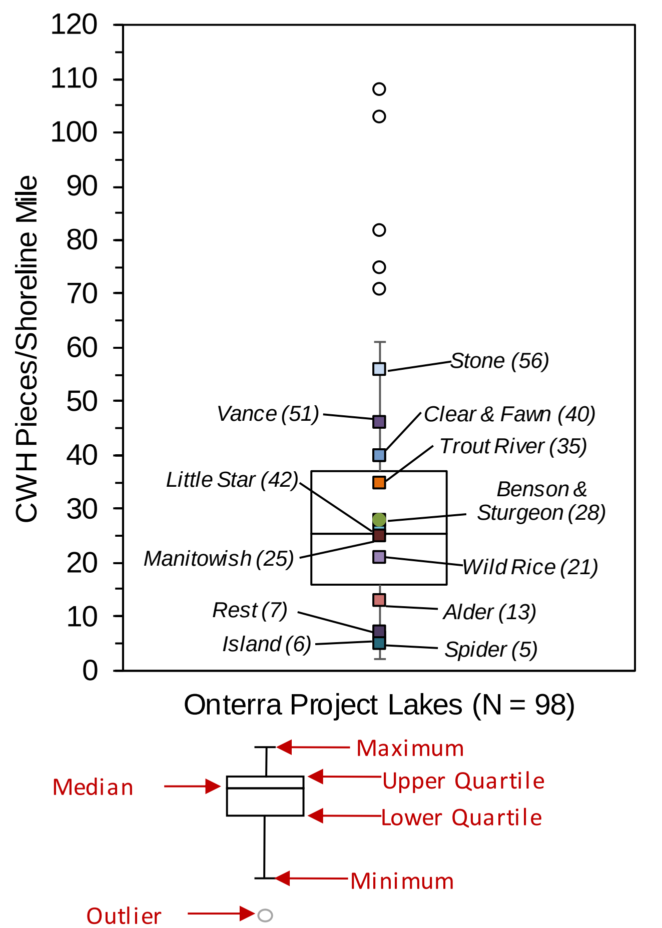


Figure 3.3-4. Phase I-V Manitowish Waters Chain of Lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. State-wide comparative data available from 98 lakes surveyed by Onterra since 2012. Maps displaying the locations of these coarse woody habitat pieces can be found in the individual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

3.4 Aquatic Plants

Introduction

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

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

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

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

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

Aquatic Plant Management and Protection

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

Important Note:
Even though most of these techniques are not applicable to the Manitowish Waters Chain of Lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake**.** The techniques applicable to Manitowish Waters Chain of Lakes are discussed in Summary and Conclusions section and the Implementation

Permits

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

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

Manual Removal

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

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

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

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

Advantages	*Disadvantages*
• Inexpensive if outlet structure exists. • May control populations of certain species, like Eurasian 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.

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

Cost

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

Advantages	*Disadvantages*
• Immediate results. • Plant biomass and associated nutrients are removed from the lake. • Select areas can be treated, leaving sensitive areas intact.	• Initial costs and maintenance are high if the lake organization intends to own and operate the equipment. • Multiple treatments are likely required.

• 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.	• Many small fish, amphibians and invertebrates may be harvested along with plants. • There is little or no reduction in plant density with harvesting. • Invasive and exotic species may spread because of plant fragmentation associated with harvester operation. • Bottom sediments may be re-suspended leading to increased turbidity and water column nutrient levels.

Herbicide Treatment

Photograph 3.4-4. Granular herbicide application.

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

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

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

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

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

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

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

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

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

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

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

Cost

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

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

Aquatic plants are an important element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, such as variable water levels or negative, such as increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways. For example, there may be a loss of one or more species. Certain life forms, such as emergents or floating-leaf communities, may disappear from specific areas of the lake. A shift in plant dominance between species may also occur. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide very useful information for management decisions.

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Manitowish Waters Chain of Lakes; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

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

Frequency of Occurrence

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

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

Species Diversity and Richness

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

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

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

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

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to Manitowish Waters Chain of Lakes. Comparisons will be displayed using boxplots that showing median values and upper/lower quartiles of lakes in the same ecoregion and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

Floristic Quality Assessment

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

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

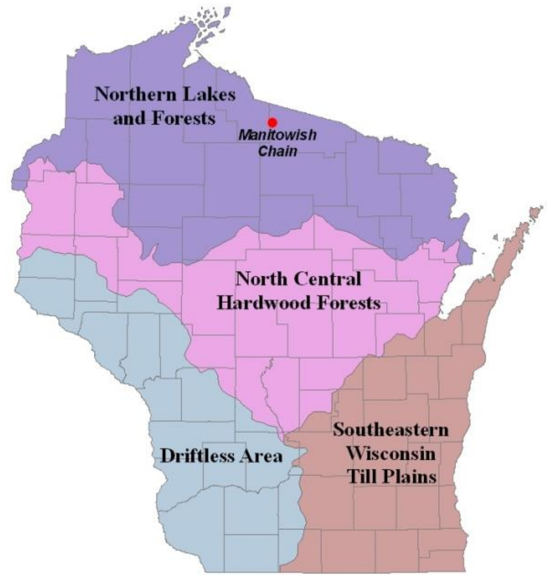


Figure 3.4-1. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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

Community Mapping

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

Exotic Plants

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

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

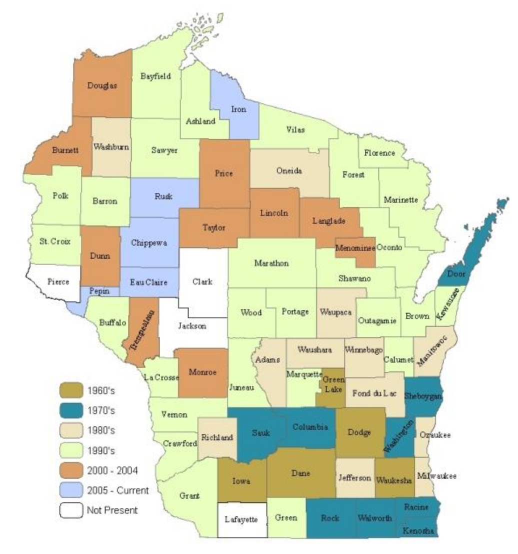


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

Aquatic Plant Survey Results

Numerous aquatic plant surveys were completed as part of this project. In early summer (typically mid-June) of each respective year, meander-based early-season aquatic invasive species surveys were completed on the Manitowish Waters Chain Lakes. While these surveys are aimed at locating potential occurrences of any aquatic invasive species, their primary focus is to locate occurrences of the invasive plant curly-leaf pondweed, which is at or near its peak growth at this time of year. Near the end of this section, matters pertaining to curly-leaf pondweed are discussed in detail.

Whole-lake point-intercept surveys were conducted on the project lakes during mid to late summer (July/August) of each study year. The whole-lake point-intercept survey on Island Lake was conducted by members of the WDNR in 2011 (aquatic plant point-intercept data may be viewed in Appendix E). The community mapping surveys, aimed at delineating areas of floating-leaf and emergent aquatic vegetation, were completed by Onterra during this same time.

A total of 109 different aquatic plant species were identified from the Manitowish Waters Chain of Lakes (Figure 3.4-3 - 3.4-5). Of the 46 submersed aquatic plant species found, seven species were common to all of the Manitowish Waters Chain Lakes.

Two native aquatic plant species, Vasey's pondweed (*Potamogeton vaseyi*) and yellow pond lily (*Nuphar microphylla*) are currently listed as species of special concern by the Wisconsin Natural Heritage Inventory due to uncertainty regarding their populations and rarity within the Wisconsin (WDNR 2011; Photo 3.4-5). Vasey's pondweed has been located in six of the ten lakes studied while yellow pond-lily was located in Rice Creek, an inlet to Island Lake. Yellow pond-lily is a close relative to the larger and more common spatterdock (*N. variegata*). These two species often hybridize, forming intermediate pond-lily (*N.* x *rubrodisca*) which was also observed growing in some of the chain's lakes.

Photograph 3.4-5. Manitowish Waters Chain of Lakes native aquatic plant species listed as special concern. Left: Yellow pond-lily (*Nuphar microphylla*). Middle: Intermediate pond-lily (*N. x rubrodisca*). Right: Vasey's pondweed (*Potamogeton vaseyi*).

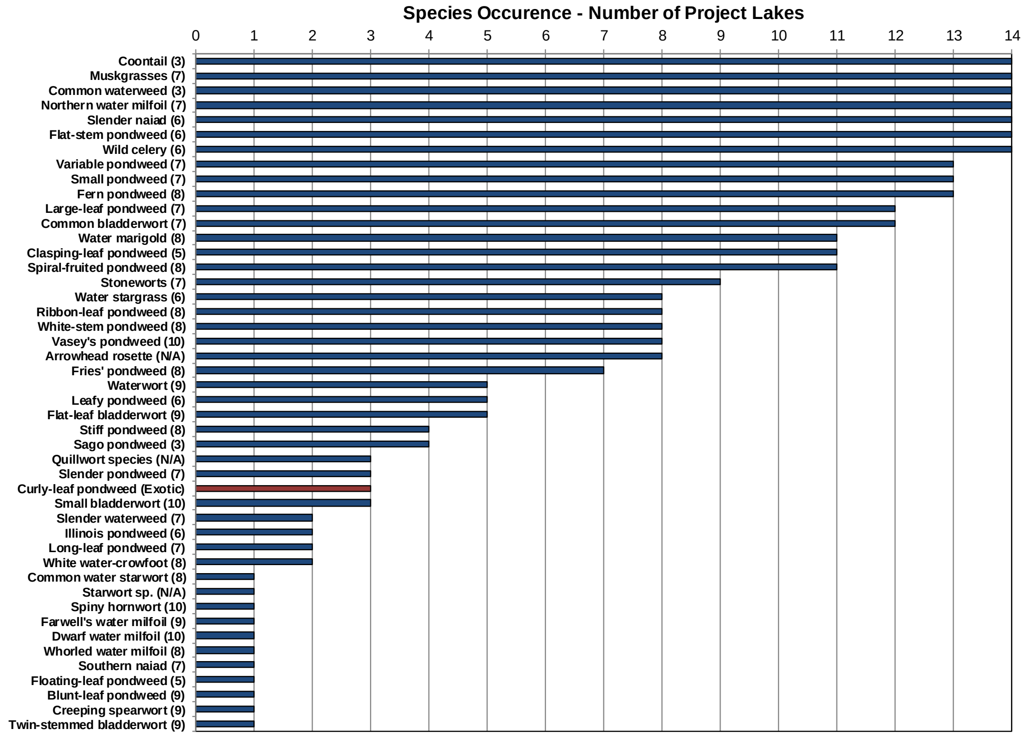


Figure 3.4-3 Manitowish Waters Chain of Lakes submergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.
* *State species of special concern*

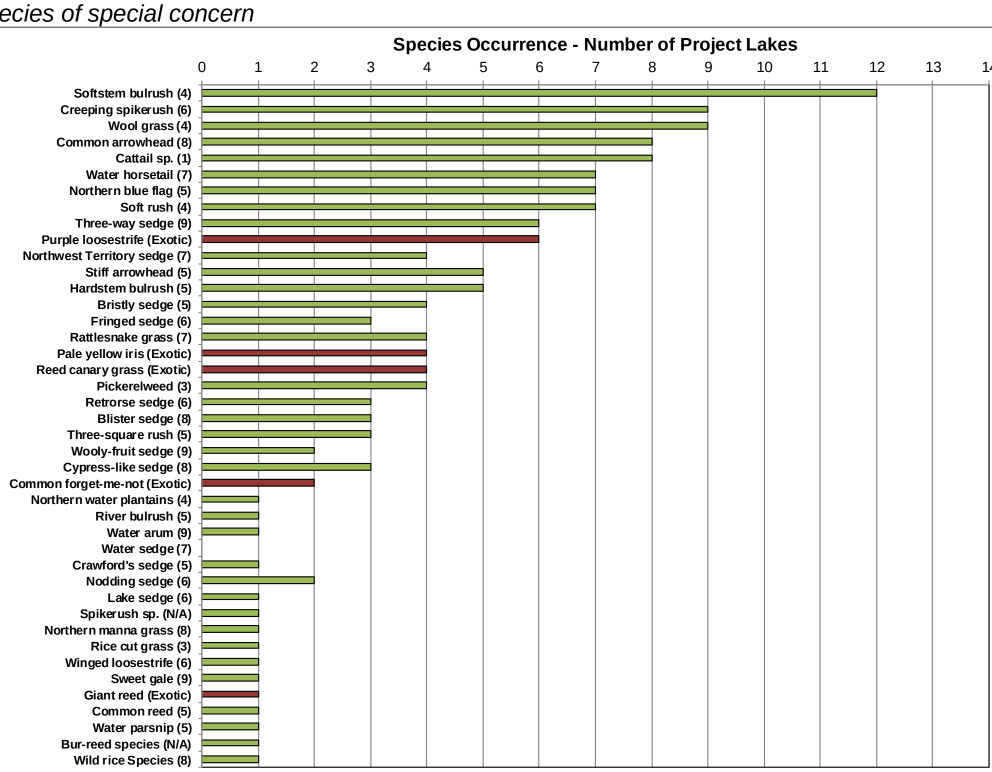


Figure 3.4-4 Manitowish Waters Chain of Lakes emergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.

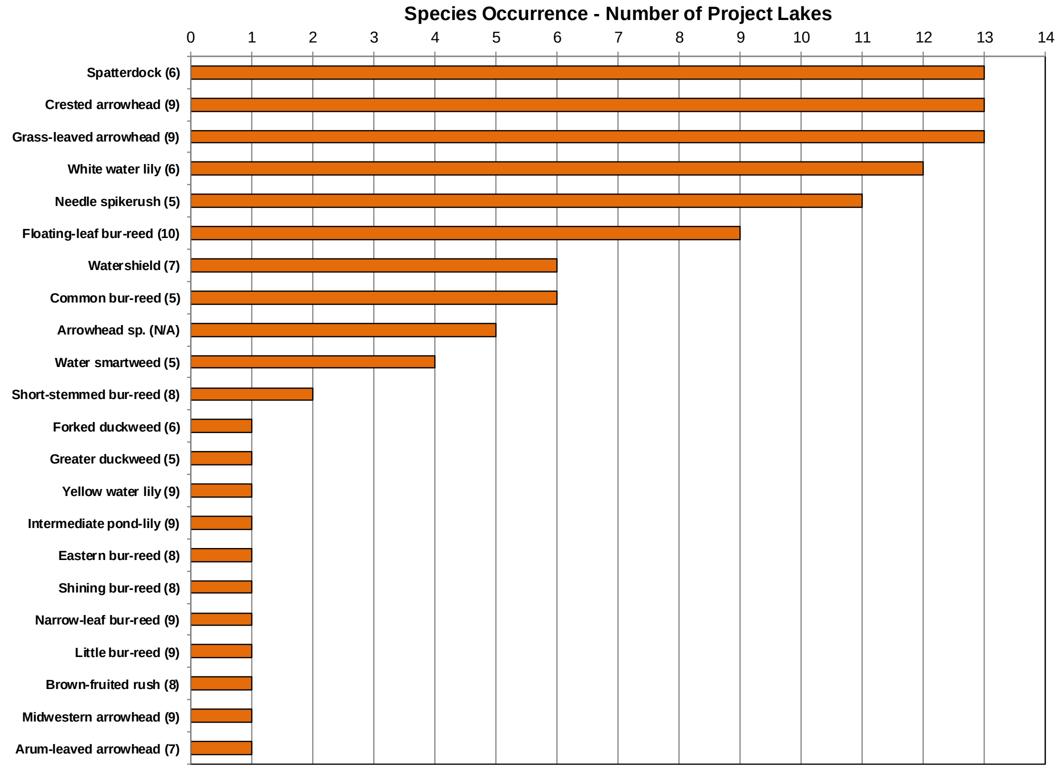


Figure 3.4-5. Manitowish Waters Chain of Lakes floating-leaf, free-floating, floating-leaf/emergent and submergent/emergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.

Of the 109 aquatic plant species located in the Manitowish Waters Chain of Lakes, six are considered to be non-native, invasive species; one submersed species, the aforementioned curly-leaf pondweed, and five emergent plants which include purple loosestrife, common forget-me-not, pale yellow iris, giant reed, and reed canary grass. Again, because of their importance, these invasive species will be discussed in a following section as well as the individual lake sections.

In the Manitowish Waters Chain of Lakes, the number of native aquatic plant species (species richness) per lake ranged from 23 in Papoose Creek to 53 in Manitowish Lake, with an average of 37 native species per lake (Figure 3.4-6). When comparing a lake's aquatic plant community to ecoregional and state medians, only those species that are sampled directly on the rake during the whole-lake point-intercept survey are used in the analysis. For example, while a total of 53 native aquatic plant species were located in Manitowish Lake in 2016, 29 were sampled on the rake during the whole-lake point-intercept survey, while 24 species were found "incidentally". The species directly sampled and their conservatism values were used to calculate the Floristic Quality Index (FQI) for each lake's aquatic plant community (equation shown below).

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

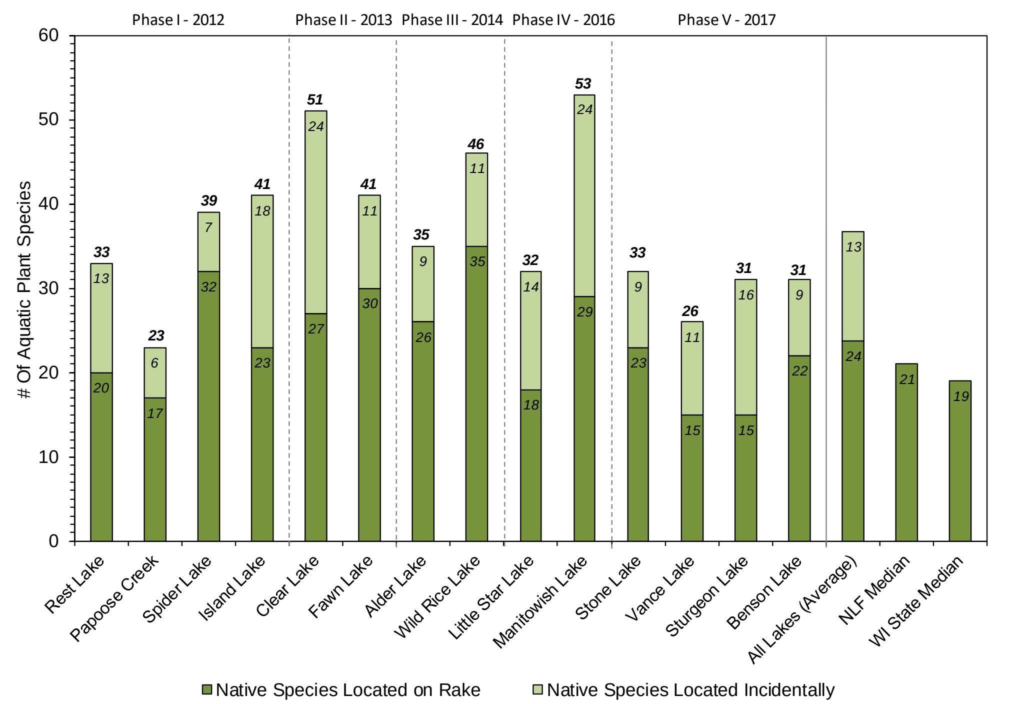


Figure 3.4-6. Manitowish Waters Chain of Lakes native aquatic plant species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

Figure 3.4-7 compares the average conservatism values of the native aquatic plant species located in each lake of the Manitowish Waters Chain of Lakes. The average conservatism values for each of the Manitowish Waters Chain Lakes lies near the Northern Lakes and Forests Lakes (NLFL) Ecoregional median with values ranging between 6.5 and 7.6. As discussed earlier, aquatic plant communities with a higher average conservatism value are higher quality communities. Further, a higher value is an indication of lesser environmental disturbance.

The Floristic Quality Index values were created for each lake using the lakes' average conservatism and native species richness values. Figure 3.4-7 illustrates that Floristic Quality Index values on the Manitowish Waters Chain of Lakes range from 26.7 to 44.2. The Floristic Quality Index values for all waterbodies exceed both the median value of lakes within the NLFL Ecoregion as well as lakes throughout Wisconsin, indicating the aquatic plant communities in terms of their richness and species composition are of higher quality than the majority of lakes within the region and the state.

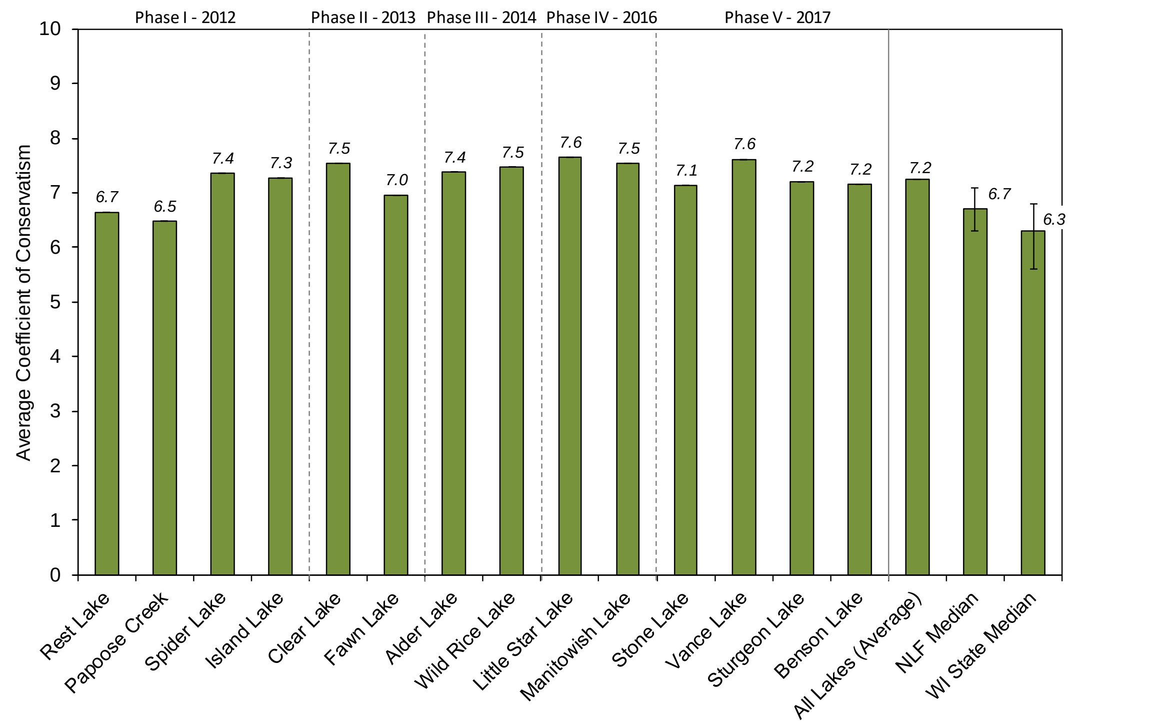


Figure 3.4-7. Manitowish Waters Chain of Lakes native species average conservatism values. Created using native aquatic plant species encountered on the rake during summer point-intercept surveys.

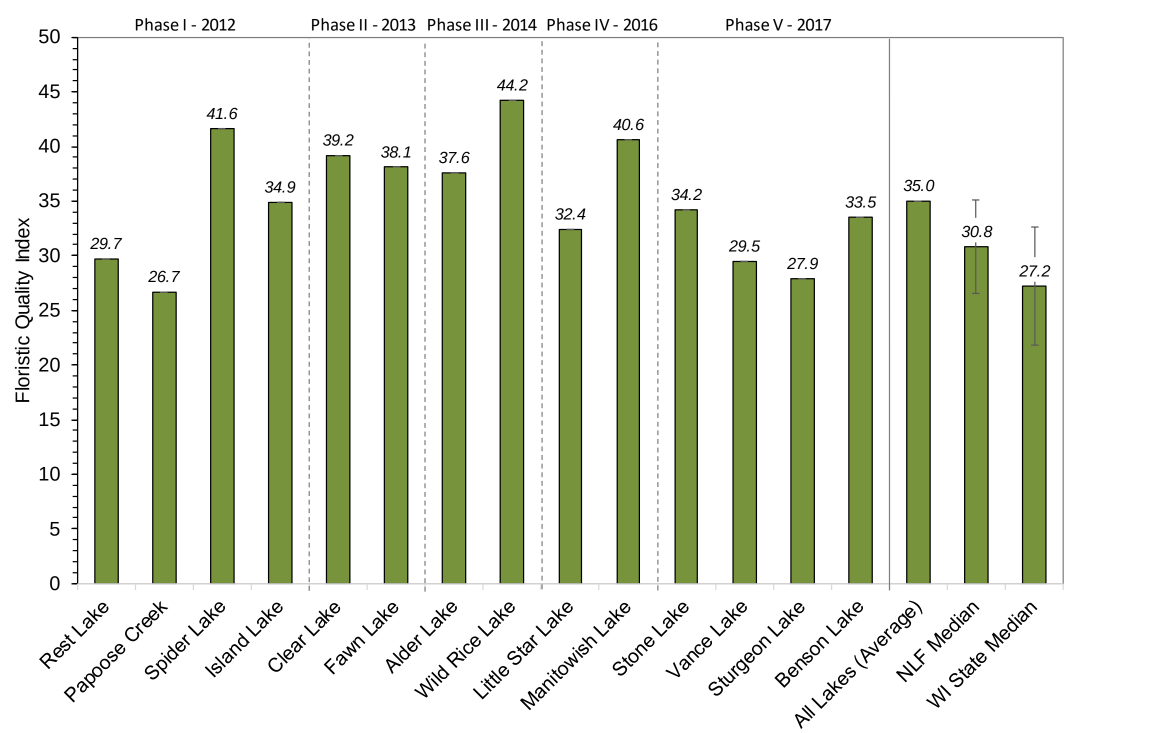


Figure 3.4-8. Manitowish Waters Chain of Lakes Floristic Quality Assessment. Created using data from native aquatic plant species encountered on the rake during summer point-intercept surveys. Analysis follows Nichols (1999).

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 variety of species with differing structures provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because the lakes in the Manitowish Waters Chain of Lakes contain a high number of native aquatic plant species, one may assume their communities also have high species diversity. However, species diversity is also influenced by how evenly the species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the Manitowish Waters Chain of Lakes' diversity values rank. Using data obtained from WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.4-9). Simpson's Diversity Index values were calculated for each lake using data collected during the summer point-intercept surveys. Figure 3.4-9 illustrates that of the Manitowish Waters Chain of Lakes, species diversity ranged from 0.83 to 0.93. As discussed within the Little Star Lake Aquatic Plant Section, the majority (64%) of its aquatic plant community is comprised of just three species: slender naiad, muskgrasses, and variable-leaf pondweed. In comparison, the aquatic plant species in Wild Rice Lake have a relatively more even distribution, with the five-most abundant aquatic plant species accounting for only approximately 50% of the community's composition. These factors determine how diverse a plant community is. Simpson's Diversity Index values for all project lakes fell at or above the median for lakes in the NLFL Ecoregion, indicating the plant communities of the Manitowish Waters Chain of Lakes are highly diverse.

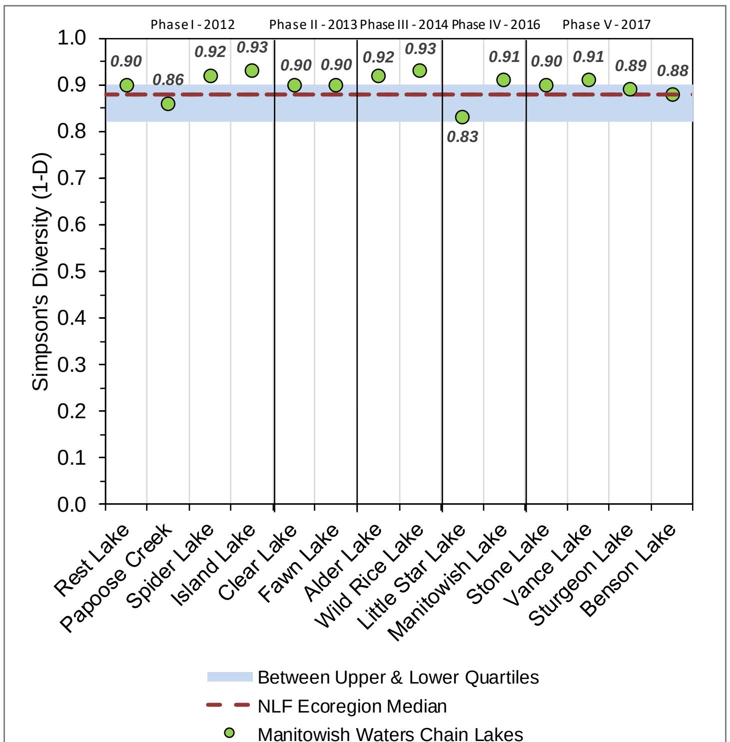


Figure 3.4-9. Manitowish Waters Chain of Lakes Simpson's Diversity Index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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

Many of the Manitowish Waters Chain of Lakes contain large areas of these plant communities. Figure 3.4-10 displays the percent of lake acreage occupied by emergent, floating-leaf, or a combined emergent and floating-leaf plant communities. Papoose Creek, a shallow bay on the north side of Rest Lake, has nearly 50% of its total acreage covered by both emergent and floating-leaf plant communities (mainly by northern wild rice). Little Star Lake, a relatively deep lake, has only 0.3% of its lake acreage covered by these communities.

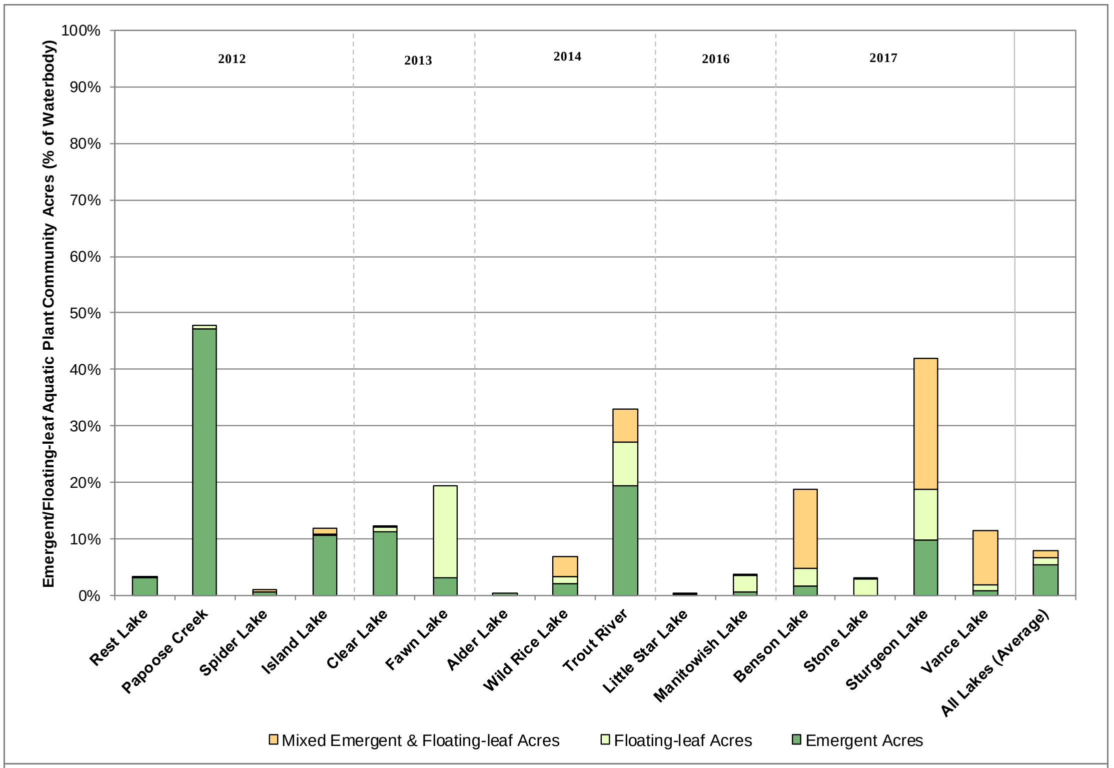


Figure 3.4-10. Manitowish Waters Chain of Lakes emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

Non-native Aquatic Plants in the Manitowish Waters Chain of Lakes

Curly-leaf pondweed

The purpose of this section is to give an overview of the curly-leaf pondweed management program, which includes both control and monitoring, on the Manitowish Waters Chain of Lakes. A brief chronology of where curly-leaf pondweed has been located in the chain is provided, as well as a simple description of the plant's lifecycle and how that affects strategies used to manage it. Monitoring strategies and results are also discussed. Detailed information regarding the year-to-year work that has been completed as a part of the four AIS grants received by the NLDC can be found in the annual reports produced from 2012-2018. These reports are available on the MWLA website.

Curly-leaf pondweed was first discovered in the Manitowish Waters Chain of Lakes in June 2010 in the northwestern area of Island Lake (Figure 3.4-11). These plants were discovered by a trained volunteer monitor with the Lake Captain and Deckhand Aquatic Invasive Species Program, which was started in 2010 by the NLDC to supplement the Clean Boats Clean Waters Program. NLDC staff and volunteers confirmed the identification of the curly-leaf pondweed and in early July 2010, intensified their monitoring of Island Lake locating a small amount of curly-leaf pondweed in Rice Creek. However, as it was mid-summer, most of the curly-leaf pondweed had likely already naturally senesced (died back), and the full extent of the population in Rice Creek was not realized. In 2011, monitoring conducted by NLDC staff, MWLA volunteers, and Vilas County staff mapped approximately 22 acres of curly-leaf pondweed in Rice Creek and located additional occurrences in southeastern Island Lake and in the channel between Island and Spider lakes.

The curly-leaf pondweed discoveries in 2010 and 2011 spurred the NLDC's first AIS-Early Detection and Response (AIS-EDR) Grant in February 2012. AIS-EDR Grants were also received in 2013 and 2014, followed by a 3-year AIS-Established Population Control (AIS-EPC) Grant in 2015. These grants helped to fund the management of curly-leaf pondweed on the chain from 2012-2017, which are elaborated on below. Continued and expanded monitoring of all chain lakes was completed by professionals and volunteers as a part of this multi-phased management planning project. These efforts located additional curly-leaf pondweed occurrences in Manitowish and Stone lakes during 2013, Rest Lake in 2015, and Fawn Lake during 2017 (Figure 3.4-11).

Curly-leaf pondweed has an odd life-cycle and relies on the development of asexual reproductive shoots called turions each year to produce plants in subsequent years. Not all of the turions sprout new plants the following year, many lie dormant in the sediment to sprout in subsequent years. Research indicates that turions can remain dormant for at least as long as five years and still sprout (Johnson et al. 2012). This results in a sediment turion bank being developed, which requires special consideration for the management of curly-leaf pondweed.

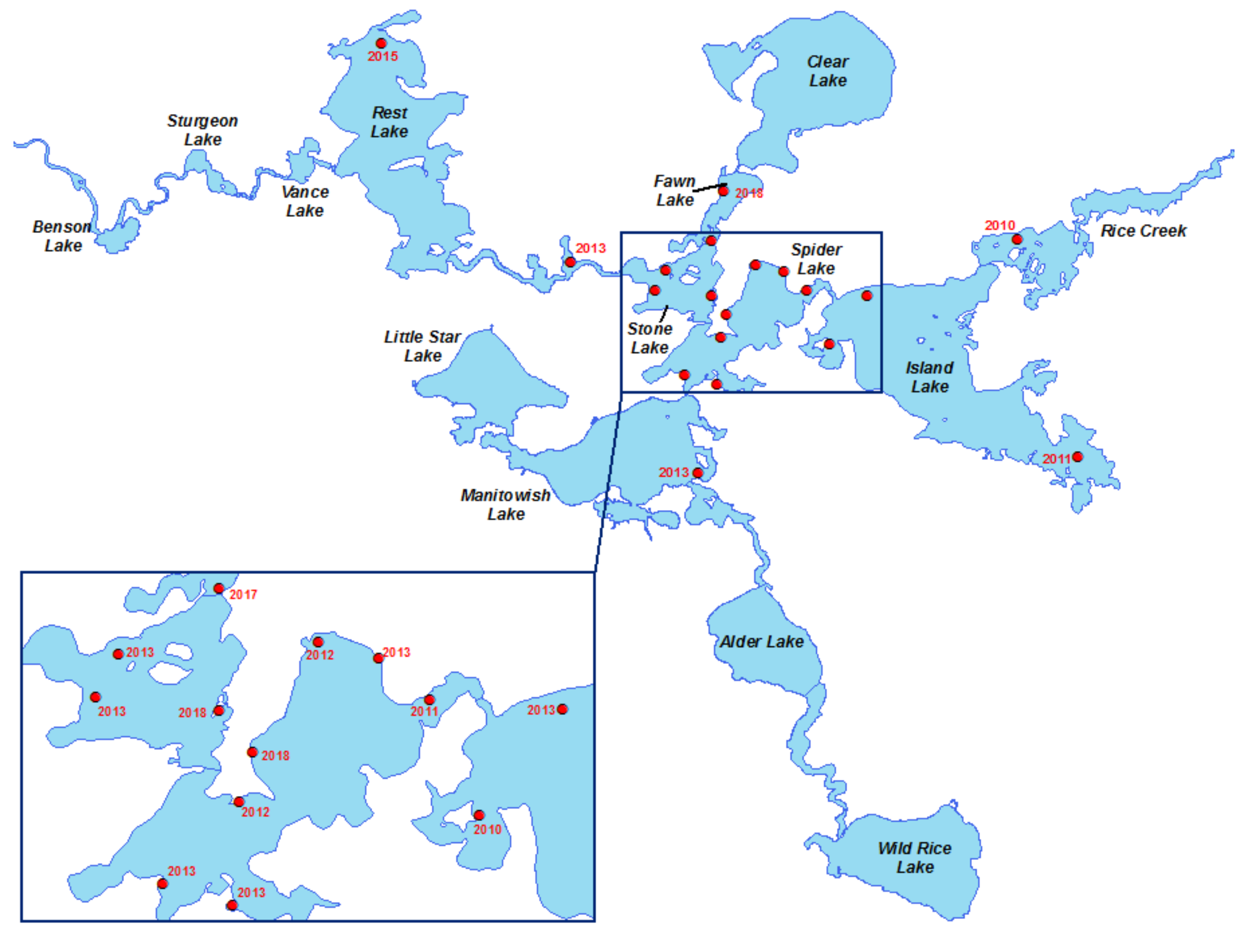


Figure 3.4-11. Curly-leaf pondweed discoveries in the Manitowish Waters Chain of Lakes. Initial discovery of curly-leaf pondweed throughout the chain, created using data from Onterra, MWLA volunteers and the NLDC.

Traditionally, control strategies of established populations of curly-leaf pondweed consist of repeated annual herbicide treatments utilizing endothall conducted in May/June. The treatment strategy is to kill each year's plants before they are able to produce turions; therefore, little or no additional turions are added to the bank during the control program. After multiple years of treatment, the turion base in the sediment is depleted and the curly-leaf pondweed population decreases significantly. Normally a control strategy for an established population includes multiple consecutive years of treatments of the same area in order to exhaust the bank of turions that can be viable for 5 or more years. Some lake managers theorize that the turion base of a more recently introduced curly-leaf pondweed population may be small and if a control program is initiated at that stage, may require fewer successive treatments than a more established population.

Early season herbicide treatments, particularly low-concentration whole-lake treatments, have shown large reductions in CLP biomass and decreased recurrence of CLP populations after multiple consecutive treatments (Skogerboe et al. 2008). Johnson et al. (2012) investigated 9 midwestern lakes that received five consecutive annual large-scale endothall treatments to control CLP. The greatest reductions in CLP frequency, biomass, and turions was observed in the first 2 years of the control program, but continued reductions were observed following all five years of the project. The authors noted that they saw no clear indication of the number of consecutive treatments needed to achieve long-term control, with viable turions (represented through sprouting) persisting greater than 5 years.

Five consecutive years of large-scale CLP treatment also occurred on Half Moon Lake (Eau Claire County, WI). Following the five-year control strategy, CLP occurrence was documented to quickly rebound to pretreatment levels, with the authors indicating that "the turion bank in the sediment was still viable after 5 consecutive years of control" (James 2017). It is unclear how the ongoing internal phosphorus management activities (alum treatments) and subsequent changes in water quality may be impacting turion sprouting and corresponding CLP populations. Half Moon Lake has entered into another 5-year CLP control program, which will result in large-scale endothall treatments occurring in ten out of eleven years.

From the existing scientific literature, it is unclear how many consecutive years of directed herbicide treatments are needed in a given waterbody to exhaust the base of turions present to meet management goals. As mentioned above, some lake managers theorize that the turion base may be small in a newly identified CLP population and if a control program is initiated at that time, may not require as many successive treatments as a more established population would. This is thought process behind the management within the Manitowish Waters Chain of Lakes. Essentially, by conducting control activities on these newly discovered areas, the duration of intense control needed to see a significant reduction in CLP would be only a few years.

In instances where large, established CLP population has been present within a lake, lake managers question whether the number of consecutive annual herbicide strategies required to reach population management goals may be imparting more strain on the environment than the existence of the invasive species. This is one of many reasons why the management of CLP and other invasive plant species need to be considered on a case-by-case basis.

Hand-harvesting, with or without DASH (diver-assisted suction harvesting), may be an appropriate method of control on light populations consisting of low acreage and scattered growth. Like the herbicide treatments, hand-harvesting must be completed prior to turion production. Turions can also be produced on the rhizome of curly-leaf pondweed; therefore, effort should be made to harvest as much of the rootstock as possible.

Typically, two surveys are completed each year in conjunction with curly-leaf pondweed control actions; a pretreatment survey completed just prior to the action and a post treatment survey completed following the control action. The post treatment survey that is assessing a hand-harvesting action can be completed immediately following the action, while a three to four-week gap is used by Onterra between an herbicide treatment and the post treatment survey. The pretreatment survey is utilized to refine the control area and confirm that the target species (curly-leaf pondweed) is present and actively growing. The post treatment survey is used to determine if the treatment met control expectations and to assist in planning the following year's control needs. However, as described below, in the case of curly-leaf pondweed herbicide treatments, assessing the success and failure of the control action can be difficult within the same year.

Onterra's monitoring protocol utilizes two methods to understand the surface acreage and density of the target species; 1) qualitative mapping with submeter GPS, and 2) quantitative sampling using a modified point-intercept method. The qualitative mapping is completed typically when the target species is at its peak growth stage and can be seen from the surface. Observations are recorded to represent points on the lake (*single or few plants*, *clumps of plants*, or *small plant colonies*) or larger beds, which are delineated with polygons and given density ratings (*highly scattered*, *scattered*, *dominant*, *highly dominant*, or *surface matted*). Submersible video and/or rake tows may be used for setting colony extents, but these methods are not appropriate as the sole method for locating the exotic or determining density. This survey is called an early-season AIS survey and while the primary focus on the Manitowish Waters Chain of Lakes was curly-leaf pondweed, it is also an excellent time to search for Eurasian watermilfoil as it is typically higher in the water column than most native plants. For clarity, the surveys reported on below were focused upon the lakes with known curly-leaf pondweed occurrences. These surveys were mostly completed as a part of the AIS Control Grant projects; however, as a part of the Manitowish Management Planning Project, all lakes had early-season AIS surveys completed on them during their respective project phase. The dates of those surveys can be found in the individual lake sections.

Quantitative sampling utilizing a point-intercept grid over the treatment area is typically only completed on treatment areas 10 acres or larger to allow for sufficient sampling points to assure confidence in statistics generated from the results. Quantitative sampling can be completed on smaller treatment areas, but greater differences in pre- and post-data must be documented to bring about confidence in the statistical analysis.

It is important to note that there are no regulatory requirements nor hard-fast protocols that determine what needs to be done as a part of an AIS control program. The monitoring is completed to understand how well the actions are working to control the target species and to what levels those same actions may be affecting non-target species. The control actions, *and* the methods used to monitor their efficacy, are evolving, so flexibility in when and how these methods, both quantitative and qualitative, are used is important. Project goals change, funding sources are not always clear, and decisions are often made in the field; therefore, pretreatment data and post treatment data may not always match entirely, so judgements in treatment impacts and management decisions need to be made with limited data at times.

Monitoring the effectiveness of a single curly-leaf pondweed herbicide treatment is difficult due to the timing of the application and the natural early senescence of the plants. Essentially, the herbicide impacts and the plant's natural senescence are occurring at approximately the same time and are indistinguishable from each other. In other words, curly-leaf pondweed naturally senesces in early summer, making it difficult to determine if a reduction in curly-leaf pondweed following a spring treatment was caused by the treatment, natural senescence, or both. When comparing pretreatment and post treatment occurrences, the only determination that can be made with confidence is that the herbicide treatment did not work due to many plants being located after treatment. This situation also makes it necessary at some point to hold off herbicide treatment for a year to allow the population to be reassessed at peak biomass. Typically, this occurs after several consecutive years of treatment, depending on the extent and density of the population before the first treatment.

Curly-leaf Pondweed Management in Manitowish Waters Chain of Lakes 2012-2018

Over the course of the six years between 2012 and 2018, two methods have been used to control curly-leaf pondweed in the Manitowish Waters Chain of Lakes; herbicides and hand-harvesting. The latter method has included volunteer, NLDC staff, and professionals using traditional hand-harvesting techniques (no DASH). Herbicide treatments have been completed on five sites on the chain, including the Spider-Island channel (2012-2016), Manitowish River (2014), and three areas on the western side of Island Lake (2012-2013). Two areas on the chain that contain curly-leaf pondweed have been monitored by professionals since 2012, but have had no control actions completed on them. These areas include Rice Creek near its entrance to Island Lake and an area in far eastern Island Lake. The results of control actions and the monitoring are summarized below. As mentioned above, specifics regarding the year-to-year efforts can be found in the annual reports produced as a part of the AIS grant projects.

Following the submission of the conditional treatment permit in early April 2012 and subsequent multi-agency review by the WDNR and Great Lakes Indian Fish and Wildlife Commission (GLIFWC), the proposed treatment of the 24-acre Rice Creek CLP colony was suspended due to concerns regarding the proximity of the treatment area to northern wild rice (*Zizania palustris*) populations. Based on laboratory and outdoor growth chamber research, wild rice has been shown to be vulnerable to early-season treatments using a variety of herbicides, including endothall (Nelson et al. 2003; Madsen et al. 2008). Northern wild rice is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers, and possesses great cultural significance to the Chippewa Tribal Communities. In addition, northern wild rice provides a number of valuable ecological services which include food and habitat sources for wildlife, soil stabilization, and nutrient uptake. In August 2012, Onterra ecologists escorted WDNR and GLIFWC staff on the Manitowish Waters Chain of Lakes to allow agency staff to gain a firsthand understanding of the survey and monitoring strategies utilized on the chain. Onterra staff member, Eddie Heath, was later invited by GLIFWC to attend a Voigt Intertribal Taskforce Workshop held in December 2012 with the purpose of sharing the monitoring strategies with representatives of the tribal nations that GLIFWC represents. The Voigt Intertribal Task Force is comprised of nine GLFWC members plus the chairperson, and recommends policy relating to natural resource management issues within the ceded territories.

During the early winter of 2013, a detailed qualitative and quantitative herbicide treatment monitoring strategy was devised that would evaluate the efficacy of the proposed endothall treatment on curly-leaf pondweed and any potential negative impacts to the northern wild rice. Similar to the qualitative methodologies used to map and compare curly-leaf pondweed colonies and densities, a methodology has been developed to monitor changes in northern wild rice populations over time. These monitoring data may be compared over time to draw conclusions on how the two populations (curly-leaf pondweed and wild rice) may be interacting. Following the submission and review of a conditional permit for treatment of curly-leaf pondweed within Rice Creek in the spring of 2013, the members of the Voigt Intertribal Task Force voted to object to the treatment for cultural reasons and concerns that the rice would be negatively impacted by the treatment. While no additional herbicide permit applications were made for the Rice Creek area, the MWLA continued managing downstream populations to minimize continued spread as much as possible. Further, the monitoring of the curly-leaf pondweed and wild rice populations continued in Rice Creek and far eastern Island Lake.

Table 3.4-1 lists the acreages of wild rice and curly-leaf pondweed mapped in Rice Creek from 2012-2017. Please note that wild rice mapping did not occur after 2018. The wild rice population in this area has fluctuated between just over 192 acres to 212 acres with most years being around 200 acres (Map 3). Wild rice is known to exhibit a “boom-and-bust” life cycle, where in a typical four-year period it will have a bumper year, two fair years, and a bust year, so these fluctuations are not surprising. Curly-leaf pondweed, on the other hand, has seen a dramatic drop in density since 2012. While the plant occupies approximately the same footprint, its density decreased noticeably in 2015 and has remained down since that time (Map 4). Due to high levels and flows, of dark-stained water, CLP mapping was not completed in 2018 (Map 8) in Rice Creek. In 2019, CLP findings appeared to be similar to those in 2016 (Map 9). Many environmental factors likely cumulate to limit curly-leaf pondweed growth in the area, including water levels, flows, and light availability. Wild rice may also be a factor as well by competing for resources as these two plants grow in early spring. Regardless of the reason as to why the CLP density has been documented to decline over the years it has been monitored, it is an indication that CLP may not become a problem in all areas of the Manitowish Waters Chain of Lakes and that should be kept in mind as a part of future management decisions.

Table 3.4-1. Rice Creek curly-leaf pondweed and northern wild rice community areal coverage, 2012-2017. Curly-leaf pondweed acreage determined through early summer peak-growth (ESAIS) surveys, wild rice mapped during late summer peak growth surveys. Areal extent may be viewed on Maps 3 and 4.

Year	Total CLP Acreage	Total Wild Rice Acreage	CLP/Wild Rice Overlap (acres)
2012	27.8	192.5	9.1
2013	26.9	202.2	9.1
2014	20.2	212.0	3.3
2015	7.1	198.4	0.1
2016	7.4	202.8	0.0
2017	4.9	198.7	0.3

Wild rice and untreated curly-leaf pondweed were also mapped over the same time period in the eastern portion of Island Lake (Maps 5 and 6). In this area, the wild rice occupied similar acreages from year-to-year, but densities fluctuated from nearly all areas being dense in 2012, to increased areas of sparse wild rice in 2013-2016, and back to nearly all dominant areas in 2017. In 2012 and 2013, the main bed of curly-leaf pondweed was mapped as *scattered* colony; while in 2014, only two *single or few plants* were mapped in the area. However, from 2014 to 2017, the occurrence of curly-leaf pondweed rebounded to including more and more *clumps of plants* and *small plant colonies* within the area. In 2018 (Map 8) and 2019 (Map 9), the area was found to have less CLP again.

The 2012 herbicide treatment strategy initially included four treatment sites, the large area in Rice Creek that is addressed above that was ultimately removed from the control strategy, a half-acre site in western Island Lake, and two areas, just over an acre each, on either side of the Spider-Island channel. These treatment sites were created using data collected the year previous by Vilas County and NLDC staff. In early April 2012, Onterra staff completed a pretreatment survey and found additional curly-leaf pondweed in those areas, so the channel site was expanded across the channel and increased to nearly 5 acres. The Island Lake site was expanded to include just over one acre. Onterra crews returned to the sites in June, following the treatment, and found curly-leaf pondweed growing in and around each of the sites, indicating an unsuccessful treatment. During that same survey a new colony was also located in the northern portion of Island Lake. A second new colony was located on west side of the lake just south of the western colony. These four areas were proposed for herbicide treatment in 2013.

In 2013, the areas described above were treated, totaling 13.8 acres. Each site had an expanded buffer and dose rates were increased in an effort to meet concentration exposure times. Herbicide concentration monitoring was completed as a part of the project. Details can be found in the 2013 annual report. Onterra staff returned in June following the treatment and recorded no visual observations of curly-leaf pondweed within any of the sites. Some small plants were brought up with the rake during the subsample point-intercept survey in the Spider-Island channel site, but random rake tows completed in the other sites turned up no curly-leaf pondweed. As mentioned earlier, the post treatment surveys can really only verify poor treatment results, as they did in 2012; however, considering healthy, growing curly-leaf pondweed was also located during the June 2013 survey in eastern Island Lake, Rice Creek, Stone Lake, and the Manitowish River, Onterra's interpretation was that the information was valid to indicate the treatment provided good results.

The 2014 treatment strategy initially included two herbicide treatment sites, an area in the Manitowish River located in June 2013 (3.9 acres) and a repeat of the 7-acre site in the Spider-Island channel. Due to the complete lack of curly-leaf pondweed located in the three Island Lake sites during June 2013, those sites were slated for professional hand-harvesting. Ice-out did not occur on the Manitowish Waters Chain of Lakes until late May, so the herbicide treatment was not completed until June 9th. A pretreatment survey completed by Onterra prior to the treatment did verify actively growing curly-leaf pondweed in both treatment sites. The hand-harvesting of the sites mentioned above, along with three small sites in Stone Lake, were completed in late June-early July. Onterra completed post treatment surveys of all sites and found few curly-leaf pondweed plants in the herbicide sites. Only *two single or few plant*s were found in the three hand-harvest sites following the removal efforts.

The use of an integrated approach to controlling curly-leaf pondweed continued in 2015. Initially, both the Manitowish River and Spider-Island channel sites were proposed for herbicide treatment; however, based upon pretreatment survey results, the Manitowish River site was dropped from the herbicide strategy and added to the hand-harvest strategy. Post treatment surveys once again indicated a reduction of CLP in the Spider-Island channel as well as in the hand-harvest areas. The results of volunteer monitoring and hand-harvesting were also encouraging during 2015. NLDC staff located a new area of curly-leaf pondweed in northern Rest Lake, provided GPS coordinates to Onterra and spent several hours removing plants from the area.

The 2016 curly-leaf pondweed control strategy included volunteer and professional hand-harvesting as well as the fifth herbicide treatment of the Spider-Island channel. Volunteers spent much of their time searching for AIS in the chain and less of it, compared to 2015, harvesting curly-leaf pondweed. The hand-harvesting contractor spent two days working on a nearly three-acre site in Island Lake, reporting that only *highly scattered* plants were located and removed. This site was one of the original three sites in Island Lake that was treated once in 2013 and of those four sites, the only one with sufficient curly-leaf pondweed remaining that it was recommended for professional hand-harvesting.

In late June 2016, Onterra visited all known sites of curly-leaf pondweed in the Manitowish Waters Chain of Lakes. The results were encouraging because in all known areas outside of Rest Lake that received control actions over the past five years, the density designation of *single or few plants* was the only one reported during the visual survey in eight instances at four sites. To be clear, these findings do not indicate that at the end of 2016 that only eight instances of curly-leaf pondweed existed in those areas as there most assuredly were plants that went undetected, but compared to what was found using the same methodology over previous years, this is a definite indication that curly-leaf pondweed frequency was lower. In the Rest Lake site, after the second year of harvesting by NLDC staff, a limited number of *single or few plants* and four *clumps of plants* were located. In 2019, a single CLP plant was located in the Rest Lake site (Map 9).

As planned, no herbicide treatment was conducted in the Spider-Island channel during 2017 to allow Onterra staff to examine the site without the impacts of a control action, including hand-harvesting. Onterra staff surveyed all lakes known to have curly-leaf pondweed on June 12 & 13, 2017 (Map 7). While no previously controlled area contained an alarming amount of curly-leaf pondweed, the northern Rest Lake site did have sufficient plants to be declared a priority site for work by the professional hand-harvesting crews. Professionals concentrated their efforts over two days on the Rest Lake site and for a single day in the Spider-Island channel removing over 13 cubic-feet of plant material all together. NLDC staff concentrated their efforts on a small colony of curly-leaf pondweed located in southern Fawn Lake near the entrance to Stone Lake. Overall, the results of the 2017 early-season AIS survey indicated that curly-leaf pondweed occurrences were lower in the treated areas. It is believed that the control program has driven much of the CLP population declines in the targeted areas; however; given the concurrent decline of the unmanaged CLP population observed in Rice Creek, it cannot be determined whether the control actions were solely responsible for the decline or if the population would have declined regardless of control actions.

The CLP population was monitored in 2018 through a combination of efforts by Onterra and by the NLDC staff. Onterra staff visited the Manitowish Waters Chain on June 18 & 19, 2018 to complete the early-season AIS survey. Water levels appeared to be slightly higher than usual at the time of the survey. All of the CLP occurrences that were located consisted of either *single or few plants* or *clumps of plants* (Map 8). No large colonized areas of CLP that required area-based mapping methodologies were located during the survey. The crew attempted to map the known CLP colony in Rice Creek, however, high water levels, high water flows, and dark-stained water made mapping CLP in the area difficult and the survey was discontinued in this particular area.

The NLDC also conducted CLP monitoring in areas of the chain in spring 2018 including the known CLP waterbodies of Rest Lake and the Manitowish River between Rest Lake and Stone Lake (Map 8). No CLP was initially located in Rest Lake in the area in which it had been present in previous years. Several CLP plants were identified NLDC staff in Fawn Lake in June. Following the discovery in Fawn Lake, Onterra staff also searched the area and mapped two *clumps of plants* and a *single plant* on the west side of the lake.

The NLDC contracted with Aquatic Plant Management, LLC (APM) to conduct professional hand-harvesting services of CLP in 2018. Onterra and the NLDC provided the spatial data for the CLP locations to APM to aid in the removal efforts. Plant removal specialists from APM visited the Manitowish Waters Chain of Lakes on June 25th-27th & July 2nd 2018. Over a combined 24 hours of diver time, approximately 10 cubic feet of CLP was harvested. Two days of the professional harvesting efforts took place in sites on the eastern side of Stone Lake, the western shore of Spider Lake, and in the Spider-Island channel. Nearly 6 hours was spent harvesting in the channel while a total of an hour was spent in the other two locations. One day of professional harvesting targeted the newly found population in Fawn Lake and one day was devoted to searching for and removing CLP from the previously known sites in Rest Lake.

Overall, the CLP occurrences in 2019 were lower in many of the known sites compared to 2017 and 2018 (Maps 9, 7, and 8, respectively). Some of that reduction is likely due to the volunteer and professional hand-harvesting efforts applied in years previous. One area of concern is the newer finding of CLP north of the island in Fawn Lake. This area has been set as a high priority for hand-harvesting that will be completed by professionals in late June 2019. Other areas of the chain, including the Spider-Island channel, will also have professional hand-harvesting completed in 2019.

Continued monitoring and diligent hand-harvesting efforts, by volunteers and professionals will likely be required to keep the population low.

As described above, quantitative monitoring of curly-leaf pondweed and native plants was completed as a part of the control program. Initially in 2012, the 24-acre site in Rice Creek was set as the quantitative monitoring site, but was dropped when the herbicide application permit was suspended. During that same year, the Spider-Island channel was the next largest site, but was under 5 acres, which is too small to realistically produce enough sampling points to even minimally understand changes in the native and non-native plant populations. However, in 2013, the Spider-Island channel site was expanded to include 7.1 acres of treatment. While this still falls short of the minimum size threshold (ten-acres) normally used by Onterra for using quantitative monitoring, in order to gain at least some information, a grid was placed over the colonized area yielding 36 sampling points. In 2016 and 2017, the grid was reconfigured to produce 70 points over the entire treatment area as plants had been found entirely within that area. The points were sampled each year during the pretreatment survey and during that year's post treatment survey (early-season AIS survey). The pretreatment sampling is appropriate for understanding the changes in curly-leaf pondweed occurrence, while the post treatment results are useful for understanding changes in the native plant community. It is important to note two concepts when using the modified point intercept survey method to monitor curly-leaf pondweed control actions:

1. As described above, the early senescence of curly-leaf pondweed occurs roughly at the same time that the impacts to the herbicide treatment would occur; therefore, determining if the reduced population is brought on by the treatment, early senescence, or both, is impossible. Realistically, and as demonstrated by the results of the 2012 herbicide treatment of the Spider-Island channel, the failure of an herbicide treatment can only be reliably determined.
2. Comparing curly-leaf pondweed pretreatment-to-pretreatment subsample point-intercept results does not indicate survival or mortality of curly-leaf pondweed plants following a treatment. A decreasing trend of curly-leaf pondweed plants each spring is taken to reflect a decrease in the turion bank, which is the goal of the annual treatment strategy. However, without actually sampling the turion bank, it cannot be absolutely stated that a decreasing trend in curly-leaf pondweed sprouting is the result of a depletion in the turion bank.

Figure 3.4-12 displays curly-leaf pondweed littoral frequency of occurrence (LFOO) results collected from 2013-2017 in the Spider-Island channel prior to control activities. Specifically, these data were collected prior to herbicide treatments in 2013-2016 and prior to professional hand-harvesting in 2017. These results indicate that over the years of the treatment program, turion sprouting each spring was reduced significantly; therefore, the control program goal of reducing curly-leaf pondweed occurrence in the channel was met. Importantly, while the goal was met to reduce the amount of the exotic in the area, it is still present; therefore, the implementation plan for the Manitowish Waters Chain of Lakes includes continued management, including monitoring and control, of curly-leaf pondweed.

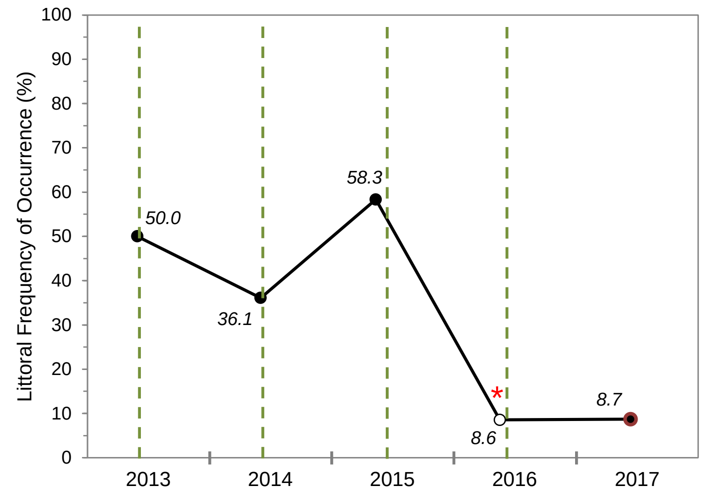


Figure 3.4-12. Curly-leaf pondweed littoral frequency of occurrence. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically valid change from 2013 to 2016; a red circle outline in 2017 indicates a statistically valid change in occurrence from 2013 (Chi-square α = 0.05). Created using data from 2013 (N=36), 2014 (N=36), 2015 (N=36), 2016 (N=70) and 2017 (N=69) sub-point intercept surveys.

The same subsample point-intercept sampling grid used to collect pretreatment quantitative data was used to collect post treatment data as well. In all years from 2013-2017, these data were collected in late June or very early July. While plant species differ in their annual lifecycles (phenology) and may not be at their peak-growth stage at this time of year, replication of the surveys at approximately the same timeframe each year allows for comparability of the dataset.

Endothall, the herbicide typically used to control curly-leaf pondweed and used during the control program reported on here, has historically been considered a contact herbicide. Recent studies by Scott Nissen (Colorado State University) have revealed significant amount of endothall translocation in some plant species from the foliage to the plant's roots, indicating that the herbicide should be reclassified as a systemic herbicide (Nissen and Ortiz in press). Unlike most herbicides that have a single mode of action, endothall impacts plants in multiple ways. The primary mode of actions is an inhibitor to lipid and protein synthesis. But in some plants, endothall can disrupt cell membranes (respiratory processes) or reduce proteolytic enzymes (Selden 2015). When used in a spot-treatment use-pattern (relatively high up-front concentration and short exposure time), some non-target species impacts are expected and considered in the treatment strategy. Impacts vary among native species and that variability is reflected in these results. Importantly, the impacts shown within the spot treatment area do not represent impacts system-wide. Along the same line, documented reductions in curly-leaf pondweed within the Spider-Island channel do not indicate reductions in the species within the entire Manitowish Waters Chain of Lakes.

Significant reductions were documented in several non-target native species found within the Spider-Island channel over the course of 2013-2017 (Figure 3.4-13). In Onterra's experience, coontail, northern watermilfoil, and large-leaf pondweed have shown variable susceptibility to endothall treatments, while fern-leaf pondweed and flat-stem pondweed are highly susceptible. Coontail, northern watermilfoil, fern-leaf pondweed, and large-leaf pondweed all had statistically valid population reductions during the final year of the herbicide control program (2016) compared with the initial year of the control program (2013). While the differences were not large enough to meet statistically valid criteria, coontail and large-leaf populations continued to decline during 2017 in absence of a treatment, whereas northern watermilfoil populations trended upwards. Population recovery of fern-leaf pondweed during 2017 was not observed.

Common waterweed within the 7.1-acres site in the Spider-island channel declined from 75% frequency of occurrence at the start of the treatment program (2013) to 40% during the last year of herbicide treatment (2016). Common waterweed has been shown to metabolize endothall much quicker than other species (particularly pondweeds) and not translocate the herbicide making it more tolerant of endothall treatments (Keckemet and Nelson 1968). Common waterweed populations showed the largest reductions in the Spider-Island Channel during 2017 when herbicide control strategies were not implemented.

Wild celery begins growing later in the year than many other native plants, so Onterra has found it to be largely unaffected by early spring herbicide spot treatments. This appears to be the case during the years when herbicides were used in the Spider-Island channel as no statistical valid changes were seen in the population between 2013-2016. Still, in 2017 when no treatment was completed, survey crews did not retrieve a single wild celery plant on the rake. This is a considerable and unexplained drop in population from the 2016 LFOO of 35.7% in this location.

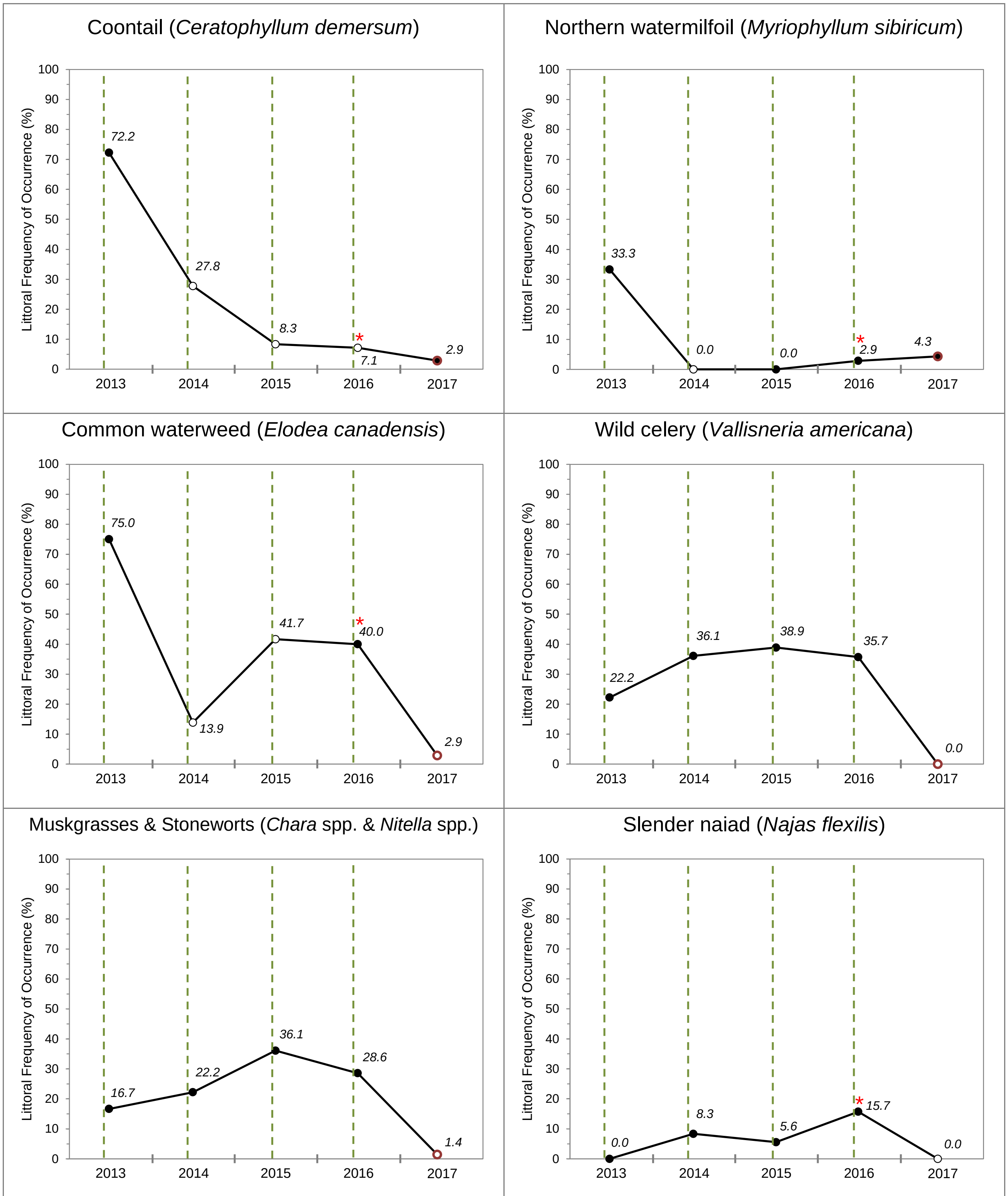


Figure 3.4-13. Spider/Island Channel littoral frequency of occurrence of aquatic plant species from 2013-2017. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically valid change from 2013 to 2016, and a red circle outline in 2017 indicates statistically valid change in occurrence from 2013 (Chi-square α = 0.05). Created using data from 2013 (N = 36), 2014 (N = 36), 2015 (N = 36), 2016 (N=70) and 2017 (N = 69) sub-point-intercept surveys.

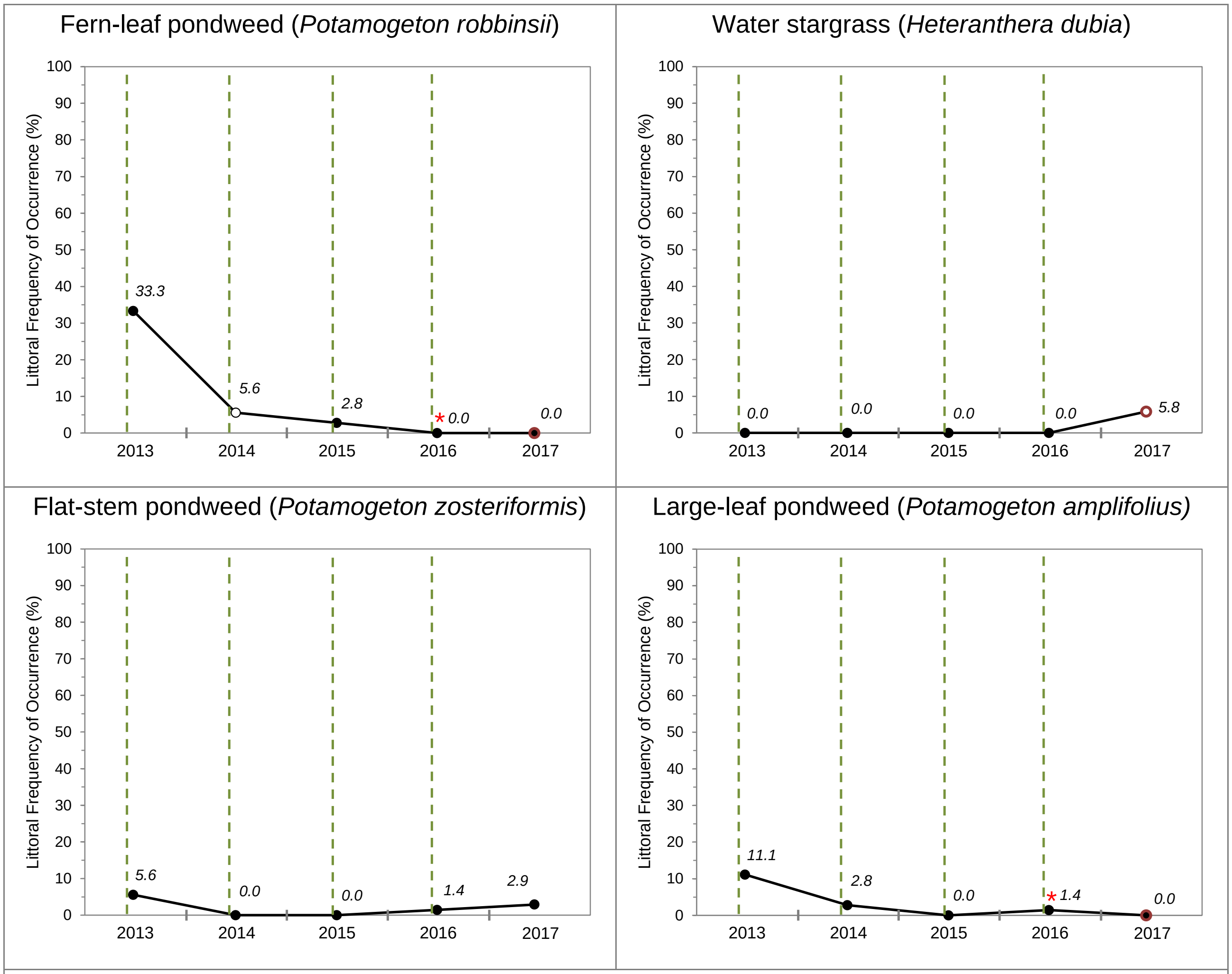


Figure 3.4-13 continued. Spider/Island Channel littoral frequency of occurrence of aquatic plant species from 2013 to 2017. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically valid change from 2013 to 2016; a red circle outline in 2017 indicates statistically valid change in occurrence from 2013 (Chi-square α = 0.05). Created using data from 2013 (N = 36), 2014 (N = 36), 2015 (N = 36), 2016 (N=70) and 2017 (N = 69) sub-point-intercept surveys.

Slender naiad showed a statistically valid increase from a LFOO of 0.0% in 2013 to 15.7 in 2016. However, in 2017, when no treatment occurred, the LFOO returned to 0.0%. Slender naiad is an annual plant that relies on seed germination each year to sustain the population. Large fluctuations of this species have been observed on systems that are likely related to factors that impact seed production and seed germination. Muskgrasses and stoneworts, like slender naiad, showed a general trend upward during the years of treatment followed by a stark crash in 2017. Muskgrasses and stoneworts are actually macroalgae and due to their lack of vascular tissue are unable to translocate herbicides; therefore, they are typically unaffected by their use. The LFOO data from the years with treatment appear to support the ineffectiveness of herbicides on these macroalgae, but the crash in 2017 when no herbicides were used is not understood.

Flat-stem pondweed, a species typically regarded as being sensitive to early-season endothall treatments, showed no statistically valid change during the entire project. Water stargrass remained at 0.0% within the Spider-Island Channel during the years of treatment, but showed a statistically valid increase in LFOO to 5.8% in 2017.

In summary, the quantitative data indicates a reduction in curly-leaf pondweed propagation in the Spider-Island channel. However, during the same timeframe, several non-target species (coontail, northern watermilfoil, fern-leaf pondweed, and large-leaf pondweed) also declined. Onterra's experience is that recovery of these native populations will take time but having unimpacted large populations of these species in other parts of the chain is valuable. Reasons for changes in littoral frequency of other species sampled in the area are not as clear during the years with treatment, nor the final year when herbicides were not used to control curly-leaf pondweed.

Shoreland AIS Occurrences

Pale yellow iris

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Pale yellow iris was observed growing on several lakes within the Manitowish Waters Chain. These locations are marked on each lakes' aquatic plant community maps. At this time, the only means of controlling pale-yellow iris populations is continual hand removal and monitoring.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Populations of purple loosestrife were observed along several Manitowish Waters Chain of Lakes – these locations would be displayed on each lake's individual aquatic plant community map.

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

Common forget-me-not

Like pale yellow iris and purple loosestrife, common forget-me-not (*Myosotis scorpioides*) is a non-native, invasive plant with origins in Europe and Asia. It produces numerous, small blue flowers with yellow centers. Now widespread throughout Wisconsin, this plant displaces native wetland vegetation along the shorelines of lakes and streams. Common forget-me-not was observed along several Manitowish Waters Chain of Lakes – these locations would be displayed on each lake's individual aquatic plant community map. At this time, the only means of controlling common forget-me-not populations are through continual hand removal and monitoring. Common forget-me-not is also common in the Manitowish River upstream of island lake (WDNR personal comm. 2019).

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed along the eastern and southern shores of Rest Lake (see the Rest Lake aquatic plant community map). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Giant reed

Giant reed (*Phragmites australis*) is a tall, perennial grass that was introduced to the United States from Europe. While a native strain of this species exists in Wisconsin, it is believed that the plants located on Alder Lake are of the non-native, invasive strain. Giant reed forms towering, dense colonies that overtake native vegetation and replace it with a monoculture that provides inadequate sources of food and habitat for wildlife. Giant reed was found growing in a single location on Alder Lake's shoreline and along the Trout River in 2014 (see the Alder Lake aquatic plant community map). Because this species has the capacity to displace the valuable wetland plants along the exposed shorelines of the lake and elsewhere, it is recommended that these plants be removed by cutting and bagging the seed heads and applying herbicide to the cut ends. This management strategy is most effective when completed in late summer or early fall when the plant is actively storing sugars and carbohydrates in its root system in preparation for over-wintering. The giant reed infestation is in its very early stages, and eradication is likely a realistic outcome if control actions are taken quickly. Update: GLIFWC staff began herbicide treatment of Phragmites in Manitowish Lake in 2017.

Stakeholder Survey Responses to Aquatic Vegetation within the Manitowish Waters Chain of Lakes

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.4-14 and 3.4-15 display the responses of members of the Manitowish Waters Chain of Lakes stakeholders to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts the enjoyment of the Manitowish Waters Chain of Lakes, the majority of stakeholder survey respondents (38%) indicated *sometimes*, 36% indicated *rarely*, 13% indicated *never*, and 13% indicated *often* or *always* (Figure 3.4-14).

When asked if they believe aquatic plant control is needed on Archibald Lake, 39% of respondents indicated *definitely yes*, 27% indicated *probably yes*, 19% indicated that they were *unsure*, and 14% indicated *probably no* or *definitely no.* The presence of AIS within the Manitowish Waters

Chain of Lakes is well-known knowledge for the stakeholders so while aquatic plants do not generally impact user's enjoyment of the lake, stakeholders believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in the Manitowish Waters Chain of Lakes is discussed within the Implementation Plan Section (Section 5.0).

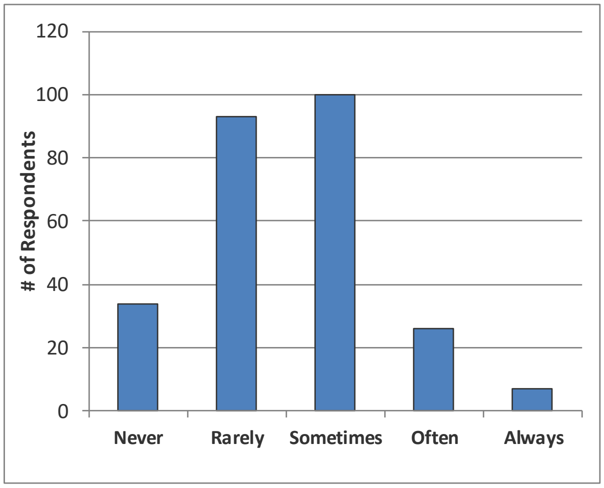


Figure 3.4-14. Stakeholder survey response Question #21. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of the Manitowish Waters Chain of Lakes?

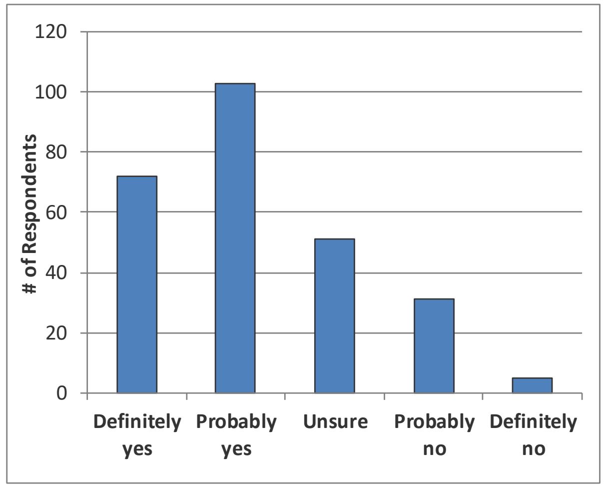


Figure 3.4-15. Stakeholder survey response Question #24. Do you believe aquatic plant control is needed on the Manitowish Waters Chain of Lakes?

Onterra LLC
Lake Management Planning

3.5 Aquatic Invasive Species in the Manitowish Waters Chain of Lakes

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

Manitowish Waters Chain of Lakes Stakeholder AIS Concerns

As with most Wisconsin lakes, there is great concern with Manitowish Waters Chain of Lakes stakeholders over the threat of aquatic invasive species. The TAISP has put forth much effort in educating area stakeholders and Manitowish Waters Chain of Lakes visitors about the threat that invasive plants pose. Table 3.5-1 lists the confirmed aquatic invasive species in each of the Manitowish Waters Chain of Lakes.

While no reasonable and efficient control strategy exists for several of the species on Table 3.5-1 (banded and Chinese mystery snails and rusty crayfish), several effective methods have been utilized for control of curly-leaf pondweed and purple loosestrife. For the Manitowish Waters Chain of Lakes in which aquatic invasive plants are present, the history and management strategy for each is discussed further within that lake's Aquatic Plant Section and Implementation Plan.

Table 3.5-1. Aquatic Invasive Species located on the Manitowish Waters Chain of Lakes. Information obtained from a WDNR internet database (http://dnr.wi.gov/lakes/invasives/BySpecies.aspx).

Lake	AIS and Year Confirmed
Island Lake	Banded mystery snail (2006), Chinese mystery snail (2013), Curly-leaf pondweed (2010), Rusty crayfish (1972), Pale yellow iris (2012), Purple loosestrife (2012)
Rest Lake	Banded mystery snail (2012), Chinese mystery snail (2007), Rusty crayfish (1980), Pale yellow iris (2012), Purple loosestrife (2012), Curly-leaf pondweed (2015)
Spider Lake	Banded mystery snail (2011), Chinese mystery snail (2010), Curly-leaf pondweed (2011), Purple loosestrife (2010), Rusty crayfish (1972)
Clear Lake	Banded mystery snail (2005), Rusty crayfish (1975)
Fawn Lake	Banded mystery snail (2005), Rusty crayfish (1975), Curly-leaf pondweed (2017)
Alder Lake	Chinese mystery snail (2007), Rusty crayfish (1975), Giant reed (2011), Purple loosestrife (2012)
Wild Rice Lake	Banded mystery snail (2006), Chinese mystery snail (2010), Purple loosestrife (2010), Rusty crayfish (1975)
Little Star Lake	Purple loosestrife (2010), Rusty crayfish (1981)
Manitowish Lake	Curly-leaf pondweed (2013), Purple loosestrife (2010), Rusty crayfish (1977)
Manitowish River	Chinese mystery snail (2006), Curly-leaf pondweed (2013), Giant reed (2011), Yellow iris (2012), Purple loosestrife (2012)
Benson Lake	Rusty crayfish (1977), Banded mystery snail (n/a), Chinese mystery snail (n/a), Purple loosestrife (n/a)
Stone Lake	Curly-leaf pondweed (2013), Rusty crayfish (1981)
Sturgeon Lake	Rusty crayfish (1977), Purple loosestrife (n/a)
Vance Lake	Rusty crayfish (1977), Purple loosestrife (n/a)

Table 3.5-2. AIS present within the Manitowish Waters Chain of Lakes

Type	Common name	Scientific name	Location within the report
Plants	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.5 – Aquatic Plants
	Pale yellow iris	*Iris pseudacorus*	Section 3.5 – Aquatic Plants
	Purple loosestrife	*Lythrum salicaria*	Section 3.5 – Aquatic Plants
	Giant reed	*Phragmites australis* subsp. *australis*	Section 3.5 – Aquatic Plants
	Common forget-me-not	*Myosotis scorpioides*	Section 3.5 – Aquatic Plants
	Reed canary grass	*Phalaris arundinacea*	Section 3.5 – Aquatic Plants
Invertebrates	Banded mystery snail	*Viviparus georgianus*	Section 3.5 Aquatic Invasive Species
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 Aquatic Invasive Species
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 Aquatic Invasive Species

Figure 3.5-1 displays the 20 aquatic invasive species that the Manitowish Waters Chain of Lakes stakeholders believe are in Manitowish Waters Chain of Lakes. While the majority of survey respondents indicated they believe Eurasian watermilfoil is present in the Manitowish Chain, as of this writing, this invasive species has not been documented in any lake in the chain. Only the species present in the Manitowish Waters Chain of Lakes are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

Aquatic Animals

Rusty Crayfish

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

Mystery snails

There are two types of mystery snails found within Wisconsin waters, the Chinese mystery snail (*Cipangopaludina chinensis*) and the banded mystery snail (*Viviparus georgianus*). Both snails can be identified by their large size, thick hard shell and hard operculum (a trap door that covers the snail's soft body). These traits also make them less edible to native predators. These species thrive in eutrophic waters with very little flow. They are bottom-dwellers eating diatoms, algae and organic and inorganic bottom materials. One study conducted in northern Wisconsin lakes found that the Chinese mystery snail did not have strong negative effects on native snail populations (Solomon et al. 2010). However, researchers did detect negative impacts to native snail communities when both Chinese mystery snails and the rusty crayfish were present (Johnson et al. 2009).

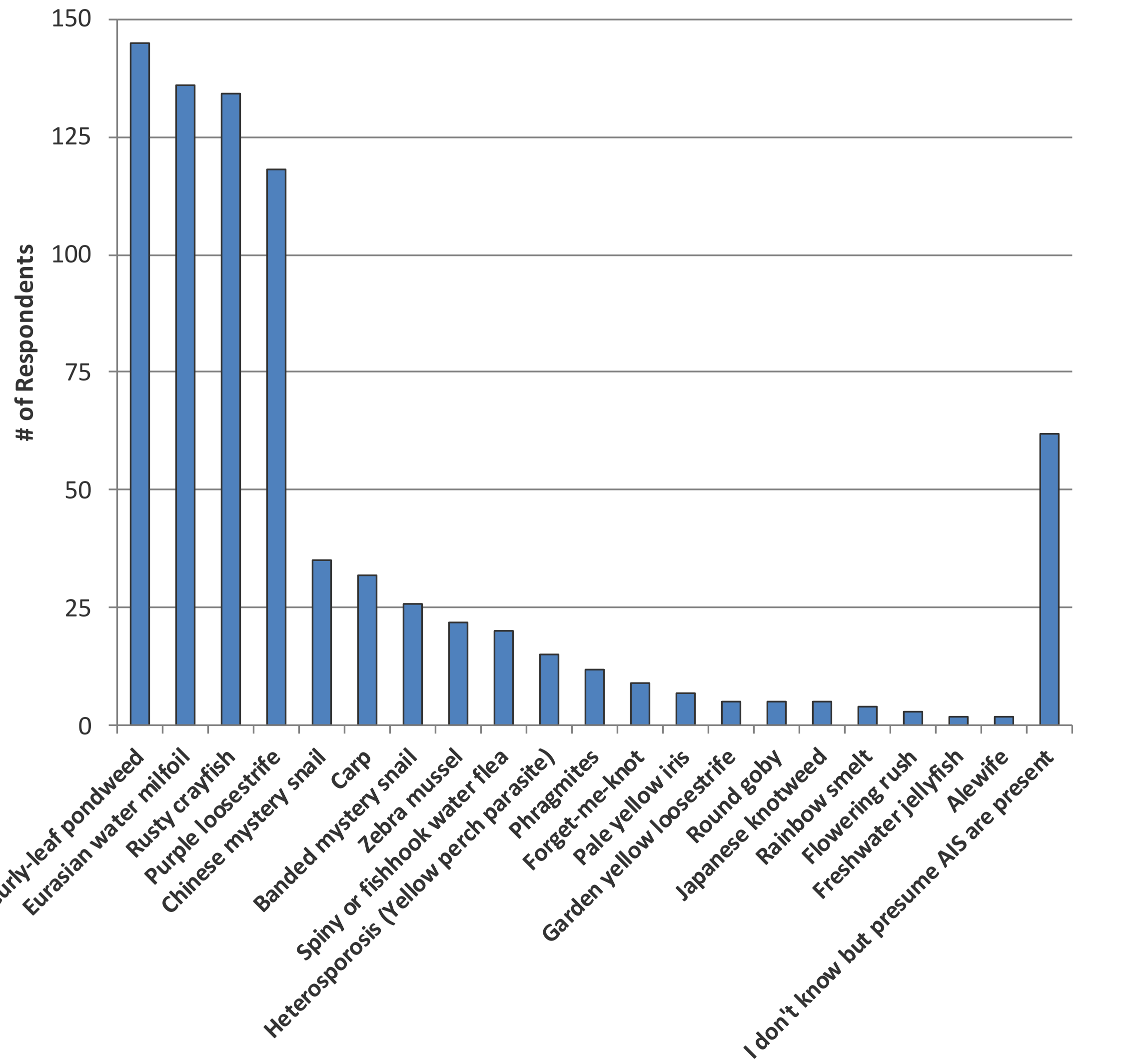


Figure 3.5-1. Stakeholder survey response Question #20. Which aquatic invasive species do you believe are in the Manitowish Waters Chain of Lakes?

3.6 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here and within each lake's individual report section as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Manitowish Waters Chain of Lakes. The goal of this section is to provide an incomplete 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 Manitowish Waters Chain of Lakes stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected as a part of this project, the following information was compiled based upon some of the data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2015 & GLIFWC 2016).

Herbicide Use and Fisheries Impacts

As mentioned in the beginning of this section, aquatic plant communities are an important component of a healthy ecosystem and provides important structural habitat for fish. Active management of the non-native plant species curly-leaf pondweed has occurred in recent years in the Manitowish Waters Chain of Lakes through herbicide treatments and hand-harvesting. Understanding the impact aquatic plant management, including the use of herbicides, has on a fishery warrants further discussion.

As is detailed in the Aquatic Plant Section (3.4), the aquatic herbicide endothall has been used in a spot-treatment use pattern on the Manitowish Waters Chain of Lakes to target and control curly-leaf pondweed. Endothall is an aquatic herbicide that is applied as either a dipotassium salt or an amine salt. These active ingredients break down following application to endothall acid, the form that acts as an herbicide (Netherland 2009). Amine salt forms of endothall (Hydrothol®) can be highly toxic to aquatic invertebrate and fish so it is recommended that they not be used in areas where fish are considered an important resource (e.g. agriculture irrigation channels). The dipotassium salt form of endothall (Aquathol® K) has been shown to have a very low to no toxicity to fish and other invertebrates (WDNR PUBL-WT-970 2012). The 2013-2016 treatments on the Manitowish Waters Chain of Lakes used the dipotassium salt from of endothall at a concentration of 2.0-3.5 ppm active ingredient (ai). The maximum application rate of the herbicide is 5.0 ppm ai.

It is important to note that US EPA registration of aquatic herbicides requires organismal toxicity studies to be conducted using concentrations and exposure times consistent with spot-treatment use patterns (high concentrations, short exposure times). Since endothall spot treatments occurred on the Manitowish Waters Chain of Lakes, the toxicological analyses of the herbicide conducted as part of the EPA registration process are transferable to the Manitowish Waters Chain of Lakes. Endothall has been a registered herbicide since 1960 and has been re-registered periodically including the latest re-registration occurring in 2017.

While endothall has not been applied in this use-pattern on the Manitowish Waters Chain of Lakes, it is important to note that only limited organismal toxicity data is available for concentrations and exposure times consistent with large-scale (aka whole-lake treatment) use patterns (low concentrations, long exposure times). The herbicide 2,4-D is commonly used to target Eurasian watermilfoil in Wisconsin and has a much different mode of action that endothall. This herbicide is also more commonly being used in large-scale use patterns. With the assistance of a WDNR AIS-Research Grant, DeQuattro and Karasov (2015) investigated the impacts on fathead minnow of 2,4-D amine concentrations more relevant to what would be observed in large-scale treatments. Because of their durability as a laboratory species, fathead minnows are often the subject of organismal toxicity studies. The LC50 (lethal concentration when half die) for fathead minnow exposure to 2,4-D (amine salt) has been determined to be 263 ppm ae sustained for 96 hours, a thousand times higher than fish would be exposed to in a large-scale treatment (target of approximately 0.3 ppm ae); however, a large-scale treatment would expose the fish to the herbicide for much longer than 96 hours.

Since the mode of action of 2,4-D involves growth regulating hormone mimicry, the focus of DeQuattro and Karasov was on reproductive toxicity and/or possible endocrine disruption potential from the herbicide. The study revealed morphological changes in reproducing male fathead minnows, such that they had lower facial tubercle scores (analogous to smaller antlers on a male white-tail deer) with some 2,4-D products/use-rates and not with others. This may suggest that the "inert" carrier may be the cause, not the 2,4-D itself. At a static exposure for 58 days (fish exposed for 28 days then eggs they laid were continued to be exposed for 30 more days post fertilization) uncovered a reduction in larval fathead survival from 97% to 83% at the lowest dose (0.05 ppm ae) of one commercially available 2,4-D amine product that was tested (no reduction at higher doses).

A cooperative UW-Steven's Point and WDNR research project entitled *Effects of 2, 4-D Herbicide Treatments Used to Control Eurasian Watermilfoil on Fish and Zooplankton in Northern Wisconsin Lakes* was conducted in response to this laboratory work to see if changes could be observed in a series of field trials. Three lakes were given large-scale 2,4-D amine treatments and a paired set of three lakes served as untreated reference lakes. The limnological, zooplankton, fisheries, and aquatic plant communities of these lakes were thoroughly sampled during the year prior to treatment, the year of treatment, and the year after treatment. A plethora of important data came from the study; however, measurable impacts from the herbicide treatments on the zooplankton and fisheries were not documented.

While the studies above discuss an herbicide not used in the Manitowish Waters Chain of Lakes to date, it underscores the acknowledgement that herbicide use comes with a risk of environmental toxicity. The use of aquatic herbicides includes regulatory oversight and must comply with the following list:

- Labeled and registered with U.S. EPA's office of Pesticide Programs;
- Permitted by the Wisconsin Department of Natural Resources (WDNR); and
- Registered for sale and use by the Department of Agriculture, Trade, and Consumer Protection (DATCP);
- Applied by a DATCP-certified and licensed applicator,

On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications or mechanical harvesting. While the Implementation Plan will discuss these specific management actions as they relate to any of the Manitowish Waters Chain of Lakes, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's fishery. Herbicide applications targeting curly-leaf pondweed occur in early-May when the water temperatures are below 60°F. As discussed above, the use of aquatic herbicides has an environmental risk that needs to be part of the decision process.

As outlined within the WDNR's Chemical Fact Sheet on Endothall (WDNR PUBL-WT-970 2012), an indirect effect of the treatment that needs to be considered is that the removal of vegetation caused by the herbicide treatment may result in temporary habitat loss at a vulnerable time of year for some fish and invertebrate species. Fish species that spawn in late spring or early summer may be impacted as water temperatures and spawning locations often overlap, and vital nursery areas for emerged fry could become susceptible. Yellow perch and muskellunge are examples of species that could potentially be affected by early season herbicide applications, as the treatments could eliminate spawning substrate or nursery areas for the emerged fry.

Manitowish Waters Chain of Lakes Fishing Activity

Table 3.5-1 is a list of popular game fish that are present in many northern Wisconsin lakes. The Manitowish Waters Chain of Lakes is host to many of these species. On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications or mechanical harvesting. While the Implementation Plan will discuss these specific management actions as they relate to any of the Manitowish Waters Chain of Lakes, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's fishery. Herbicide applications targeting curly-leaf pondweed occur in early-May when the water temperatures are below 60°F. As discussed above, the use of aquatic herbicides has an environmental risk that needs to be part of the decision process.

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.5-1.

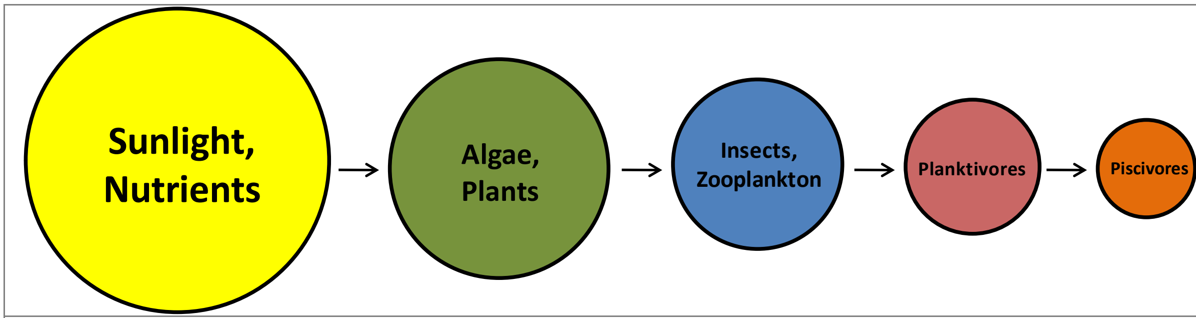

Figure 3.6-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, the majority of lakes in the Manitowish Waters Chain of Lakes are mesotrophic, meaning they have a moderate nutrient content and thus relatively moderate primary productivity. Simply put, this means Manitowish Waters Chain of Lakes, considered as a system, should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Within this project's stakeholder survey, residents were asked about their fishing activities and numerous questions included "fishing" as a potential response. Walleye is the most sought-after species on the chain (Question #10), while smallmouth bass and muskellunge are popular species as well. 82 of 215 respondents (the plurality) to Question #11 indicated that the current quality of fishing on the chain is "Fair" while 69 of 215 responded "Good". 69 and 76 respondents (out of 215) indicated that they believed the fishing had gotten either "Much Worse" or "Somewhat Worse" since they began fishing the lake (Question #12).

Although not an exhaustive list of fish species in the lake, additional species documented in past surveys of the Manitowish Waters Chain of Lakes include blackchin shiner (*Notropis heterodon*), bluntnose minnow (*Pimephales notatus*), burbot (*Lota lota*), central mudminnow (*Umbra limi*), common shiner (*Luxilus cornutus*), creek chub (*Semotilus atromaculatus*), golden shiner (*Notemigonus crysoleucas*), greater redhorse (*Moxostoma valenciennesi*), iowa darter (*Etheostoma exile*), johnny darter (*Etheostoma nigrum*), log perch (*percina caprodes*), mimic shiner (*Notropis volucellus*), mottled sculpin (*Cottus bairdi*), pugnose shiner (*Notropis anogenus*), shorthead redhorse (*Moxostoma macrolepidotum*), silver redhorse (*Moxostoma anisurum*), spottail shiner (*Notropis hudsonium*), trout perch (*Percopsis omiscomaycus*), and the white sucker (*Catostomus commersonii*).

Table 3.6.-1. Gamefish present in the Manitowish Waters Chain of Lakes with corresponding biological information (Becker, 1983).

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Bullhead	*Ictalurus melas*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Cisco*	*Coregonus artedii*	22	Late November - Early December	No clear substrate preference.	Microscopic zooplankton, aquatic insect larvae, adult mayflies, stoneflies, bottom-dwelling invertebrates.
Lake Whitefish*	*Coregonus clupeaformis*	16	Mid October - Early December	Gravel, rubble or small rocks near shores of a lake	Insects, freshwater shrimp, small fish and fish eggs
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Longear Sunfish	*Lepomis megalotis*	9	June - Early August	Water 0.25 - 0.36 m, with gravel, sand, or hard mud bottom	Aquatic insects, fish eggs, terrestrial foods, crustacea and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	*Lepomis gibbosus*	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	*Ambloplites rupestris*	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	*Micropterus dolomieu*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye	*Sander vitreus*	18	Mid April - early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Bullhead	*Ameiurus natalis*	7	May - July	Heavy weeded banks, beneath logs or tree roots	Crustaceans, insect larvae, small fish, some algae
Yellow Perch	*Perca flavescens*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

*Lake whitefish and cisco were sampled in Rest, Clear, Fawn, Spider, Island, Manitowish and Little Star during a 2014 WDNR whitefishes survey

Overview of the Manitowish Waters Chain of Lakes Fishery

Currently, 35 species of fish have been documented within the Manitowish Waters Chain of Lakes. Two of these species, pugnose shiner (*Notropis anogenus*) and the longear sunfish (*Lepomis megalotis*) are of special concern in Wisconsin. Both of these species have the listing of "threatened" within the state. The pugnose shiner has a state ranking of S2, indicating it is imperiled in Wisconsin waters because of its rarity or because of some factors making it very vulnerable to extirpation from the state. And the longear sunfish, also listed under the S2 category, is potentially imperiled in Wisconsin waters (WDNR 2011).

Other interesting species to note within the Manitowish Waters Chain (Specifically Rest, Clear, Fawn, Spider, Island, Manitowish and Little Star) include the Cisco (*Cregonus artedii*) and the lake whitefish (*Coregonus clupeaformis*). Cisco and lake whitefish also prefer cooler, deeper water. Naturally sustaining inland populations of lake whitefish are rare within the United States, and also within Wisconsin. The Manitowish Waters Chain was sampled for both species in 2014 which found a high relative abundance of cisco and low relative abundance of lake whitefish (WDNR 2014).

Downstream of the Rest Lake Dam, in the Manitowish River and smaller lakes, a fishery exists that is in some ways similar and some ways different from the Manitowish Waters Chain of Lakes fishery upstream of the dam. 42 fish species have been recorded between the Rest Lake Dam and the Turtle Flambeau Flowage. One species, the lake sturgeon (*Acipenser fulvescens*), is a relic from the Middle Ages of fish evolution. The sturgeon is a primitive looking, large fish that has a cultural significance to the states of Wisconsin and Michigan, who host the only major populations of this species. Within Wisconsin, the lake sturgeon is listed as a special concern/heritage species, and has been given a state rank of S3 meaning it is rare or uncommon statewide (WDNR 2011).

The WDNR began a study in the early 1990's aimed at learning more about the movement of sturgeon between the Turtle Flambeau Flowage and the Manitowish River. Further components include determination of spawning habitat conditions, natural reproduction outlook and an estimate of the adult population within this system. WDNR have been able to trace sturgeon movement through the use of telemetry and GPS technology. It is currently believed that sturgeon migrate from the Turtle Flambeau Flowage upstream to the Manitowish/Bear River confluence or Benson Lake to spawn, but do not make such a migration up the flowage's other main tributary, the Turtle River. The sturgeon population is currently bolstered by periodic stocking, which is conducted primarily by the WNDR but also by the Lac du Flambeau tribe. The Manitowish River lake sturgeon fishery below the Rest Lake Dam has been closed since 2004 to minimize impacts on the population until further studies indicate that a sustainable fishery exists.

In addition to playing host to the variety of interesting and unique species discussed above, the Manitowish Waters Chain has a robust fishery for walleye and muskellunge – two of Wisconsin's most popular gamefish species. While sturgeon have been studied in the waters below the Rest Lake Dam, extensive studies have taken place to track walleye and muskellunge movement in the waters upstream of the dam. Between 2004 and 2005, Jordan Weeks completed work on the Manitowish Waters Chain of Lakes as part of his graduate studies at the University of Wisconsin-Stevens Point. This work was completed with assistance from WDNR fisheries biologists as well as numerous non-profit fishing organizations. During this study, Mr. Weeks and others tracked walleye and muskellunge movement throughout the chain lakes through several methods, essentially determining if considerable movement occurred between lakes in the chain or not. The monitoring found that most walleyes remained in the same lake during the year, and between years (2004-2005). Muskellunge movement was considerable between lakes, with half of all muskellunge sampled being found in different lakes during the course of one year or between years. The study recommended that management focus (angling regulations and spearing management) should be conducted on an individual lake basis for walleye and on a chain-wide basis for muskellunge (Weeks and Hansen, 2009).

Manitowish Waters Chain of Lakes Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.6-2). The Manitowish Waters Chain of Lakes falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake, either by spear harvest or angler harvest, is a highly regimented and dictated process. This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a "total allowable catch" (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population. A "safe harvest" value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through tribal or recreational harvesting means. By March 15th of each year the relevant Indian communities may declare a proportion of the total Safe Harvest on each lake; this declaration represents the maximum number of fish that can be taken by tribal spearers or netters annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

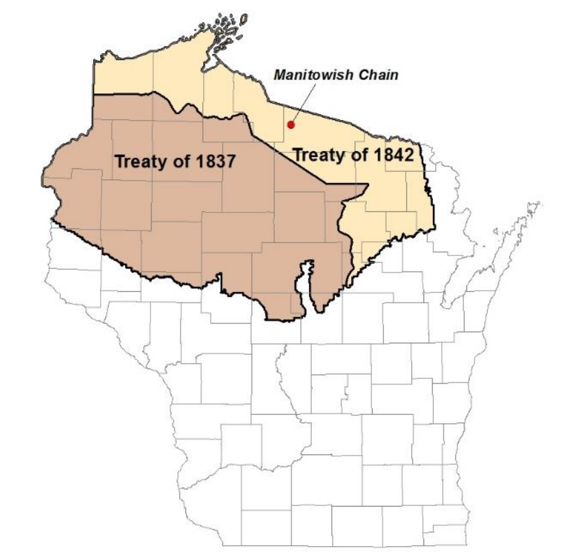

Figure 3.6-2. Location of the Manitowish Waters Chain of Lakes within the Native American Ceded Territory (GLIFWC 2017). This map was digitized by Onterra; therefore, it is a representation and not legally binding.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2016). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIWC 2016). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Harvest of a particular species ends once the declaration is met. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

The relationship between the safe harvest number, declaration and actual harvest is displayed on a chain-wide basis for walleye and muskellunge (Table 3.5-2). For individual lake harvest, safe harvest and declaration data see individual lake sections.

Table 3.5-2. Native American spear harvest frequency on the Manitowish Waters Chain of Lakes. The table summarizes the years in which each lake has experienced a walleye or muskellunge harvest. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Lake	Years of walleye harvest, 1988-2017	Years of muskellunge harvest, 1988-2017
Clear Lake	29	27
Rest Lake	29	19
Island Lake	29	12
Manitowish Lake	24	12
Alder Lake	19	1
Spider Lake	18	8
Little Star Lake	14	4
Wild Rice Lake	11	6
Stone Lake	1	1
Benson Lake	-	-
Fawn Lake	-	-
Sturgeon Lake	-	-
Vance Lake	-	-

The relationship between the safe harvest number, declaration and actual harvest is displayed on a chain-wide basis for walleye (Figure 3.5-3) and muskellunge (Figure 3.5-4). From 1989 to 2017, tribal spearers have claimed a walleye quota that is between 39.4% and 83.7% of the safe harvest, with the average safe harvest claim being 58.5%. Typically, Native American spear fishermen have harvested 75.9% of the declared quota on the Manitowish Waters Chain of Lakes with respect to walleye. For lake specific walleye spearing data see individual lake section.

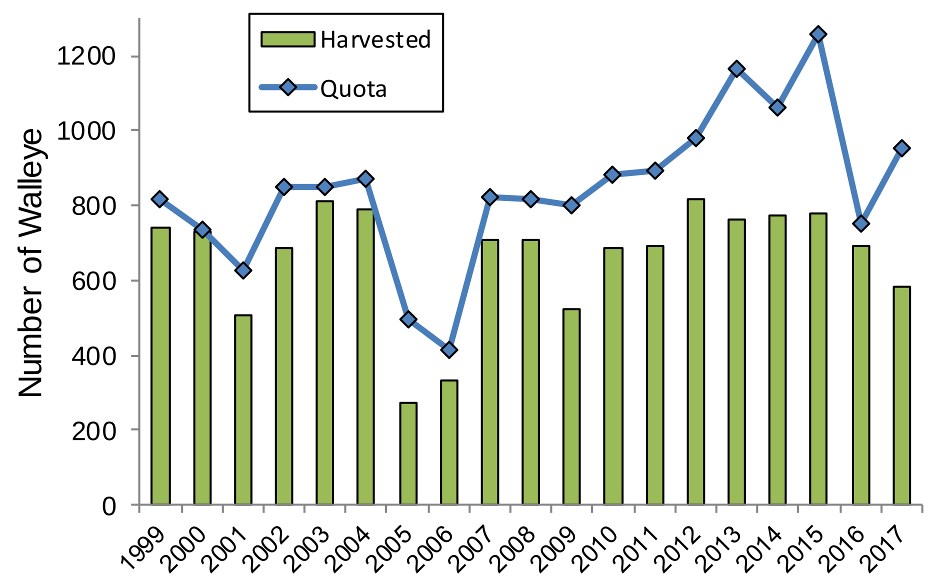

Figure 3.6-3. The Manitowish Waters Chain of Lakes walleye spear harvest data. (GLIFWC 1999-2017).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1999. From 1999 to 2017, tribal spearers have claimed a muskellunge quota that is between 45.8% and 56.0% of the safe harvest, with the average safe harvest claim being 51.7%. Between 1999 and 2017, Native American spear fishermen have harvested an annual average of 18.0% of the declared quota on the Manitowish Waters Chain of Lakes with respect to muskellunge. For lake specific muskellunge spearing data see individual lake section.

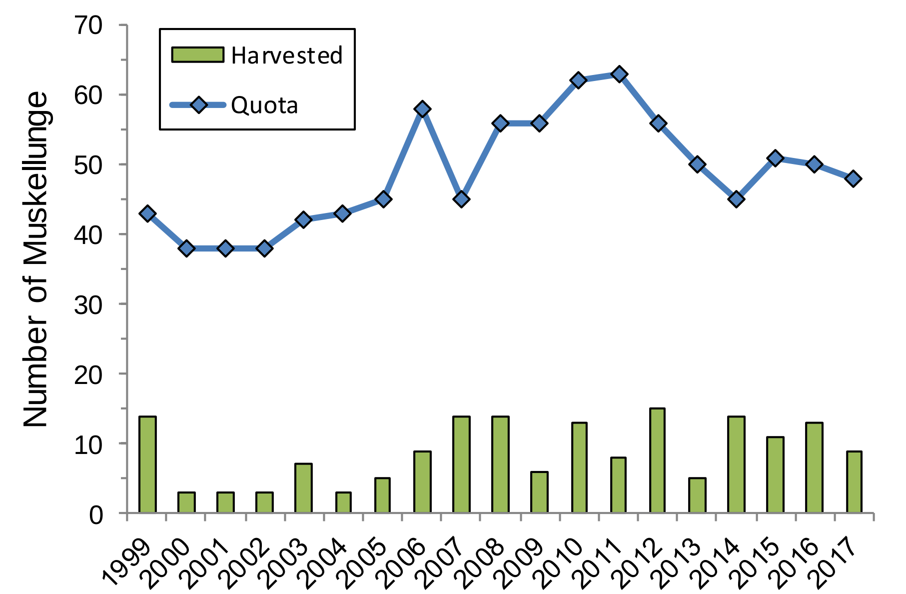

Figure 3.6-4. The Manitowish Waters Chain of Lakes muskellunge spear harvest data. (GLIFWC 1999-2017).

Manitowish Waters Chain of Lakes Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra, the lakes within the Manitowish Waters Chain of Lakes varied quite a bit in terms of their substrate type. Some of the lakes contained mostly a soft, mucky bottom, while others were dominated by sand (Table 3.5-3). Some of the lakes had a good mixture of both substrates and incorporated some rocky areas as well.

Table 3.5-3 Substrate types for the Manitowish Waters Chain of Lakes. Data collected during point intercept surveys by Onterra and the WNDR.

Project Phase	Lake	% Muck	% Sand	% Rock
I - 2012	Island Lake	62	26	12
	Rest Lake	35	60	5
	Papoose Bay	76	21	3
	Spider Lake	17	63	20
II - 2013	Clear Lake	54	34	12
	Fawn Lake	87	13	0
III - 2014	Alder Lake	31	61	8
	Wild Rice Lake	65	26	10
IV - 2016	Little Star Lake	3	83	13
	Manitowish Lake	25	64	11
V - 2017	Benson Lake	41	47	12
	Stone Lake	48	40	12
	Sturgeon Lake	28	69	3
	Vance Lake	6	67	26

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barren of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass 2006).

According to the point-intercept survey conducted by Onterra, the lakes within the Manitowish Waters Chain of Lakes varied quite a bit in terms of their amount of coarse woody habitat (Table 3.6-4). The lake with the most coarse woody habitat per mile of shoreline was Stone Lake, the least was Spider Lake.

Table 3.6-4 Percent substrate types in the Manitowish Waters Chain of Lakes.

Project Phase	Lake	Total Pieces	Ratio per mile of shoreline
I - 2012	Island Lake	83	7 to 1
	Rest Lake	59	7 to 1
	Papoose Bay	13	16 to 1
	Spider Lake	27	5 to 1
II - 2013	Clear Lake	246	40 to 1
	Fawn Lake	113	40 to 1
III - 2014	Alder Lake	36	13 to 1
	Wild Rice Lake	85	21 to 1
IV - 2016	Little Star Lake	110	26 to 1
	Manitowish Lake	175	25 to 1
V - 2017	Benson Lake	33	28 to 1
	Stone Lake	447	56 to 1
	Sturgeon Lake	34	28 to 1
	Vance Lake	113	46 to 1

Fish Habitat Structures

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

Fishing Regulations

Because the Manitowish Waters Chain of Lakes is located within the northern region of Wisconsin, special regulations may occur that differ from those in other areas of the state. For example, the Manitowish Waters Chain of Lakes is in the northern large and smallmouth bass management zone. Also, parts of the Manitowish River are considered a refuge in the spring and are closed to all fishing. Until 2015, annual walleye bag limits were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season.

In 2015, new regulations for walleye were created to accompany the state's Walleye Initiative. Because of the numerous waters included with the chain, anglers should visit the WDNR website (www. http://dnr.wi.gov/topic/fishing/regulations/hookline.html) for specific fishing regulations or a local bait and tackle shops to receive a free fishing pamphlet that would contain this information.

Mercury Contamination and Fish Consumption Advisories

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

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

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

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

Figure 3.6-5. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

4.0 SUMMARY AND CONCLUSIONS

While this project was spurred about largely due to the discovery of curly-leaf pondweed on the Manitowish Waters Chain of Lakes, the design of the phased approach captured detailed information about a wealth of components. These include aquatic invasive species inventories, of course, but also much baseline data on the Manitowish Waters Chain of Lakes ecosystem as well as sociological information from Manitowish Waters Chain of Lakes stakeholders regarding their use of the chain and its management. The objectives filled during this planning process have provided the NLDC, MWLA and other entities with the information and guidance needed to manage the Manitowish Waters Chain of Lakes in an effective manner.

The scientific studies conducted on the chain have covered a variety of ecological components, including water quality, watershed and shoreland analysis, aquatic plant surveys, and an integration of available fisheries data. These studies indicate that the Manitowish Waters Chain of Lakes is a healthy ecosystem, albeit with several pressing issues that are of concern to lake residents. Both the exceptional health of the lakes, and the troubling aspects, are discussed in depth within this report.

The water quality analysis included over 20 years of available data for some parameters. This analysis would not have been possible without sampling undertaken by volunteers through the Citizens Lake Monitoring Network (CLMN). The importance in these volunteer efforts is that in building a large database, lake managers are able to determine if trends are occurring for certain, instead of relying upon anecdotal accounts of what is occurring. The CLMN volunteers' work should be commended and actions taken to ensure these efforts continue. Though historical data was very prevalent for some factors, it was non-existent for others. The Implementation Plan that follows describes the importance of entering the Manitowish Waters Chain of Lakes into the CLMN's advanced monitoring program, which will allow for the inclusion of other parameters to be collected each year by Manitowish Waters Chain of Lakes volunteers.

The water quality of the Manitowish Waters Chain of Lakes was determined to be consistent with what is typically seen in lowland drainage lakes, such as those found in the Manitowish Waters Chain of Lakes. This conclusion is drawn from comparisons with similar lake types across the state, and alongside all lakes in the Northern Lakes and Forests Ecoregion. The lakes receive water from a vast area of land, which drains primarily wooded and wetland areas in northern Wisconsin. These natural, well-vegetated lands help to reduce erosion and pollutant transport to the chain. With that, it becomes increasingly important that if the Manitowish Waters Chain of Lakes residents wish to maintain this water quality, they must preserve as much of the natural lands within the watershed as possible. This includes land that is a distance from the receiving waters as well as the immediate shoreland zone of the lakes.

A major component of this project's studies included assessments of the native, and if applicable, non-native aquatic species in each project lake. It is interesting to note that although these lakes are interconnected, and very close in proximity to each other, each project lake contains some similar species yet has its own unique aquatic plant community as well. Along with water quality differences, factors such as shoreline condition, substrate type, and lake morphology can determine the amount and type of habitat for aquatic plant species. As described in the Aquatic Plant Section, there is a great diversity of these habitat conditions so it is not surprising that a species rich aquatic plant community exists.

A significant threat that has been imposed on the ecology of the Manitowish Waters Chain of Lakes is the introduction of curly-leaf pondweed. The MWLA and NLDC have worked with professional lake managers, hand-harvesters, and applicators to manage curly-leaf pondweed. The two entities have also applied many of their own hours monitoring the chain and hand-harvesting curly-leaf pondweed. In all areas of the chain besides Rice Creek and one very small area in Fawn Lake, only point-based data were collected during Onterra's 2019 early-season AIS survey. These results indicate that while the footprint of curly-leaf pondweed has increased since 2012, its density is still very low. Continued diligent monitoring and hand-harvesting will need to be continued to keep the population low.

The Manitowish Waters Chain of Lakes is a unique resource that many individuals with many different interests utilize. It provides for an outstanding recreational facility that anglers, boaters, swimmers, connoisseurs of nature and others can enjoy. It is a large and complex ecosystem that inspires one with its picturesque beauty and serene, "up north" feeling. With the knowledge that has been gained through this series of studies, the NLDC, MWLA and TAISP now have a strategic plan in place to maximize the positive attributes of each lake, address the negative attributes, and effectively and efficiently manage the entire ecosystem as a whole. The Chain Wide Implementation Plan that follows is a result of the hard work of many Manitowish Waters Chain of Lakes stakeholders, and can be applied to each and every lake within the chain.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the MWLA, NLDC, the Towns of Manitowish Waters and Boulder Junction (collectively termed the Town Aquatic Invasive Species Partnership, or TAISP) as well as ecologist/planners from Onterra. It represents the path the TAISP will follow in order to meet their lake management goals. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Manitowish Waters Chain of Lakes stakeholders as portrayed by the members of the Planning Committee, the returned stakeholder surveys, and numerous communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under continuous review and adjustment depending on the condition of the chain of lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders. While the MWLA and NLDC are listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by an individual. The MWLA and NLDC will be responsible for deciding upon individual coordinator positions which will be utilized to achieve the various management goals.

Management Goal 1: Strengthen Association Relationships, Effectiveness and Lake Management Capability

Management Action:	Enhance involvement with other entities that have a role in managing the Manitowish Waters Chain of Lakes.
Timeframe:	Continuation of existing efforts
Facilitator:	NLDC; MWLA Board of Directors; Towns of Manitowish Waters and Boulder Junction.
Description:	The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. It is important that the NLDC, MWLA, and Towns of Manitowish Waters and Boulder Junction actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities reduce the duplication of efforts. While not an inclusive list, the pertinent parties for the Manitowish Waters Chain of Lakes range from those located locally (Town of Manitowish Waters, Town of Boulder Junction, Lac du Flambeau Tribe) to those at the County level (Vilas County AIS Coordinator, Vilas County Lakes & Rivers Association) and at the level of the State of Wisconsin (WDNR, GLIFWC). Each entity is specifically addressed Table 5.0-1.

Table 5.0-1 Management Partner List.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Town of Manitowish Waters	General Town Chair (John Hanson,715.543.8413, townchair@mwtown.org)	Oversees ordinances, funding, and other items pertaining to town	As needed.	Involved in lake management activities, monitoring, implementation, funding, volunteer recruitment. May be contacted regarding ordinance questions, and for information on community events.
Town of Boulder Junction	General Town Chair (Dennis Reuss, 262.993.1857, d.reuss@townofboulderjunction.org)	Oversees ordinances, funding, and other items pertaining to town	As needed.	Directly involved in lake management activities, monitoring, implementation, funding, and volunteer recruitment. Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Manitowish Waters Lake Association	President (Bob Becker, 715.543.2219)	Advocates for clean, healthy and safe waters within township.	As needed.	Directly involved in lake management activities including grants, monitoring, implementation and volunteer recruitment.
North Lakeland Discovery Center	Executive Director (John Heusinkveld, 715.543.2085, john@discoverycenter.net) Water Program Coordinator (Emily Heald, 715.543.2085, water@discoverycenter.net)	Educates and inspires connection to the natural state of the Northwoods	As needed.	Project sponsor. Direct resource for AIS education and monitoring needs, operates aquatic education programs and assists with volunteer recruitment.
Chamber of Commerce: Manitowish Waters and Boulder Junction	Manitowish Waters Executive Director (Sarah Pischer, 715.543.8488, sarah@manitowishwaters.org) Boulder Junction Executive Director (Theresa Smith, 715.385.2400)	Disseminate literature and coordinate events	As needed.	Disseminates AIS and lake management materials to members of the public and coordinate community events.
Lac du Flambeau Tribe	Water Resource Specialist (Celeste Hockings, 715.588.4163 chockings@ldftribe.com)	Manages reservation water resources	As needed.	Collaborate on lake management activities including grants, monitoring, and implementation within tribal waters.
Great Lakes Indian Fish and Wildlife Commission	General (715.682.6619)	Resource management within Ceded Territory	As needed.	Collaborate on lake related studies, AIS management, inform of meetings, etc.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Vilas County Lakes & Rivers Association (VCLRA)	President (Tom Ewing, president@vclra.us)	Protects Vilas Co. waters through facilitating discussion and education.	Twice a year or as needed.	Become aware of training or education opportunities, partner in special projects, or networking on other topics pertaining to Vilas Co. waterways.
Vilas County Land and Water Conservation Department	Lake Conservation Specialist (Cathy Higley, 715.479.3738, cahigl@vilascountywi.gov)	Oversees AIS monitoring and education activities county-wide.	Twice a year or more as issues arise.	AIS training and ID, monitoring techniques, CBCW training, report summer activities.
	Conservation Specialist (Mariquita (Quita) Sheehan, 715.479.3721, mashee@vilascountywi.gov)	Oversees conservation efforts for lake grants and projects.	Twice a year or more as needed.	Contact for shoreland remediation/restoration techniques and cost-share procedures, wildlife damage programs, education and outreach documents.
Wisconsin Department of Natural Resources	Fisheries Biologists Upstream of Rest Lake Dam: (Steve Gilbert, 715.356.5211) Downstream of Rest Lake Dam: (Zach Lawson, 715.476.7847)	Manages the fish populations and fish habitat enhancement efforts.	Once a year, or more as issues arise.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
	Lakes Coordinator (Kevin Gauthier, 715.356.5211)	Oversees management plans, grants, all lake activities.	As needed.	Information on planning/AIS projects, grant applications or to seek advice on other lake issues.
	Environmental Grant Specialist (Laura Macfarland, 715.365.8920, laura.macfarland@wisconsin.gov)	Oversees financial aspects of grants.	As needed.	Information on grant financials and reimbursement, CBCW grant applications.
	Conservation Warden (Rich Thole, 715.605.2130)	Oversees regulations handed down by the state.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367, 24 hours a day).	Contact regarding suspected violations pertaining to recreational activity, include fishing, boating safety, ordinance violations, etc.
	Water Resources Mgmt Specialist (Sandra Wickman, 715.365.8951, Sandra.Wickman@wisconsin.gov)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Arrange for training as needed, report monitoring activities.
	Trout Lake Station staff (Susan Knight and Carol Warden (715.356.9494)	Conducts lake research on multiple levels	As needed.	Can be contacted for identification or consultation on AIS.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Vilas County Sheriff Dept.	Manitowish Waters Chain of Lakes Water Safety Patrol Officer (Dan Cardinal, 715.543.8400 non-emergency, 911 for emergencies only.)	Perform law enforcement duties to protect Manitowish Waters lakes, especially pertaining to compliance with boating safety rules.	As needed.	Contact regarding suspected violations pertaining to boating safety rules on the Manitowish Waters Chain of Lakes.
University of Wisconsin Extension Office	Lake Specialist (Pat Goggin, 715.365.8943, Patrick.Goggin@wisconsin.gov)	Provides guidance for lakes, shoreline restoration, and outreach/education.	As needed.	Contact for shoreland remediation/restoration techniques, outreach/education.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates	Those interested may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.

During the planning process associated with this project, discussions were had regarding a list of other groups/individuals that play an important role in the Manitowish Waters Chain of Lakes' health and functionality. Several of these entities were identified during planning meetings:

1. New lake residents: New residents may be unfamiliar with their neighbors, the MWLA and NLDC or the tremendous effort that has gone into protecting the health of the Manitowish Waters Chain of Lakes. New lake residents will receive a packet in the mail including information about the MWLA, its mission, projects, volunteer opportunities; TAISP; individual lake information; and general lake stewardship outreach materials. This packet will be based off of the efforts and educational outreach materials developed by the VCLRA Homebuyer Initiative Committee and UW-Lakes Extension.

2. Economic Development Association: The Northwoods of Wisconsin is well known for its natural beauty and freshwater lakes and streams. Economic developers often use these attractions as selling points for encouraging tourism. The MWLA and NLDC will work to encourage open communication with the Manitowish Waters Economic Development Association (MWEDA) on matters pertaining to recreational and tourism opportunities. In turn, the MWEDA will continue to promote the Manitowish Waters Chain of Lakes as an attraction unique to the region. The process

is currently moving efficiently, with several MWLA and NLDC members serving on the MWEDA board of directors.

Action Steps:

1. Refer to management entity table and contact partners as necessary.
2. TAISP select a contact person to discuss lake-friendly property management and AIS with above named groups.

<u>Management Action:</u> Increase the Manitowish Waters Chain of Lakes' volunteer base

Timeframe: Continuation of existing efforts

Facilitator: MWLA Board of Directors; NLDC

Description: Even though lake associations consist of large groups of people, it can be hard to recruit members to offer their time for lake management. Many lake association members are elderly and retired, so labor intensive jobs can be difficult to perform. Other members may visit their lake infrequently. Some have cut back on volunteering because of recent economic downturns or have concerns over the time commitment involved with volunteer tasks. Those that have volunteered in the past and have had a poor experience may be hesitant to volunteer again. Others may simply have not been asked to lend their services. Without good management, volunteers may become underutilized. Volunteers want to feel good about themselves, so every effort must be made by volunteer managers to organize help efficiently and effectively while fostering a healthy work environment.

The MWLA and NLDC are proud of their active role in preserving the Manitowish Waters Chain of Lakes for all stakeholders; however, they are in constant need of volunteers to continue this high level of commitment. As a result of the pressure of issues such as aquatic invasive species, the Manitowish Waters Chain is now in need of more oversight than ever before. During this planning process, MWLA and NLDC Board Members discussed various techniques for engaging more volunteers.

In order to retain volunteer help and recruit more volunteers for these tasks, the MWLA and NLDC will undertake a volunteer recruitment strategy as outlined below. While volunteer recruitment for a lake association may be difficult, the following tips will be helpful in the MWLA's efforts to solicit help for lake-related efforts.

Action Steps:

1. Recruiting techniques (passive): on the annual MWLA membership form, a checkbox would be added indicating interest in volunteering. Checking this box would allow a MWLA or NLDC Board Member to contact the person for a volunteer task. An additional passive technique would be the display of a small booth or pamphlets at a public location, such as the town library, chamber of commerce meetings, or NLDC offices / lobby.
2. Recruiting technique (direct): recruiting through active means is often more effective than passively. A direct recruiting measure would include speaking to new property owners as part of a "Welcome Wagon" campaign. A TAISP representative would visit the new property owner's home and discuss matters on the chain, the TAISP, and volunteering opportunities.
3. NLDC serves as volunteer coordinator. The coordinator's duties are to train, supervise, track and recognize volunteers. Building and maintaining a volunteer database with names, contact information, tasks and hours completed will be necessary. MWLA Board of Directors identifies volunteer opportunities that may arise. Volunteer coordinators should be friendly, outgoing persons who are able to engage people.
4. MWLA Board of Directors will initially recruit and encourage volunteers through personal means. Engaging a person in a friendly atmosphere through a personal invitation is more likely to result in a successful recruitment. Other means of recruitment such as telephone, email, newsletter notification, website, social media, bulletin boards, or newspapers will also be utilized.
5. MWLA Board of Directors and volunteer coordinator will build and maintain a comprehensive volunteer database, periodically updating contact information of all volunteers (active and non-active) and enlisting assistance from lake captains in reviewing and updating database.
6. Coordinator will have duties and expectations outlined prior to recruiting volunteers. Work descriptions, timeframes, logistics, and other specifics should be known by each volunteer prior to beginning a project or task.
7. Coordinator will be flexible in allowing volunteers to contribute towards project logistics. Recruiting new leaders through delegating tasks will empower volunteers and give them reason to continue volunteering.
8. The board of directors and volunteer coordinator will recognize volunteers through incentives and appreciation. Snacks, beverages, public acknowledgement and other means of expressing appreciation are encouraged.

Management Goal 2: Maintain Current Water Quality Conditions

Management Action: Continue and expand monitoring of the Manitowish Waters Chain of Lakes' water quality through the WDNR Citizen Lake Monitoring Network.

Timeframe: Continuation of current effort.

Facilitator: MWLA Board of Directors; NLDC

Description: Monitoring water quality is an important aspect of lake management. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. Early discovery of negative trends will likely aid in an earlier definition of what may be causing the trend.

The Citizens Lake Monitoring Network (CLMN) is a program in which volunteers are trained to collect water quality data on their lake. Volunteers trained as a part of the CLMN program begin by collecting Secchi disk transparency data for one year, then if space is available, the lake group may enter into the *advanced program* and collect water chemistry data (chlorophyll-a and total phosphorus). The Secchi disk readings and water chemistry samples are collected three times during the summer and once during the spring. As a part of this program, these data are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS).

Some of the lakes within the Manitowish Waters Chain of Lakes have active volunteers collecting data each year – either within the confines of the initial or advanced program. Ideally, all lakes within the chain would have advanced monitoring occurring each year; however, it is a more realistic goal to push for all lakes monitoring Secchi disk transparency for now. It is important to get volunteers on board with the base Secchi disk data CLMN program so that when additional spots open in the advanced monitoring program, volunteers from interested lakes will be ready to make the transition into advanced monitoring.

When volunteer turnover occurs, the Board of Directors/ NLDC will contact Sandra Wickman (715-365-8951) or the appropriate WDNR/UW Extension staff to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Board of Directors/NLDC recruit contact person/coordinator and identify potential water quality volunteers per lake.
2. Coordinator directs water quality monitoring program efforts.

3. Coordinator reports results to WDNR as well as MWLA and NLDC members during annual meeting.

Management Action:	Educate property owners about the impacts of highly developed shoreland areas on the health of the Manitowish Waters Chain of Lakes and encourage shoreland restoration of these areas.
Timeframe:	Initiate 2014.
Facilitator:	MWLA Board of Directors with assistance from NLDC
Description:	As discussed within the Shoreland Condition Section, the shoreland zone of a lake is highly important to the ecology of a lake. When shorelands are developed, the resulting impacts on a lake range from a loss of biological diversity to impaired water quality. Because of its proximity to the waters of the lake, even small disturbances to a natural shoreland area can produce ill effects. A shoreland assessment survey has indicated that 14.2 miles (19%) of the entire Manitowish Waters Chain of Lakes shoreline holds Urbanized or Developed-Unnatural areas. Fortunately, restoration of the shoreland zone can be less expensive, less time-consuming and much easier to accomplish than restoration efforts in other parts of the watershed. Cost-sharing grants and Vilas County staff devoted to these types of projects give private property owners the funds and information resources to restore quality shoreland habitat to their lakeside residence. Map 1 of each individual lake report displays the locations of Urbanized and Developed-Unnatural shorelands on the Manitowish Waters Chain of Lakes that present opportunities for restoration. The MWLA and NLDC will work with appropriate entities such as the Vilas County Land & Water Conservation Department to research grant programs, shoreland restoration techniques and other pertinent information that will help restore and protect portions of the shoreland. Educational outreach materials will be developed and distributed via newsletters, websites, brochures, and personal contact. These materials will include information about the importance of shorelands impacts, restoration techniques, and opportunities that will help landowners make informed decisions about managing their shoreland. Previously restored shoreland properties can serve as excellent demonstration sites. The NLDC has an easily accessible shoreline restoration area and rain garden that present area residents the opportunity to view a shoreland that has been restored to a more natural state and learn techniques, maintenance, and labor and cost-sharing opportunities that exist for these projects. NLDC staff will oversee/plan demonstration tours at this location and potentially other restoration areas with the assistance of MWLA. The MWLA could also nominate lakeshore property owners for the Vilas County Lakes and Rivers Association's Blue Heron Award, which recognizes lake property

owners who demonstrate lake stewardship principles in development and use of their waterfront property to minimize environmental impacts. In addition, the NLDC will serve as a point-of-contact for Manitowish Waters Chain property owners who request more information on this topic.

Action Steps:

1. Develop and/or disseminate educational outreach materials regarding shoreline importance, impacts, restoration techniques, and opportunities.
2. Identify a contact person for shoreland restoration questions who will direct interested property owners to Vilas County Land & Water Conservation Department officials.
3. Interested property owners work with Vilas County Conservation Specialist to determine site eligibility, design plans, etc.
5. NLDC and MWLA utilize existing shoreline restorations and rain gardens at the NLDC property as a demonstration site for educational purposes; and identify and promote other restoration projects as needed

Management Action: Protect natural shoreland zones along the Manitowish Waters Chain of Lakes.

Timeframe: Initiate 2014.

Facilitator: MWLA Board of Directors with assistance from NLDC

Description: Despite the developed shoreland that surrounds the Manitowish Waters Chain of Lakes, a fair amount (44.1 miles or 60% of shoreline on Phase I-V lakes) of natural and developed-natural shorelands are present as well. It is therefore very important that owners and land managers of these properties increase their awareness of the benefits that their shoreland is providing to these waterbodies and that these shorelands remain in a natural state.

Map 1 of each individual lake report displays the locations of Natural and Developed-Natural shorelands on the Manitowish Waters Chain of Lakes. These shorelands present opportunities for educational outreach initiatives and physical preservation. The MWLA and NLDC will work with appropriate entities to research grant programs and other pertinent information that will aid in preserving the Manitowish Waters Chain of Lakes' shoreland. This would be accomplished through education of property owners and land managers; and/or direct preservation of land through encouragement of conservation easements or land trusts.

Valuable resources for this type of conservation work include the WDNR, UW-Extension and Vilas County Land & Water Conservation Department. Several websites of interest include:

- Wisconsin Lakes website: (www.wisconsinlakes.org/shorelands)

- Conservation easements or land trusts: (www.northwoodslandtrust.org; www.vclra.us)
- UW-Extension Shoreland Restoration: (http://www.uwex.edu/ces/shoreland/Why1/whyres.htm)
- WDNR Shoreland Zoning website: (http://dnr.wi.gov/topic/ShorelandZoning/)

Action Steps:

1. Develop and/or disseminate educational outreach materials regarding shoreline importance and benefits of preservation. Material will include biological research as well as grant/funding opportunities.
2. Identify a contact person to assist residents that are interested in protecting shoreland areas by answering questions and directing interested residents to appropriate resources/sources.

Management Goal 3: Expand Awareness and Education of Lake Management and Stewardship Matters

Management Action:	Engage stakeholders on priority education items through efficient communication and outreach.
Timeframe:	Continuation of current efforts and expansion in 2014.
Facilitator:	NLDC and MWLA Board of Directors

The mission of the NLDC is to enrich lives and inspire an ethic of care for Wisconsin's Northwoods, through the facilitation of connections among people, nature and community. The purpose of the MWLA is to educate the public and maintain, protect and enhance the water quality, fishery, boating safety, and native habitat of the Manitowish Waters Chain of Lakes and other waters in Manitowish Waters Township for the benefit of the members and the general public. These two entities have instituted a great number of educational and outreach programs, as well as conservation minded projects which benefit the chain lakes and those that enjoy them.

Education represents an effective tool to address lake issues like water quality, invasive species, shoreline development, lawn fertilization, as well as other concerns such as community involvement, noise or light pollution, and boating safety. Education of lake stakeholders on all matters is important, however during conversations with the NLDC and MWLA it became apparent that certain topics require focused time and effort. These topics have direct implication on the ecology and health of the lake, as well overall management of the lake and its recreational opportunity. They include:

1. Lake stewardship: This includes preservation of the natural watershed, enhance lake habitat along the shoreland, volunteering opportunities for lake monitoring, etc. Additional lake stewardship responsibilities include following posted ordinances or courtesy codes for noise, light, etc.

2. Recreation and safety: Ordinances for the Town of Manitowish Waters may be found on the town's website (http://mwtown.org/index.html), and are displayed at several public access locations. The towns maintain a series of navigational signs and buoys on the chain. Statewide watercraft operation regulations can be found at http://dnr.wi.gov/topic/boat/.

3. Lake ecology: This category may include aquatic invasive species, native plant communities, water quality, fisheries management and habitat enhancement, etc. Many of the sources listed within the table under Management Goal 1 are good resources for information on lake ecology. More information can be found on the WDNR's website for:

   - Aquatic plants - http://dnr.wi.gov/lakes/plants/
   - Water quality - http://dnr.wi.gov/topic/surfacewater/
   - Shoreland protection - http://dnr.wi.gov/topic/ShorelandZoning/
   - Waterways protection - http://dnr.wi.gov/topic/waterways/

4. Political events: Much of the decision-making that pertains to lake management is related to the legislation that is developed through our federal, state and local political institutions. As lake stewards, it is important for the TAISP and other partners to be knowledgeable on legislation pertaining to lakes. The TAISP may share information on lake legislation with members and partners, obtaining this information from reputable sources such as Wisconsin Lakes (www.wisconsinlakes.org) or other environmental public policy entities.

With advances in technology, sharing informational material has become multi-faceted. Currently, the level of communication is high between the MWLA and NLDC and Manitowish Waters Chain stakeholders. The MWLA provides three newsletters a year to members, both in hard copy and electronic (email) format. Email alerts are sent out whenever immediate attention is needed on an issue. The MWLA and TAISP have developed brochures that are available in numerous locations across the Town of Manitowish Waters. A working relationship has been formed between the MWLA and NLDC with the Lakeland Times and FYI Northwoods to distribute news releases. Both the MWLA and NLDC also host a Facebook® page, blog, as well as their own websites. An annual MWLA meeting is held each summer in collaboration with the NLDC and is well attended.

Streamlining educational initiatives through the TAISP will ensure that information continues to be updated within these numerous outlets in an efficient manner. The NLDC will be responsible for reaching out to state or local affiliates which can provide them with educational pamphlets, other materials or ideas for content. These partners may be some of those included in the table found under the table included with Management Goal 1.

Action Steps:

1. The NLDC with the support of the Board of Directors prepares materials for specific issues, such as those defined above.
2. Educational outreach materials are incorporated into MWLA annual meetings, NLDC programming, and within respective newsletters, websites, etc.

Management Goal 4: Control Existing and Prevent Further Aquatic Invasive Species Establishment within the Manitowish Waters Chain of Lakes

Management Action:	Conduct curly-leaf pondweed Population Control on the Manitowish Waters Chain of Lakes using Hand-Harvesting and Herbicide Spot Treatments
Timeframe:	Continuation of current effort
Facilitator:	NLDC with assistance from TAISP
Description:	As described in the Aquatic Plant Section (3.4), the goal of curly-leaf pondweed management is to annually kill or remove the plants before they are able to produce and deposit new turions, and thus, overtime, deplete the existing turion bank within the sediment. As a result, curly-leaf pondweed control actions traditionally occur each year when surface water temperatures are between 50°F and 60°F. After multiple years of treatment, the turion base becomes exhausted and the curly-leaf pondweed infestation becomes significantly less. Normally a control strategy such as this includes 5-7 years of treatments of the same area. Based upon the low quantities of curly-leaf pondweed located in 2017-2019, it is believed that the exotic is under control. This is particularly the case within the Spider-Island Channel where the bulk of active management has occurred. If the following trigger is met, the NLDC would begin discussions regarding herbicide spot treatments for curly-leaf pondweed: colonized areas (i.e. mapped with polygons) where a sufficiently large treatment area can be constructed to hold concentration and exposure

times (preference to *dominant* or greater density curly-leaf pondweed populations). These discussions would include WDNR staff at an early stage. The NLDC acknowledges the difficulty that associates conducting spot treatments within narrow littoral bands or areas of high flow. To assist in the logistics and planning of areas to be targeted for herbicide control, the NLDC would follow the following guidelines:

- All areas targeted the previous year would be considered for treatment and included within each year's conditional permit application. Based upon the pretreatment survey, these areas may be reduced or removed.
- All areas of colonized curly-leaf pondweed exceeding a *dominant* density rating will be considered for treatment during the following spring. The NLDC's treatment threshold (trigger) may also extend to immediately adjacent colonies of curly-leaf pondweed that are below this density-based threshold.

The NLDC would also conduct pre- and post-treatment monitoring of these areas by comparing the early-season AIS mapping surveys the year before and the year of the treatment. A pretreatment survey would be conducted during the spring prior to the herbicide treatment implementation to potentially make refinements and/or dictate timing of the treatment. If an individual herbicide treatment size exceeds 10 acres, the addition of quantitative (sub-sample point-intercept) sampling component to the monitoring plan would likely occur.

Where spot treatments are not anticipated to be effective but control of target species is still sought (as opposed to just monitoring them), a professional-based hand-harvesting efforts may be chosen. At the time of this writing, the newly identified curly-leaf pondweed population in Rest Lake just south of Papoose Bay is a likely location where professional hand-harvesting would occur. If a Diver Assisted Suction Harvest (DASH) component is utilized, the NLDC and contracted firm would be responsible for permit procedures. The contracted firm would be guided with GPS data from the consultant and would track their effort for post assessments.

Overall, the NLDC will evaluate the effectiveness of the management option, financial costs, and other factors to determine the control effort chosen.

Annual Curly-leaf Pondweed Monitoring

Since 2012, the MWLA has utilized professional surveys to monitor curly-leaf pondweed occurrences in lakes known to have the most frequent curly-leaf pondweed occurrences. As of 2018, these waterbodies included, Rice Creek, Island Lake, Spider Lake, Stone

Lake, and Manitowish Lake. These waterbodies would continue to be monitored by professionals each spring to guide that year's hand-harvesting efforts (both professional and local) and to detect areas that may require consideration for potential herbicide spot treatments. Rest Lake, the Manitowish River to Stone Lake, and Fawn Lake would be monitored by NLDC staff. The remaining waterbodies in the chain would also be monitored on a rotating basis by NLDC staff and annually as a part of the MWLA AIS monitoring program discussed below.

Action Steps:

See description above as this is an ongoing program

<u>Management Action:</u> Continue control and monitoring efforts on other aquatic invasive species that pose a threat to the Manitowish Waters Chain of Lakes.

Timeframe: Continuation of current effort.

Facilitator: NLDC

Description: Purple loosestrife and pale yellow iris are two emergent, wetland aquatic invasive species known to exist in several areas throughout the chain, residing on the shoreland zone. Phragmites (confirmed to be the non-native strain) was discovered in 2011 along the Trout River corridor between Alder and Manitowish Lakes, and several plants were found on Alder Lake in 2014. Japanese knotweed is known to exist in close proximity to the chain. And spiny water flea has been confirmed in the upstream waters of Trout Lake.

The NLDC has initiated several monitoring and control efforts against these species, including extensive monitoring of the chain's shoreland and connected rivers, raising *Galerucella* sp. beetles for release on purple loosestrife colonies, mapping Phragmites and Japanese knotweed, manually removing plants and offering many educational workshops school groups, lake residents and others.

The NLDC has great capacity to lead efforts against these species and to search for emerging AIS threats, such as Eurasian watermilfoil which is unfortunately quite common in northern Wisconsin lakes including in the upstream waters of the Gresham Chain. The NLDC will continue leading this initiative, while collaborating with the MWLA, Towns of Manitowish Waters, Boulder Junction, and Lac du Flambeau, GLIFWC, and local private property owners on volunteer recruitment, funding and educational outreach.

Action Steps:

1. Spiny water flea – TAISP will coordinate annual monitoring of Wild Rice Lake for spiny water flea, which is known to exist upstream. A partnership with GLIFWC will be initiated for assistance on the matter.

2. Phragmites – first observed in 2011, the Phragmites on the Trout River was sent for identification to the Robert Freckmann Herbarium at UW-Stevens Point in 2013, where it was confirmed to be non-native. It is the only known non-native Phragmites population in Vilas County. Onterra staff mapped its distribution on the river and in Alder Lake in 2014. While the colony is still relatively small in size, the TAISP is concerned that expansion could pose a problem at this site – and within the Manitowish Waters Chain of Lakes. Beginning in 2016, NLDC staff will partner with GLIFWC to monitor the extent of the colony size annually. If the colony is observed to be increasing, a control strategy may be considered by the partnership to reduce its threat to neighboring areas. Property owner permission would be required in order to access the locations for monitoring and control purposes. Update: GLIFWC staff began herbicide treatment of Phragmites in Manitowish Lake in 2017.
3. Purple loosestrife – The NLDC will continue purple loosestrife monitoring, mapping, and control efforts against this species. NLDC, in partnership with volunteers from MWLA will complete extensive monitoring of the chain's shorelands, wetlands, and connected rivers. Control methods such as flowerhead clipping and raising Galerucella sp. beetles for release on purple loosestrife colonies will continue with the assistance of MWLA and local schools. Additionally, educational opportunities will continue to be offered to school groups, lake residents, and others.
4. Pale yellow iris and Japanese knotweed – the NLDC has led many volunteer-based surveys for these plants and has provided information to property owners on manual removal techniques. These efforts will be continued into the future to continue to reduce the populations of these species.

Management Action:	Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.
Timeframe:	Continuation of current effort.
Facilitator:	NLDC with assistance of TAISP
Description:	Aquatic invasive species management has utilized many "tools" by lake managers, state legislators, and lake stakeholders. As a result of the spread of these species, programs such as Clean Boats Clean Waters have developed, educational media such as signs, posters, billboards and television commercials have been crafted, and laws have been generated to reduce the spread of these species. Some programs have been developed to take another step in stopping the spread of aquatic invasives, such as providing boat and trailer washing stations at public boat landings. The aforementioned techniques may be categorized as preventative actions. Control actions for reducing aquatic invasive species include mechanical harvesting, aquatic herbicide applications, and hand removal through SCUBA or snorkeling. These techniques are not appropriate for all lakes or situations. In some cases, monitoring of an

infestation is the most appropriate action. As management of aquatic invasive species continues, managers are learning more about the applicability of techniques and how they may be refined for better control. It is expected that time moves forward, these techniques will become more effective as managers develop better and creative ways to control aquatic invasive species.

As new or improved techniques become available, it will be up to the NLDC and TAISP to determine if these are applicable to the Manitowish Waters Chain of Lakes. Assistance may come from WDNR or county staff, as well as lake management consultants. The NLDC will review current and upcoming aquatic invasive species control and prevention methods. Specifically, NLDC will research cost sharing opportunities, overall cost of implementation, environmental impact, logistic capability and other factors associated with implementation of a new technique. A summary will be provided to TAISP as needed.

Action Steps:

1. NLDC researches the feasibility of alternative and innovative aquatic invasive species control methods such as watercraft washing programs, determining applicability to the Manitowish Waters Chain of Lakes.
2. Based upon findings, TAISP may decide to pursue one or several options.
3. Contact made with the County, WDNR, and consultant to determine if options would be approved for use, what barriers exist and what funding could be applicable.

Management Goal 5: Enhance the Available Habitat and General Understanding of the Manitowish Waters Chain of Lakes Fishery

Management Action: Work with WDNR fisheries managers and other stakeholders to enhance and understand the fishery.

Timeframe: Enhancement of current effort.

Facilitator: NLDC and MWLA Committee

With over nearly 4,500 acres of water, many residences and visitors and several fishing tournaments, it is safe to say the Manitowish Waters Chain of Lakes draws much attention from anglers both local and non-local. Initial studies on the native aquatic plant community and water quality of the Manitowish Waters Chain of Lakes suggest that the ecosystem of the chain is in great shape currently, which is beneficial for producing a quality fishery for anglers to enjoy. However, with the amount of attention and use the Manitowish Waters Chain of Lakes receives it remains important to continuously monitor the fish populations on the chain to ensure that overexploitation is not occurring.

Many factors go into determining a lake or chain's fishery, including biological (water chemistry, fish species interactions), physical (habitat, water levels, lake morphology) and social (angler catch and harvest, angler perceptions, angler/resident desire) components that govern what a fishery's potential is and how it is managed. Balance is important within a fishery as it is a factor needed to sustain fish populations into the future. In summary, fisheries managers have much to consider when making management decisions.

Understanding the limitations and characterizations of the Manitowish Waters Chain of Lake's fishery is critical. Education of anglers and other stakeholders is an important step to having an understanding of a fishery. For example, it is also important for stakeholders to understand how nutrient impairment influences a fishery, how removal of shoreland habitat (aquatic plants, coarse woody habitat) impacts spawning, and how harvesting fish translates to the sustainability of the population.

The importance of diversity in fish habitat cannot be stressed enough. As the Shoreland Condition Section and Fisheries Data Integration Section explains, coarse woody habitat, rocky shoals, organic silty substrate, and other factors are necessary to sustain a fishery of many species. Human disturbance of these aspects can translate upwards to a fish population, impacting spawning, predation, and food availability. Understanding this, the MWLA has undertaken a fish crib project which has generated much support from volunteers around the chain. In 2011, 17 cribs were added to Rest and Spider Lakes. 22 cribs were placed in Alder and Manitowish Lakes in 2012, and 12 cribs placed in Little Star Lake in 2013. While no cribs were added in 2014, in 2015 18 cribs were placed within Island Lake. Currently, at the request of the WDNR Fisheries Specialist, the MWLA is focusing more on the introduction of tree drops to add fish habitat.

TAISP is committed to fostering a quality fishery in the Manitowish Waters Chain of Lakes. The TAISP will strive for open communication with other management partners about the fishery and what can be done to protect and potentially improve it. Two areas of effort will be focused upon: 1) education and 2) habitat protection and enhancement.

The MWLA and NLDC will strive to educate stakeholders about the preservation and characteristics of the Manitowish Waters Chain of Lakes fishery. This may be conducted through "Catch and Release" service announcements, speakers at the MWLA board and annual meetings, NLDC programming, newsletter articles, or informative releases within some of the media described in Management Goal 3. A goal of the educational program will be to preserve natural habitat that is currently found within the Manitowish Waters Chain of Lakes. This will be done through an educational campaign aimed at lake property owners. The message translated will be to keep in-lake coarse woody habitat available, and protect aquatic plant communities as much as possible. Educational materials can be shared from some of the resources listed within the table of Management Goal 1.

The NLDC and MWLA Committee will partner with local angling groups such as Walleyes for Tomorrow when these opportunities exist. Programs aimed at shoreland restoration and coarse woody habitat projects will continue to be developed in conjunction with Vilas County, the Towns of Manitowish Waters and Boulder Junction, WDNR, Lac du Flambeau Tribe, and other management partners. Grant opportunities exist through the Healthy Lakes grant program for these efforts. Volunteers will be an important component of this project as manual labor will be required to build habitat structures and private shoreland property will be required to host these projects. Note that all projects should seek recommendation and approval by the two WDNR fisheries biologists who oversee the Manitowish Waters Chain of Lakes, Steve Gilbert (upstream of Rest Lake Dam) and Zach Lawson (downstream of Rest Lake Dam).

Action Steps:

1. NLDC and MWLA incorporate fisheries component into educational campaigns.
2. MWLA appoint a representative to work with NLDC and coordinate fisheries enhancement projects with oversight by WDNR fisheries biologists.
3. NLDC staff will investigate feasibility of Healthy Lakes grants, available through the WDNR. These grants are available to assist project sponsors with a variety of habitat related projects, including shoreland restorations, water conservation efforts and in-lake habitat improvement.

Management Goal 6: Continue to Understand, Protect and Enhance the Ecology of the Manitowish Waters Chain of Lakes Through Stakeholder Stewardship and Science-based Studies

Management Action: Conduct periodic quantitative vegetation monitoring on Manitowish Waters Chain of Lakes.

Timeframe: Begin 2022

Facilitator: NLDC and MWLA

Grant: Lake Planning or AIS-Education, Prevention, and Planning Grants

Description: The NLDC, MWLA and TAISP and Towns of Manitowish Waters and Boulder Junction have been diligent about protecting the Manitowish Waters Chain of Lakes and preserving it as a recreational and natural resource. They realize that the best way to protect the waterbodies in the chain is to fully understand their current level of health so that proper planning and management may occur.

The NLDC, with assistance from their extensive partner list including the MWLA, will continue to support and update the chain's management plan by regularly monitoring the chain's aquatic plant community. Water quality is addressed in Management Goal 2.

As part of the ongoing planning program, a whole-lake point-intercept survey and floating-leaf and emergent community mapping survey will be conducted on each chain lake every 8-10 years. This will allow a continued understanding of the aquatic plant community dynamics within chain lakes. A point intercept and community mapping survey will be completed on Rest Lake and Papoose Bay (Phase I waterbodies) in approximately 2022. The surveys would then begin at the upper lakes the following year and move down following the same phased approach and order utilized in this project (Map 1).

Action Steps:

See description above as this is an ongoing program.

Management Goal 7: Maintain Reasonable Navigation within Rest Lake

Management Action: Use mechanical harvesting to maintain reasonable navigation on Rest Lake.

Description: As Rest Lake stakeholders know, and this project's field studies have confirmed, the Papoose Bay area of Rest Lake is a productive system which includes abundant plant growth. So much growth, in fact, that navigation is impeded in much of this area. Papoose Bay Map 3 displays the mechanical harvesting plan that the Papoose Bay Association (PBA) has followed to ensure navigability for Papoose

Bay property owners and others navigating through Rest Lake. This map illustrates two types of harvesting lanes; riparian access lanes, which are 15 feet wide, and common use lanes, which are 30 feet wide. Altogether, the total cutting area depicted consists of 1.7 acres, or 12.5% of the bay's surface area. The PBA has conducted harvesting in these areas since 2008 through annual permits that have been issued by the WDNR. These permits typically includes stipulations for harvesting activity, such as:

1. The permit is valid for one year.
2. The harvesting lanes should not exceed 30 feet (navigation lane) and 15 feet (riparian access lane) in width.
3. Harvesting is permitted for submergent and emergent plants only, no floating-leaf plants may be harvested.
4. Aquatic plant harvesting is strictly for human access concerns – no harvesting shall occur in areas where riparian property owner docks are not located.
5. Harvesting must be done in a manner such that the impacts to the wild rice community are minimized.
6. Harvesting must be done in areas where water depth is great enough to prevent suspension of bottom materials.
7. All aquatic plants that are cut must be removed immediately from the water.
8. Harvesting operations shall not disturb spawning or nesting fish, and must minimize accidental capture of fish.
9. All harvesting equipment shall be de-contaminated for invasive species and viruses prior to and after use.

These regulations are put in place to protect the natural ecosystem of Papoose Bay. Note that this list serves as a general overview - further stipulations may be viewed within the annual WDNR permit for Papoose Bay.

The plan the PBA has been following is valuable in that it minimizes the area of harvesting while still providing Papoose Bay property owners access to Rest Lake. The PBA will continue this harvesting strategy in accordance with WDNR permits. Should significant changes occur within the bay, such as the introduction of aquatic invasive species, a new harvesting strategy would need to be developed. Specifically, this strategy would include coordination of NLDC and consultant mapping results along with harvesting activities to ensure that aquatic invasive species are not picked up and spread by the harvesting unit. In addition to detailed mapping and effective communication, hand-harvesting of aquatic invasive species may be utilized to remove plants from harvesting areas prior to harvesting use, thereby minimizing the opportunity for spread throughout Papoose Bay.

6.0 METHODS

Lake Water Quality

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

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

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

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

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on the system to characterize the existing communities within each lake and included inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the 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 following point spacing and resulting number of points comprised the surveys:

Phase & Field Work Year	Lake	Point-intercept Resolution (meters)	Number of Points	Survey Dates
Phase I - 2012	Rest Lake	55	879	July 24, 2012
	Papoose Creek	25	85	July 24, 2012
	Spider Lake	35	913	July 25, 2012
	Island Lake	73	655	WDNR July 5&8, 2011
Phase II - 2013	Clear Lake	62	543	July 31, 2013
	Fawn Lake	37	207	July 31, 2013
Phase III - 2014	Alder Lake	55	354	July 29, 2014
	Wild Rice Lake	61	418	July 29, 2014
Phase IV - 2016	Manitowish Lake	39	1315	July 18 & 19, 2016
	Little Star Lake	36	808	July 19, 2016

Community Mapping

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

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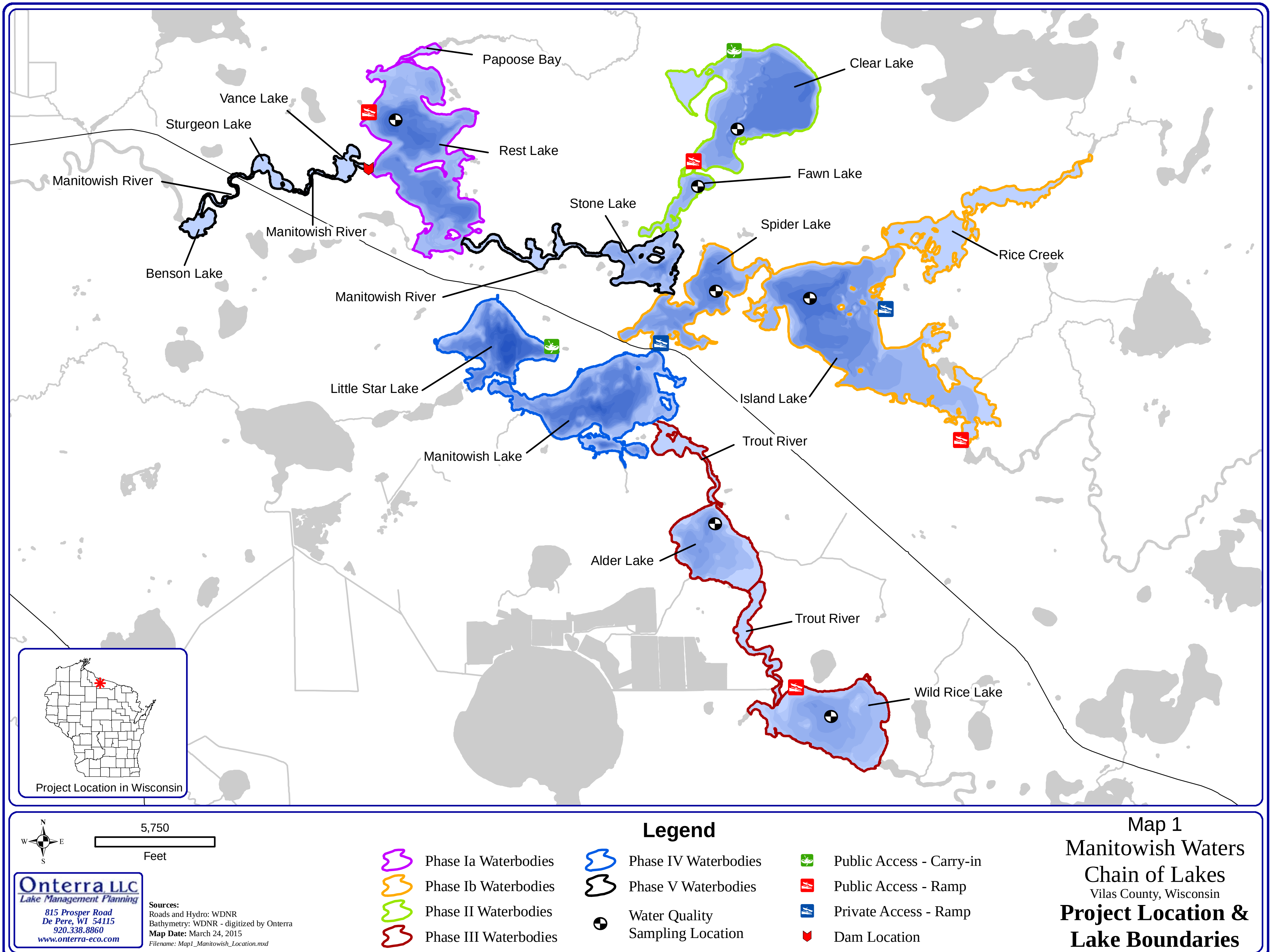
Papoose Bay
Vance Lake
Sturgeon Lake
Rest Lake
Manitowish River
Manitowish River
Benson Lake
Manitowish River
Stone Lake
Clear Lake
Fawn Lake
Spider Lake
Rice Creek
Little Star Lake
Island Lake
Manitowish Lake
Trout River
Alder Lake
Trout River
Wild Rice Lake
Project Location in Wisconsin
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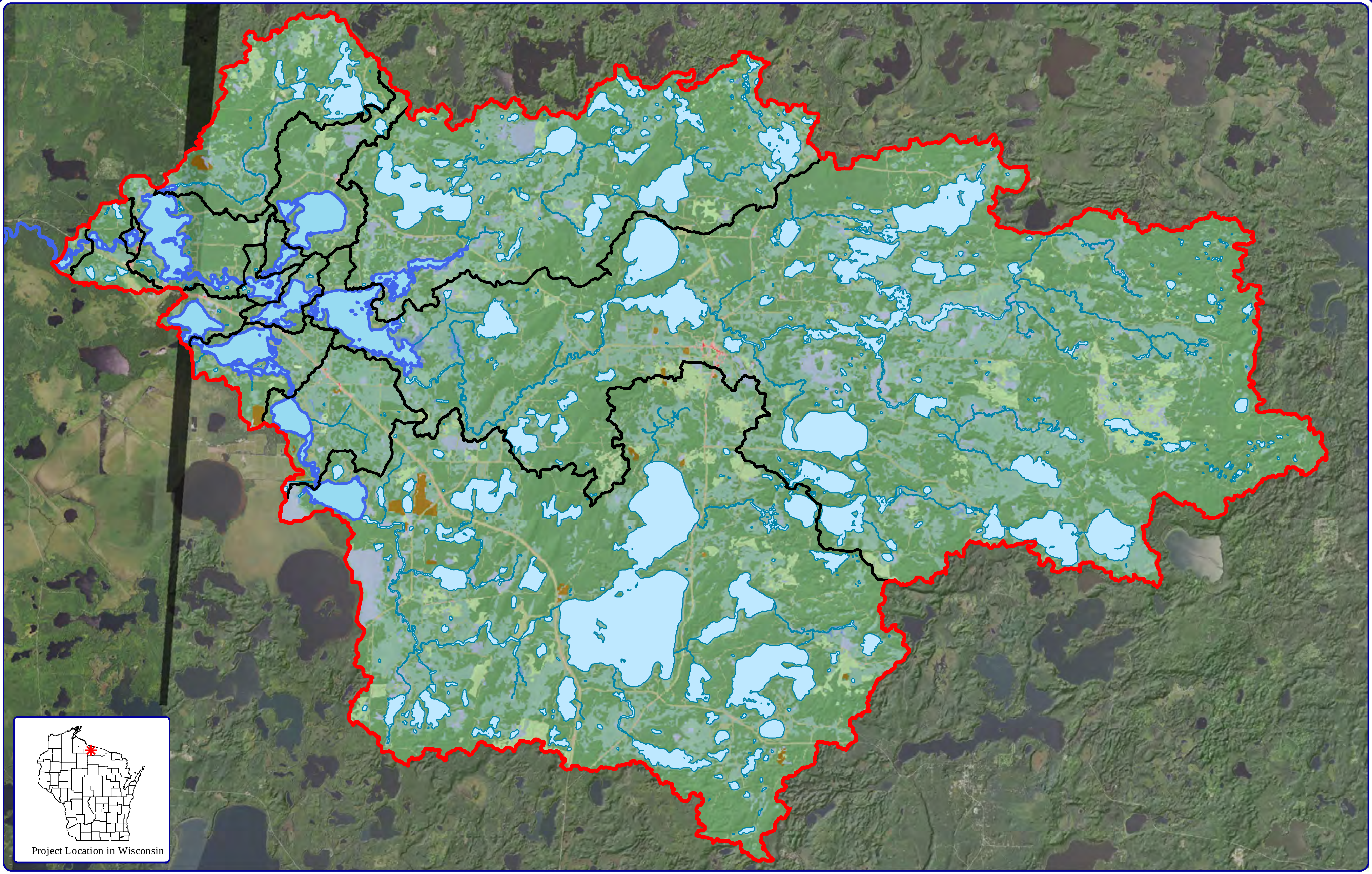
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR - digitized by Onterra
Map Date: March 24, 2015
Filename: Map1_Manitowish_Location.mxd
Legend
Phase Ia Waterbodies
Phase Ib Waterbodies
Phase II Waterbodies
Phase III Waterbodies
Phase IV Waterbodies
Phase V Waterbodies
Water Quality Sampling Location
Public Access - Carry-in
Public Access - Ramp
Private Access - Ramp
Dam Location
Map 1
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
Project Location & Lake Boundaries



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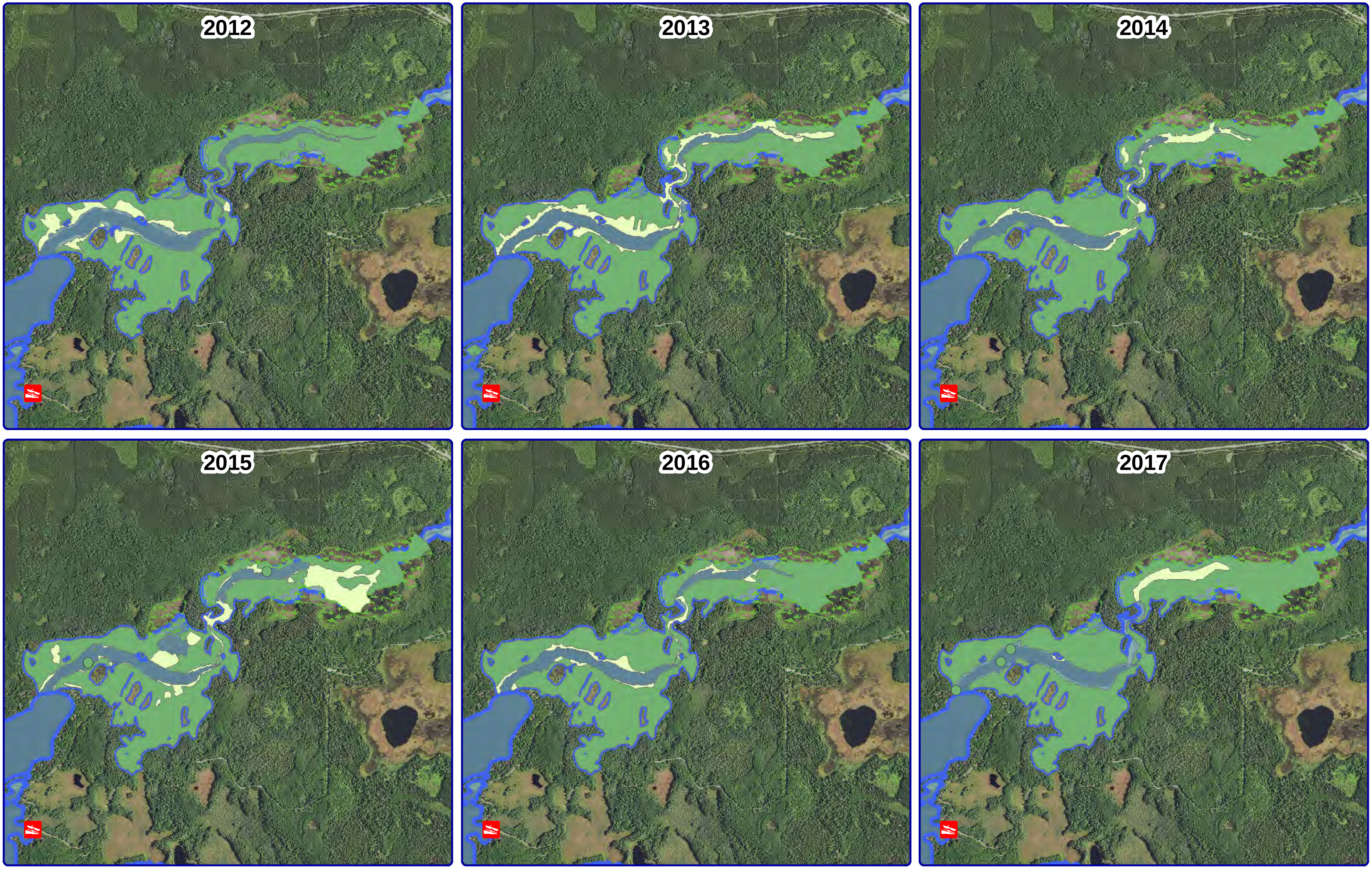
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2017
Land Cover: NLCD, 2011
Watershed Boundaries: Onterra, 2017
Map date: September 22, 2018 JLW
Filename: *Map2_ManChain_WS.mxd*

Legend

- Forest
- Forested Wetlands
- Pasture/Grass
- Rural Open Space
- Row Crops
- Wetland
- Open Water
- Rural Residential
- Urban - Medium Density
- Urban - High Density
- Subwatershed Boundaries
- Manitowish Chain of Lakes Watershed Boundary
- Manitowish Chain of Lakes

Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Watershed Boundaries & Land Cover Types



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Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
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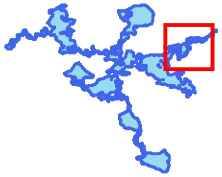


Inset Map Location in red

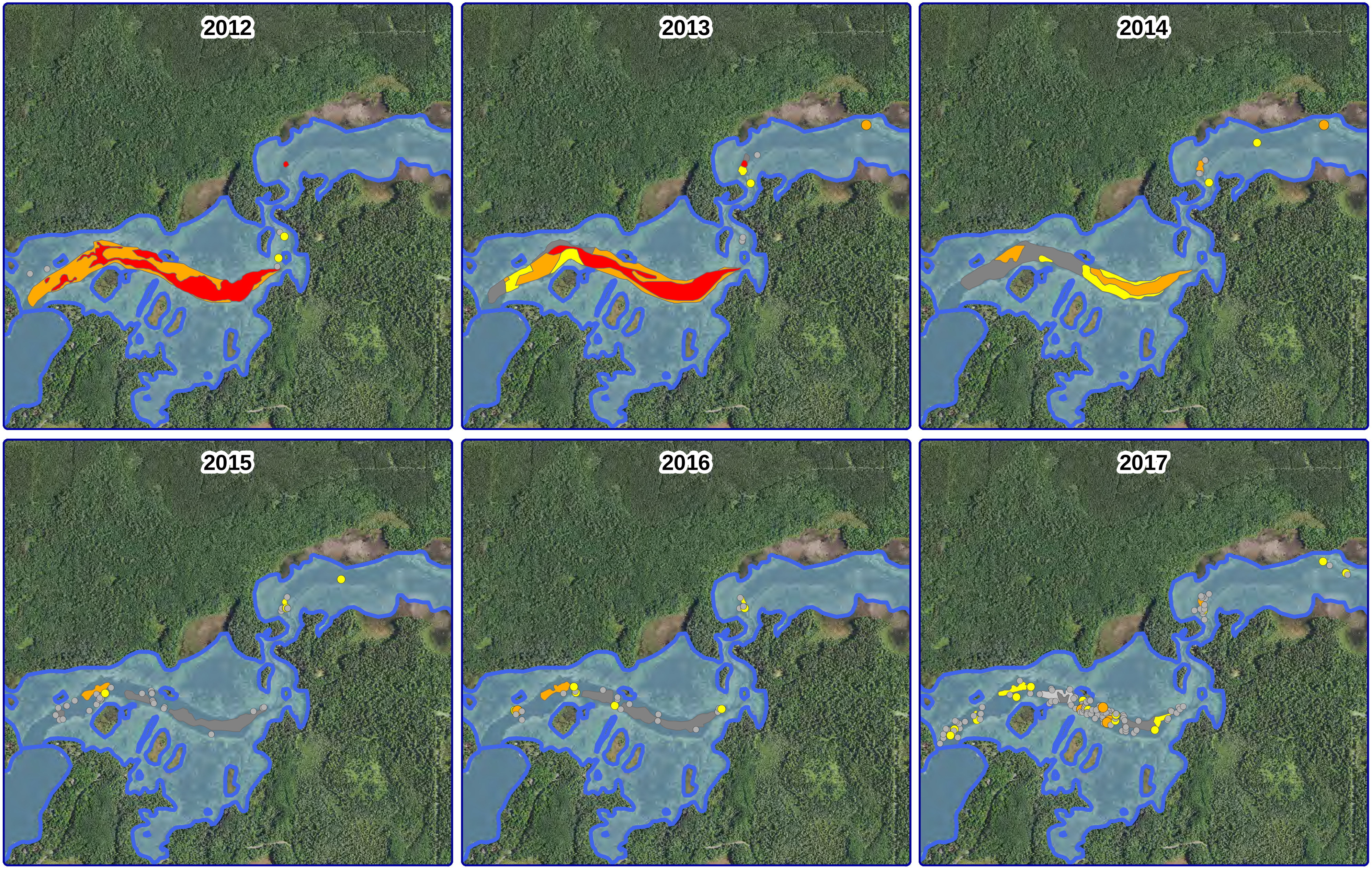
Legend

- Sparse Wild Rice
- Dense Wild Rice
- Adjacent Wetland Habitat

Map 3

Rice Creek
Vilas County, Wisconsin

Rice Creek Wild Rice Communities



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Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
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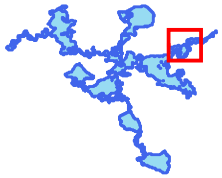


Inset Map Location in red

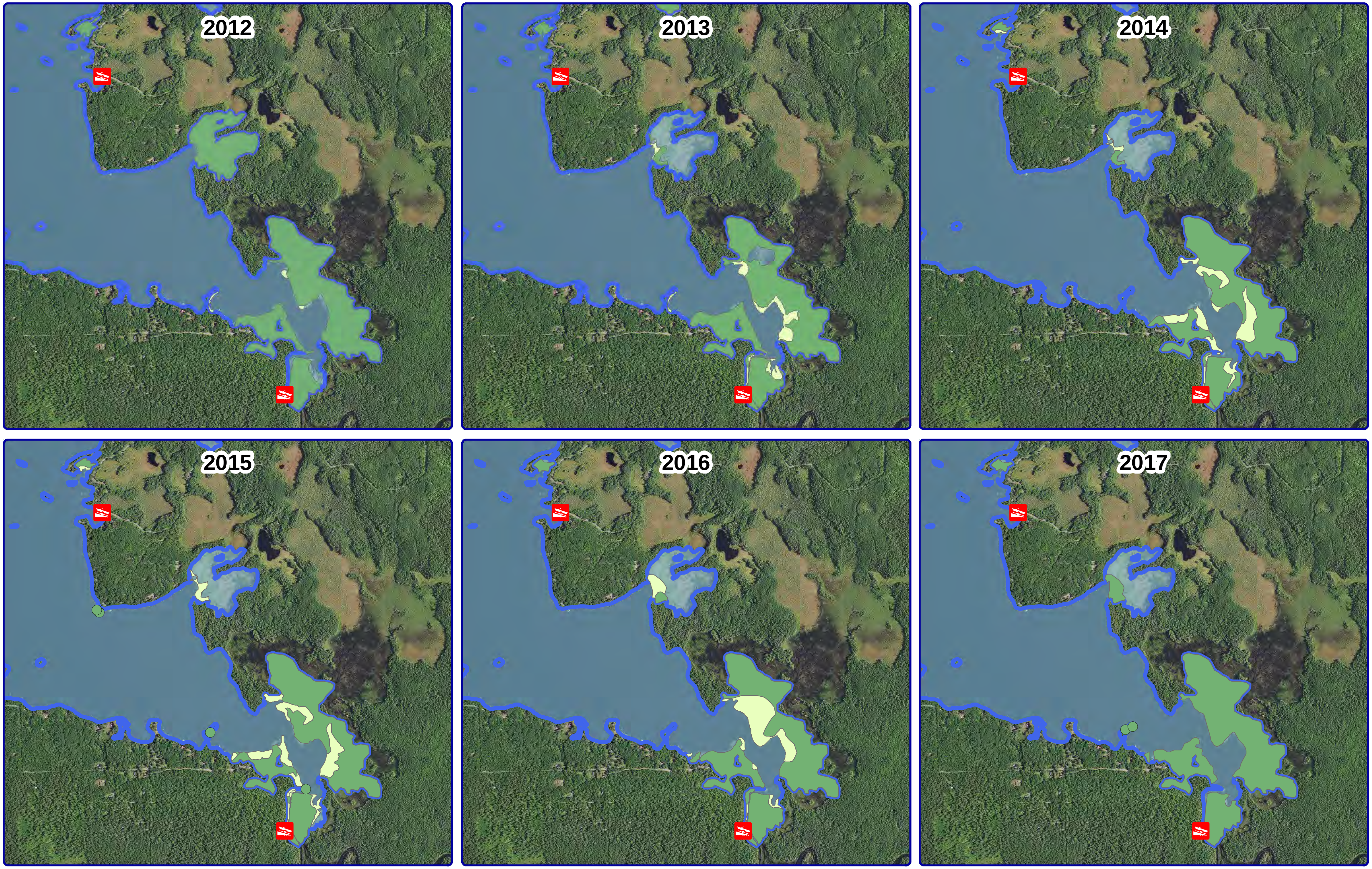
Legend

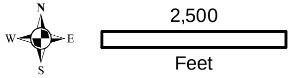
- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 4

Rice Creek
Vilas County, Wisconsin

Rice Creek CLP
Peak-Growth Mapping





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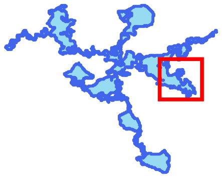
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_Island_WildRice_2012-2017.mxd


Inset Map Location in red

Legend

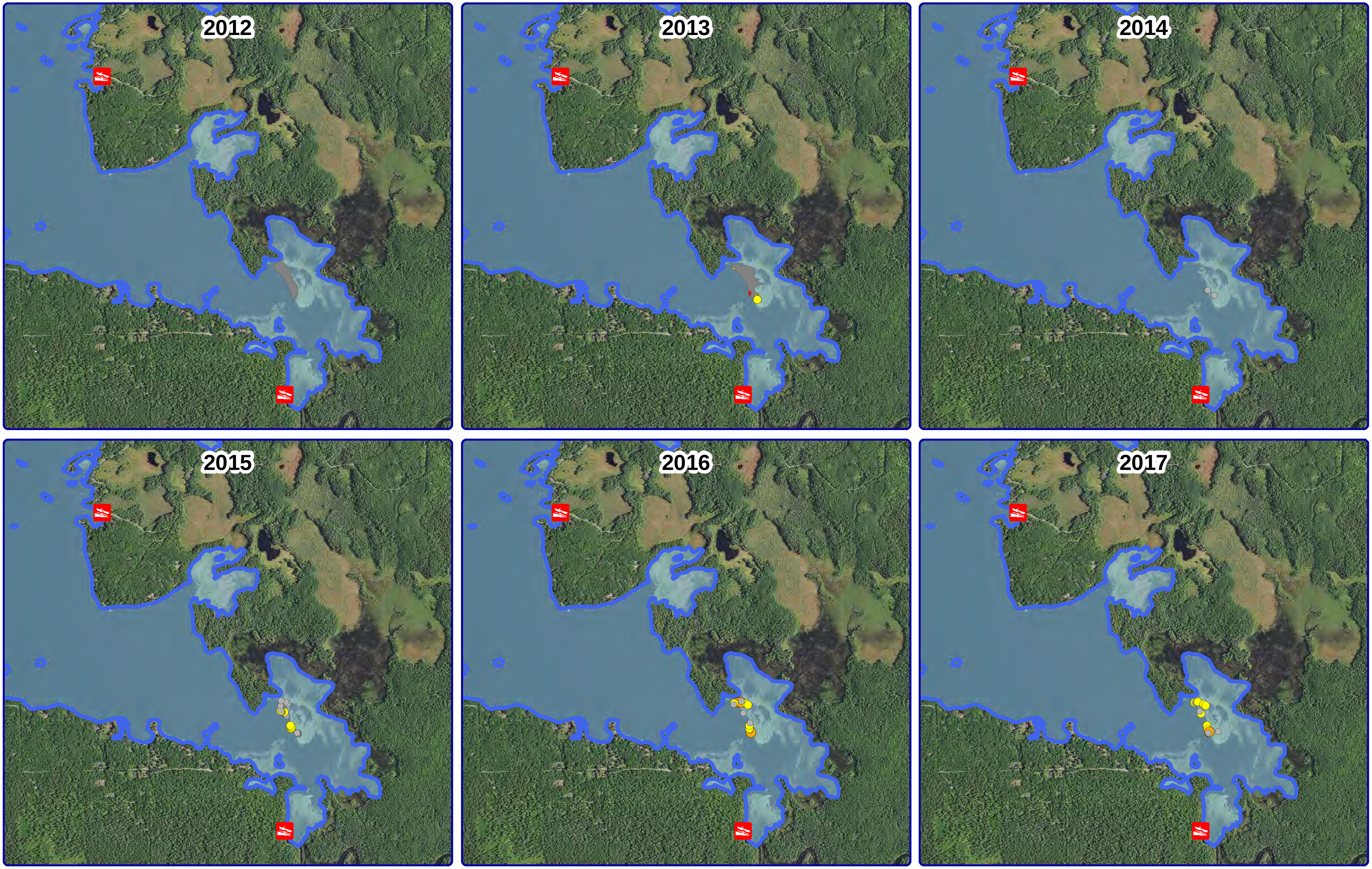
- Sparse Wild Rice
- Dense Wild Rice
- Adjacent Wetland Habitat

Map 5

Island Lake

Vilas County, Wisconsin

Island Lake Wild Rice Communities



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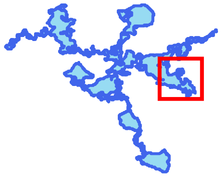
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_Island_CLP_2012-2017.mxd


Inset Map Location in red

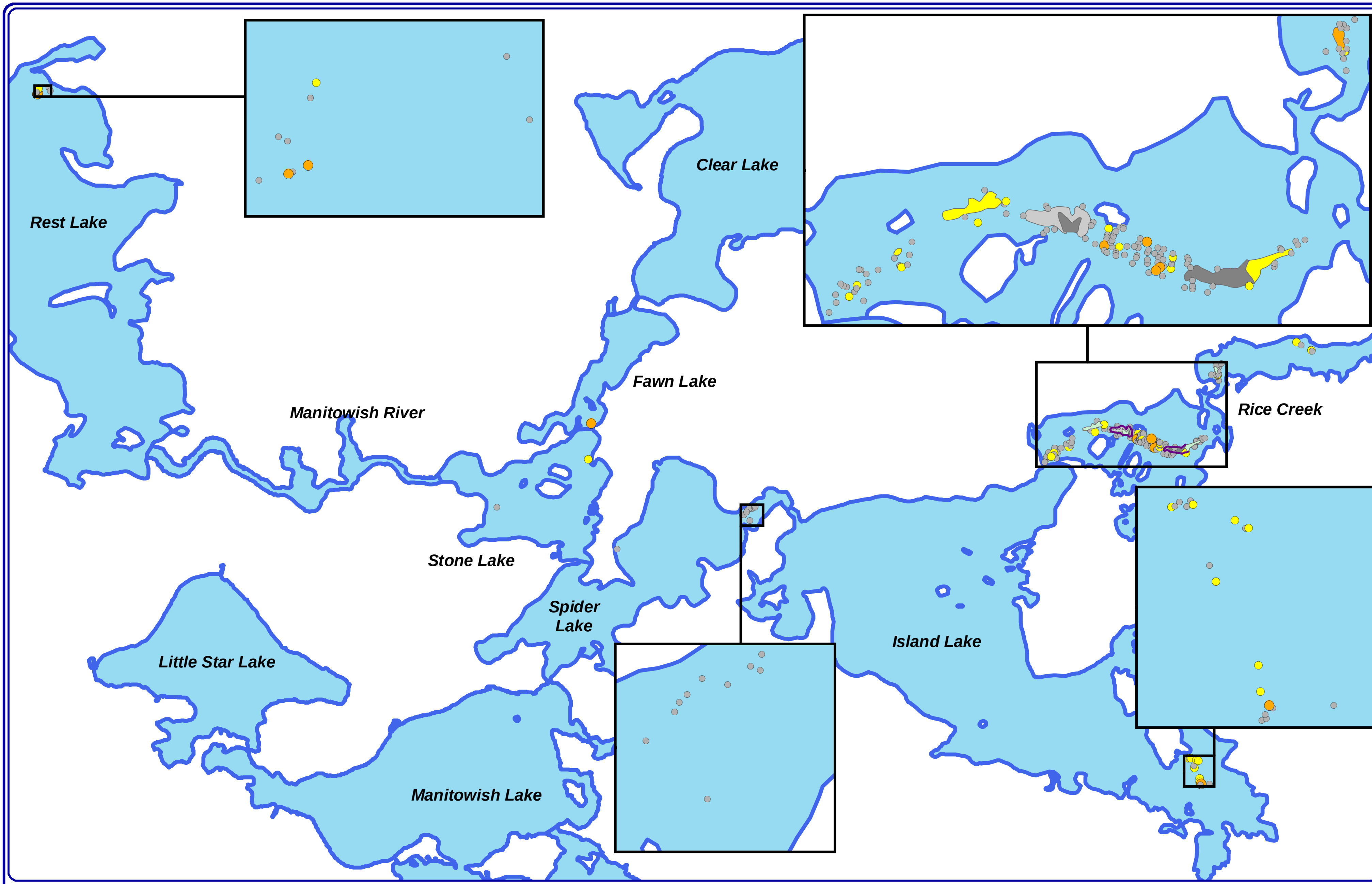
Legend

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clump of Plants
- Small Plant Colony

Map 6

Island Lake
Vilas County, Wisconsin

Island Lake CLP Peak-Growth Mapping



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920.338.8860
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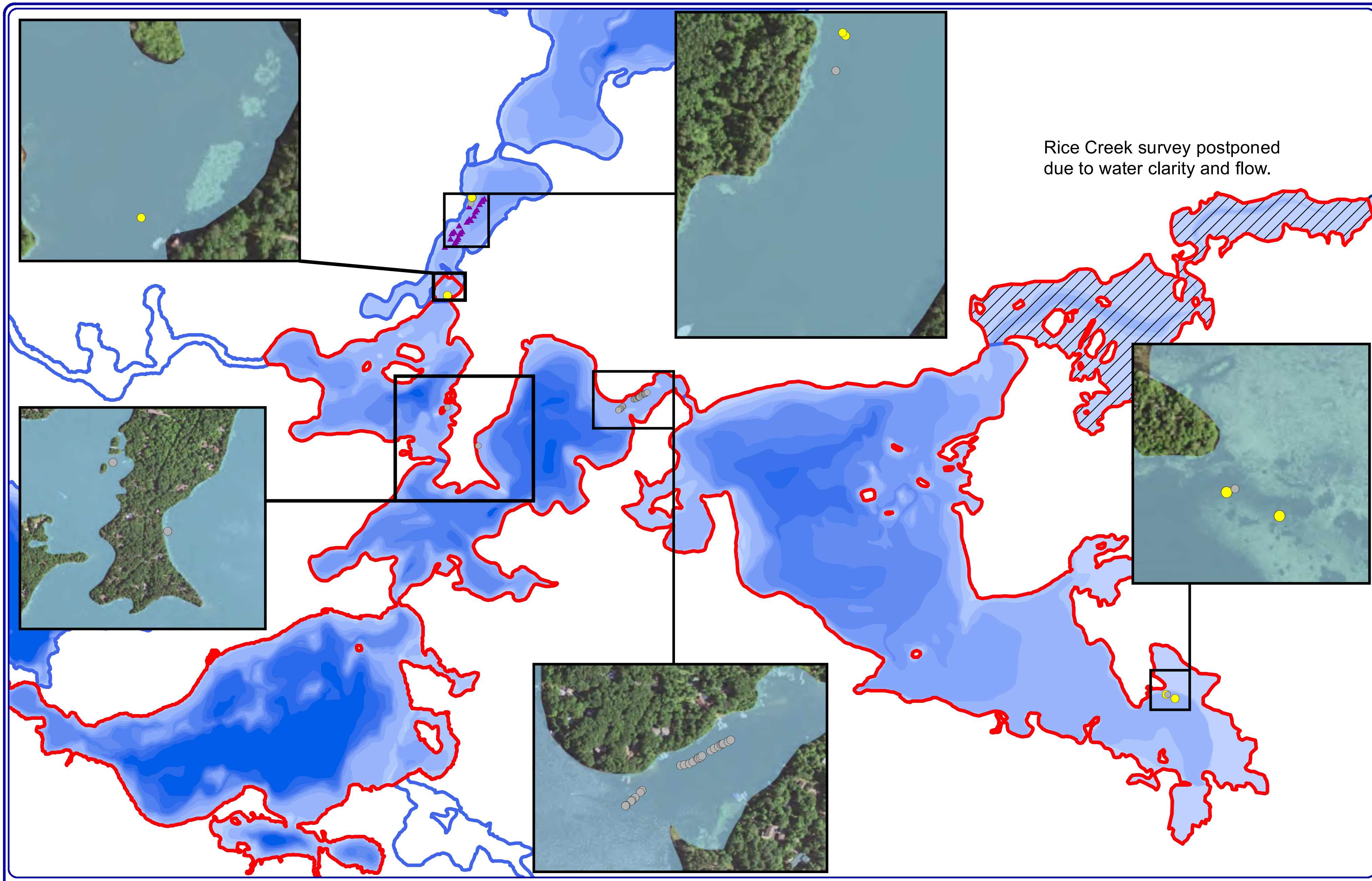
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2017
Map Date: June 21, 2017
Filename: Manitowish_CLPPB_June17.mxd

Map 7
Manitowish Chain of Lakes
Vilas County, Wisconsin

June 2017 Curly-leaf Pondweed Survey Results



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Onterra LLC
Lake Management Planning

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920.338.8860
www.onterra-eco.com

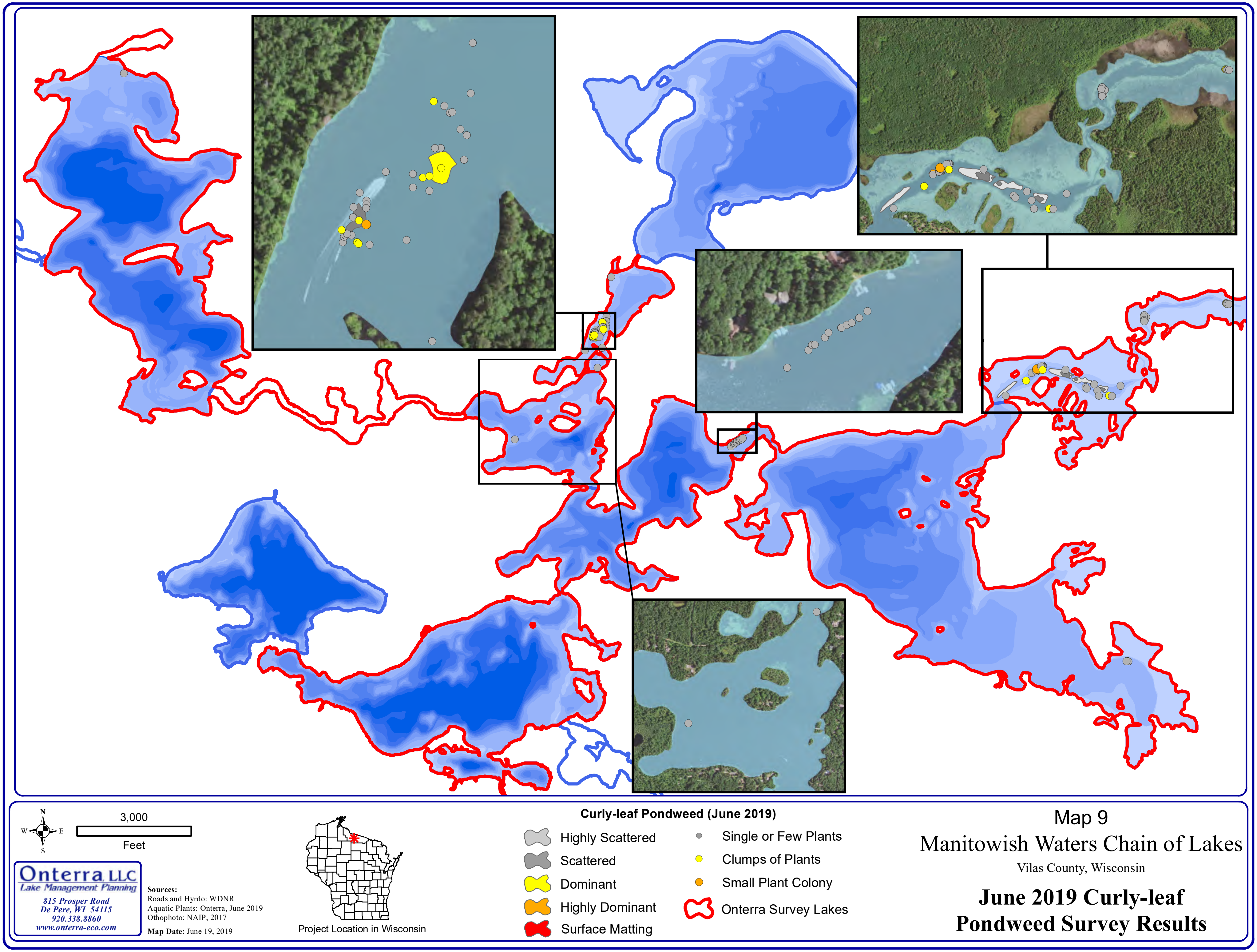
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2018
Othophoto: NAIP, 2017
Map Date: June 22, 2018

Project Location in Wisconsin

Curly-leaf Pondweed (June 2018)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Onterra Survey Lakes

Map 8
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
June 2018 Curly-leaf Pondweed Survey Results


Map 9
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
June 2019 Curly-leaf Pondweed Survey Results
Curly-leaf Pondweed (June 2019)
Highly Scattered
Scattered
Dominant
Highly Dominant
Surface Matting
Single or Few Plants
Clumps of Plants
Small Plant Colony
Onterra Survey Lakes
Project Location in Wisconsin
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Onterra LLC
Lake Management Planning
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De Pere, WI 54115
920.338.8860
www.onterra-eco.com
Sources:
Roads and Hyrdo: WDNR
Aquatic Plants: Onterra, June 2019
Othophoto: NAIP, 2017
Map Date: June 19, 2019

8.0 INDIVIDUAL LAKE SECTIONS

The following are the individual lake sections. They contain the results of each individual lake. A better understanding of these results can be reached by first reading the chain-wide document.

Individual Lake Table of Contents

Phase I

Phase II

Phase III

Phase IV

Phase V

Note: Methodology, explanation of analysis, and biological background on Rest Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.1 Rest Lake

An Introduction to Rest Lake

Rest Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 53 feet, a mean depth of 18 feet, and a surface area of approximately 664 acres. It is fed via Papoose Creek from the north and the Manitowish River from the southeast. The Rest Lake Reservoir Dam is located on the west side of the lake, and maintains/controls water levels for upstream lakes in the Manitowish Waters Chain of Lakes. The lake is currently in a mesotrophic state, and its watershed encompasses approximately 146,515 acres. In 2012, 37 native aquatic plant species were located in the lake, of which common waterweed (*Elodea canadensis*) was the most common. Three non-native plants, pale yellow iris, purple loosestrife, and reed canary grass, were observed growing along areas of Rest Lake's shoreline in 2012.

Field Survey Notes

Primarily sandy substrate observed during point-intercept survey. Great habitat diversity, with sand, rock and shallow wetlands being found around the lake's perimeter.

Photo 8.1. Rest Lake, Vilas County

Lake at a Glance* – Rest Lake

Morphology	
Acreage	664
Maximum Depth (ft)	53
Mean Depth (ft)	18
Volume (acre-feet)	14,544
Shoreline Complexity	6.4
Vegetation	
Curly-leaf Survey Date	May 29, 2012
Comprehensive Survey Date	July 24-25, 2012
Number of Native Species	37
Threatened/Special Concern Species	0
Exotic Plant Species	Pale yellow iris; Purple loosestrife; Reed canary grass
Simpson's Diversity	0.90
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	223:1

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

8.1.1 Rest Lake Water Quality

Water quality data was collected from Rest Lake on six occasions in 2012/2013. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2012/2013, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2012, average summer phosphorus concentrations (14.3 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.1.1-1) The values measured through this management planning process are similar to several data points which were collected in years past. A weighted value from all available data ranks as *Excellent* for a deep, lowland drainage lake.

Total phosphorus surface values from 2012 are compared with bottom-lake samples collected during this same time frame in Figure 8.1.1-2. As displayed in this figure, on several occasions surface and bottom total phosphorus concentrations were similar. However, on some occasions, namely during July and August of 2012, the bottom phosphorus concentrations were much greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.1.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain of Lakes-wide document. While this process may be contributing some phosphorus to Rest Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Rest Lake's surface water total phosphorus values are slightly lower than the median value for comparable lakes in Wisconsin.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (2.3 µg/L) were less than the median value (7.0 µg/L) for other lakes of this type (Figure 8.1.1-3). These values are comparable to several historical values that have been collected on Rest Lake.

Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2012 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

As lakes become more eutrophic from man-made and naturally occurring processes, the potential for algae blooms exist. As discussed above, algae are correlated with nutrient content in Wisconsin lakes. In other words, as nutrients increase so should the algae in a lake. While it is healthy to have a limited to moderate abundance of algae in a lake ecosystem, excessive algae can lead to recreational and aesthetic impairments. Health concerns may become an issue if some species, namely blue-green algae, get out of hand.

In 2013, some residents had concerns over an algae bloom in Papoose Bay of Rest Lake. The type of algae found within this bloom was not identified, and concerns reported included unpleasing aesthetics and negative effects on watercraft motors. In 2014 algae samples were collected and identified by WDNR staff. The Papoose Bay samples included a filamentous golden-brown algae (*Chrysophyta*).

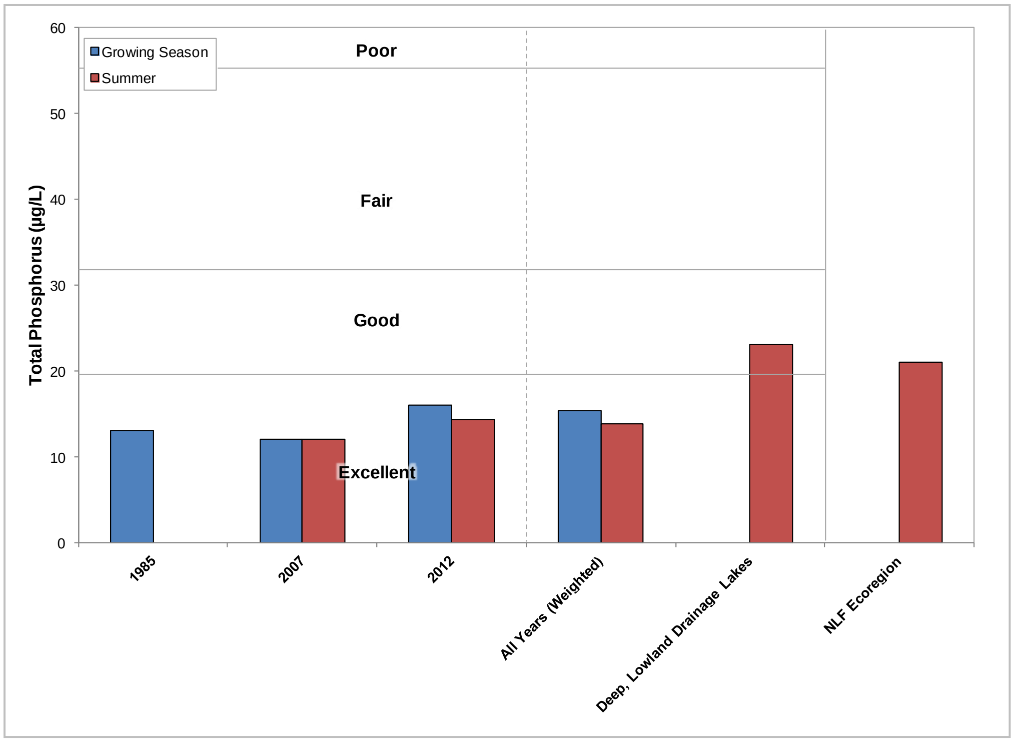


Figure 8.1.1-1. Rest Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

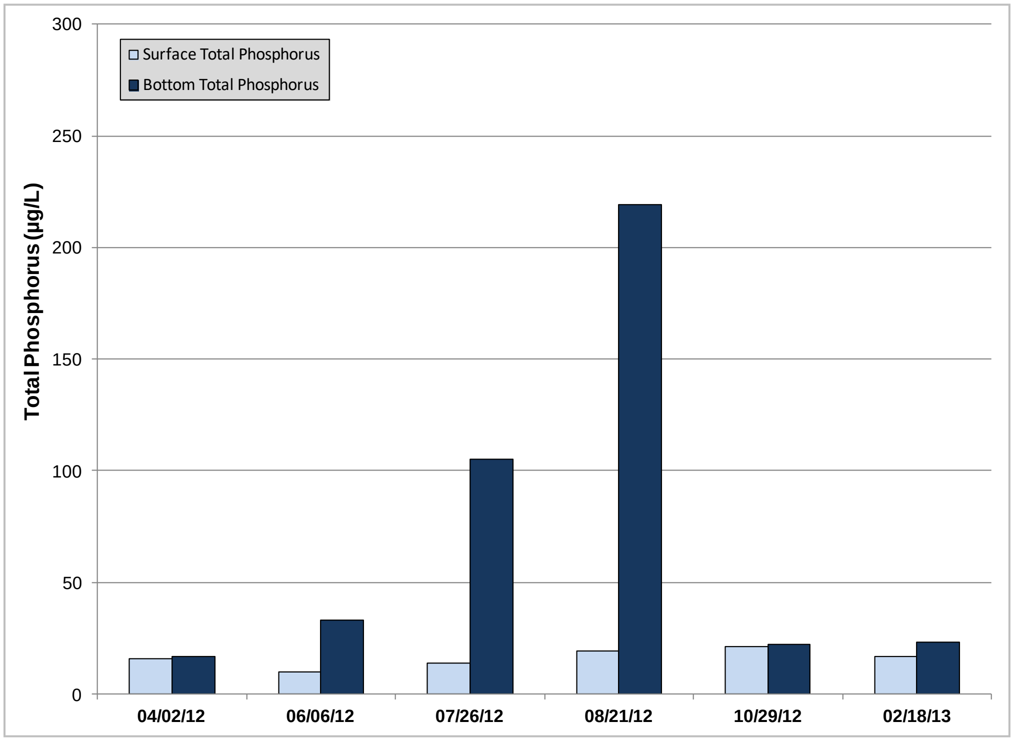


Figure 8.1.1-2. Rest Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

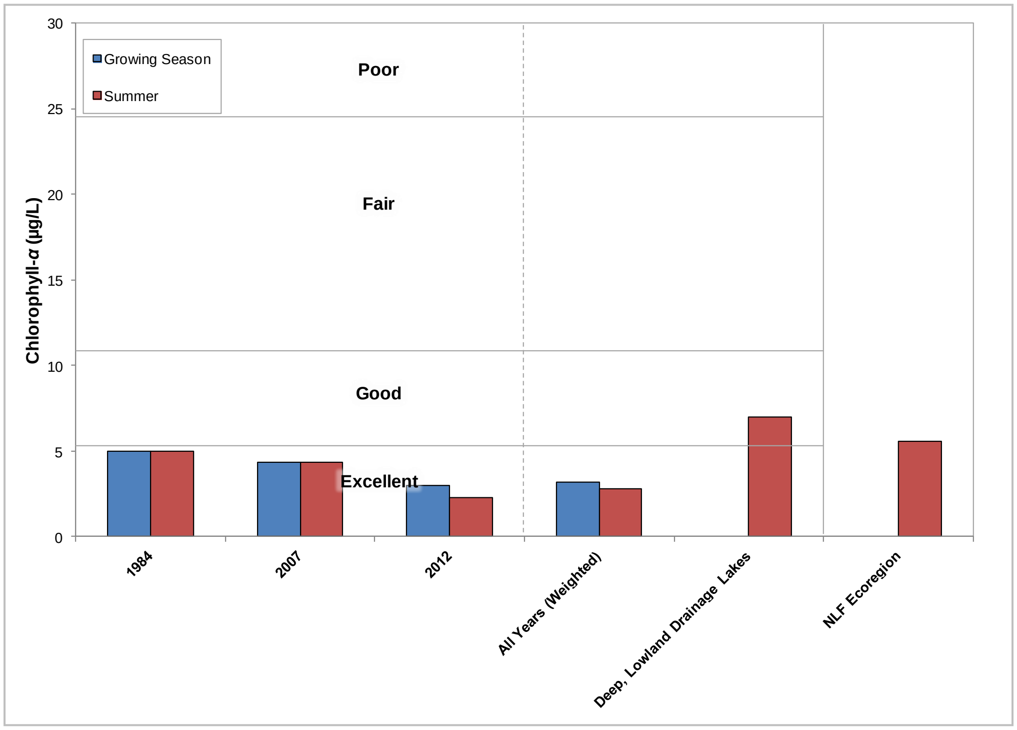


Figure 8.1.1-3. Rest Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of nearly two decades worth of intermittent Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Rest Lake's water can be described as *Excellent* in most years (Figure 8.1.1-4). A weighted average over this timeframe is greater than the median value for other deep, lowland drainage lakes in the state as well as all lakes within the ecoregion. Secondly, there is very little variation seen in this data set indicating there is little reason to believe the water clarity has improved, or more importantly, gotten worse over this time period.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Rest Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Rest Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in April and July of 2012 were measured for this parameter, and were found to be at 10 Platinum-cobalt units (Pt-co units, or PCU). Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

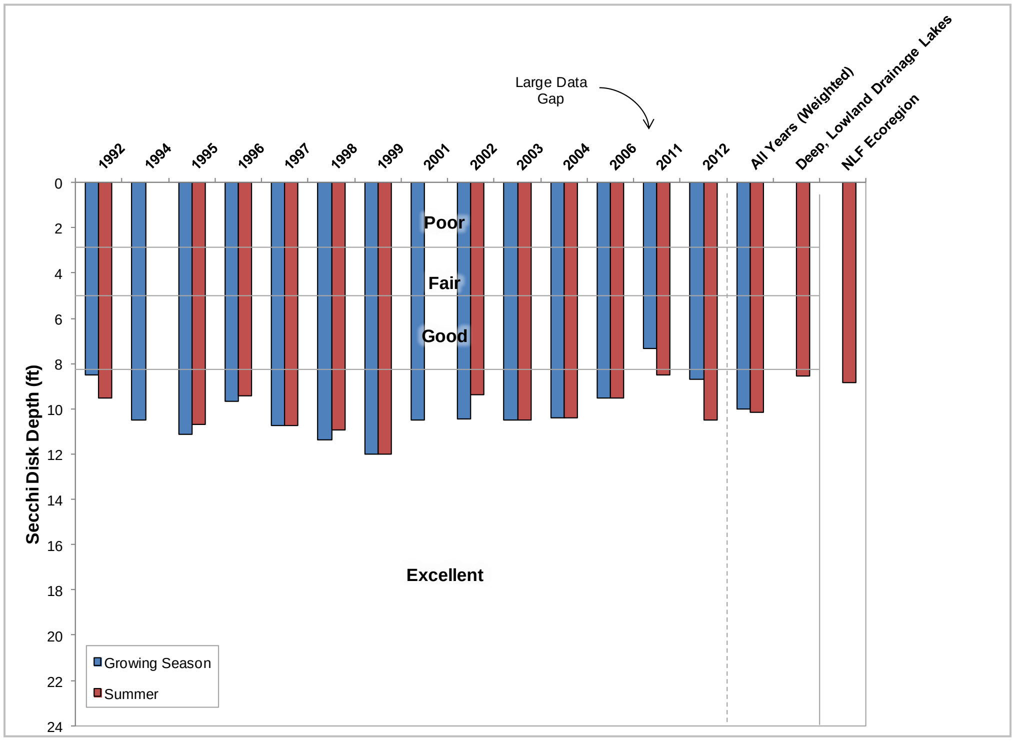


Figure 8.1.1-4. Rest Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Rest Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.1.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Rest Lake is in a mesotrophic state.

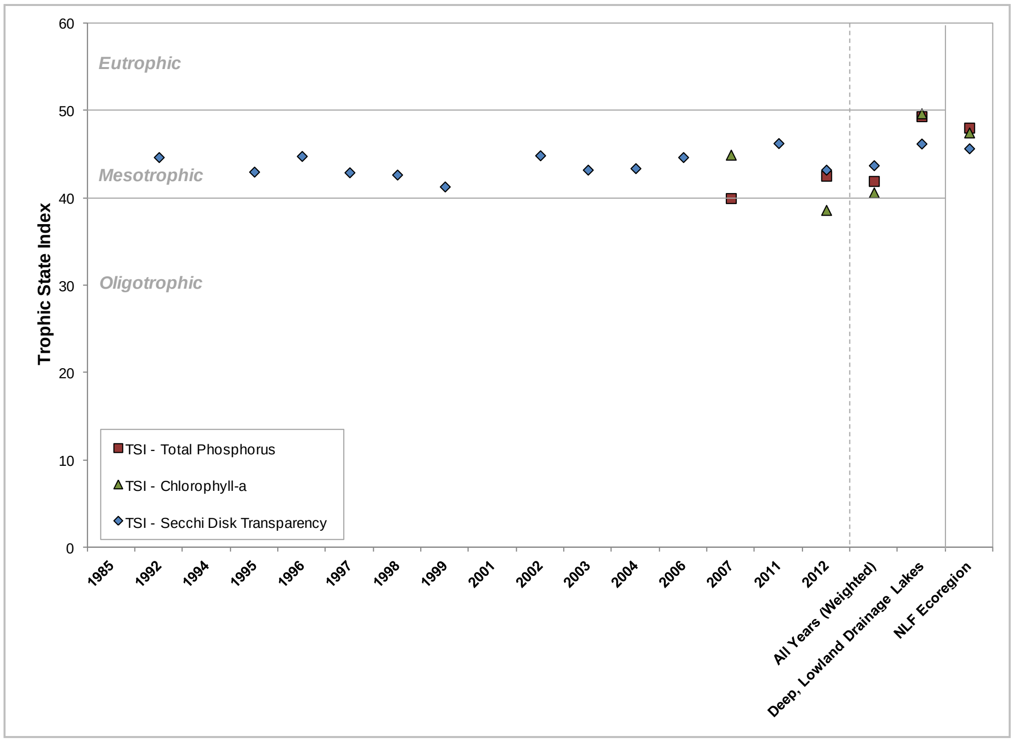


Figure 8.1.1-5. Rest Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Rest Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Rest Lake by Onterra staff. Graphs of those data are displayed in Figure 8.1.1-6 for all sampling events.

Rest Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of

2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

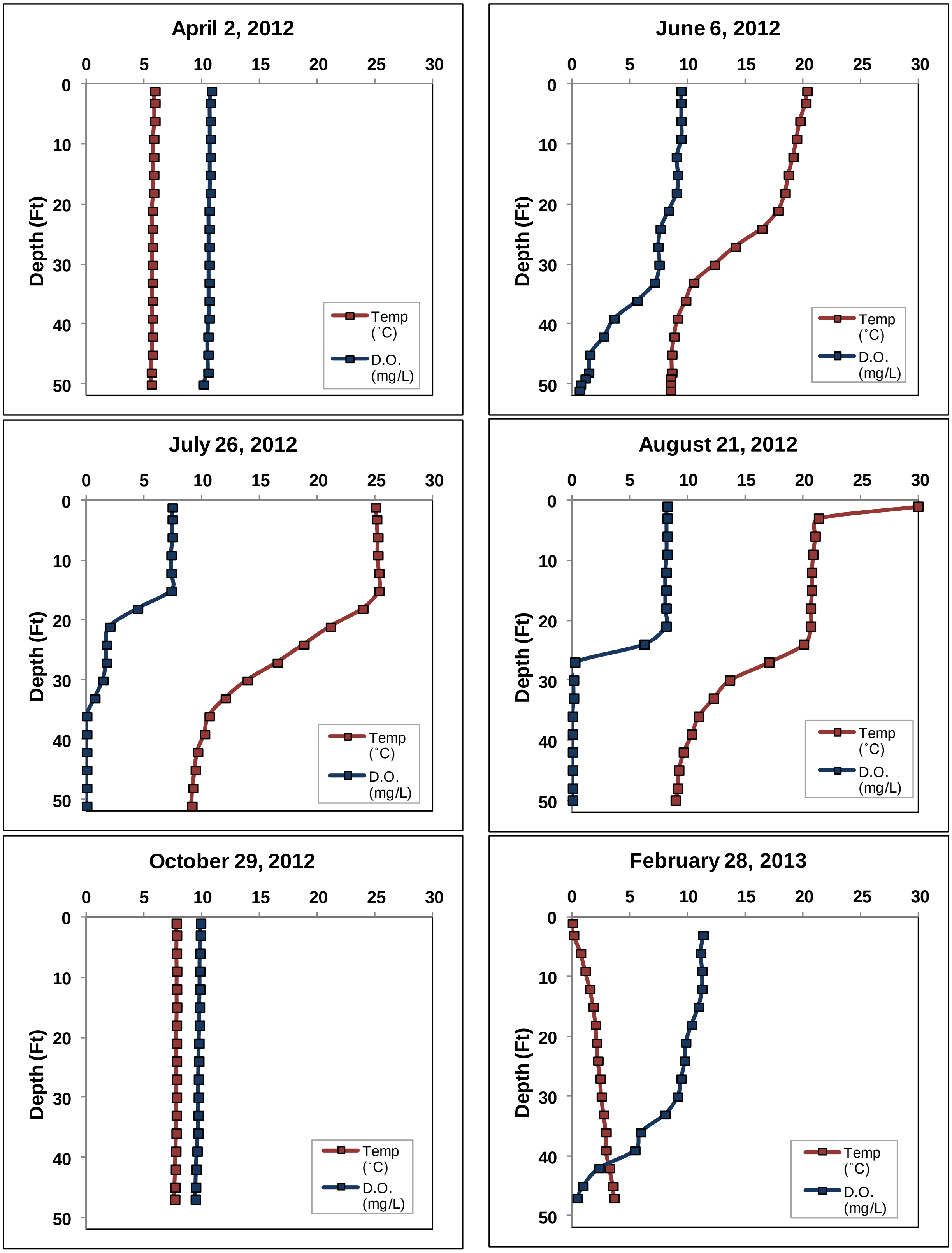


Figure 8.1.1-6. Rest Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Rest Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Rest Lake's surface water pH was measured at roughly 8.5 during April and 7.2 during July of 2012. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Rest Lake was measured at 47 mg/L as $CaCO_3$ in April and July of 2012. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Rest Lake during 2012. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Rest Lake's pH of 7.2 – 8.5 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Rest Lake was found to be 14.2 mg/L in April and 12.7 mg/L in July of 2012, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval stage of zebra mussels) were observed within these samples.

8.1.2 Rest Lake Watershed Assessment

Rest Lake's watershed is 146,517 acres in size. Compared to Rest Lake's size of 81 acres, this makes for a large watershed to lake area ratio of 223:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lake immediately upstream. For Rest Lake this means that 137,942 acres (94%) of the lake's watershed is the Stone Lake subwatershed and the rest of the Rest Lake's watershed is comprised of land cover types including forest (3%), wetlands (2%), and smaller amounts of other landuses (Figure 8.1.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Rest Lake's residence time is approximately 33 days, or the water within the lake is completely replaced 11 times per year.

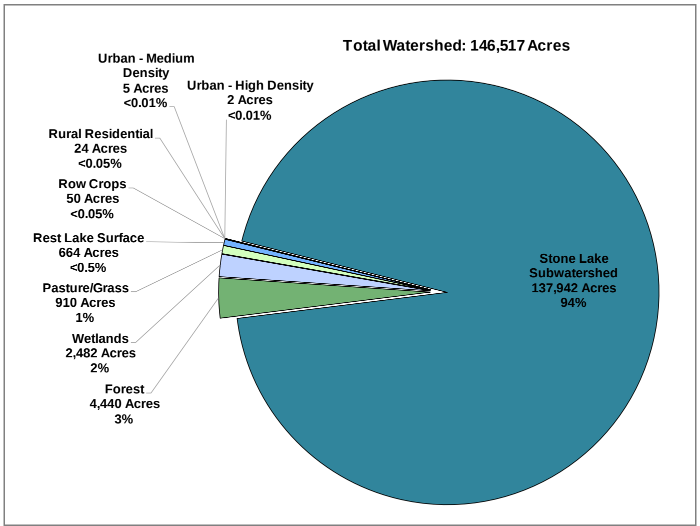


Figure 8.1.2-1. Rest Lake watershed proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Of the estimated 9,220 pounds of phosphorus being delivered to Rest Lake on an annual basis, approximately 8,170 pounds (89%) originates from the Stone Lake subwatershed, with next largest source being forest at 357 pounds (4%) pasture/grass at 243 pounds (3%), and the remainder being from various landuses and atmospheric inputs (Figure 8.1.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 18 µg/L, which is similar to the measured growing season average total phosphorus concentration of 14 µg/L. This means the model works reasonably well for Rest Lake.

Because the large majority of the phosphorus that enters Rest Lake comes from the upstream Stone Lake, efforts to reduce phosphorus levels in Rest Lake should concentrate on reducing phosphorus inputs to the upstream lake.

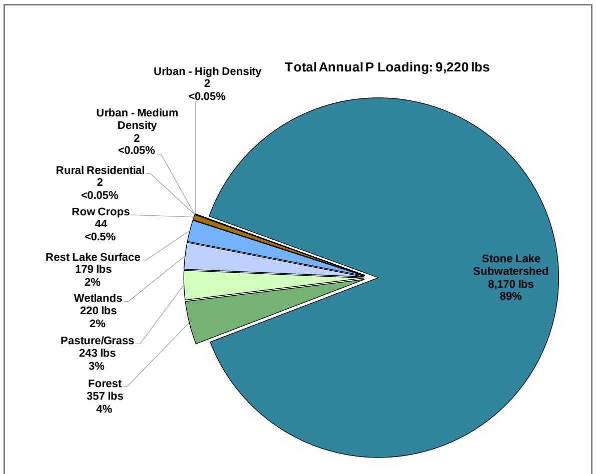


Figure 8.1.2-2. Rest Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

8.1.3 Rest Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Rest Lake's immediate shoreline was assessed in terms of its development. Rest Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 4.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). This constitutes about 50% of Rest Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.5 miles of urbanized and developed–unnatural shoreline (28%) was observed. If restoration of the Rest Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Rest Lake Map 1 displays the location of these shoreline lengths around the entire lake.

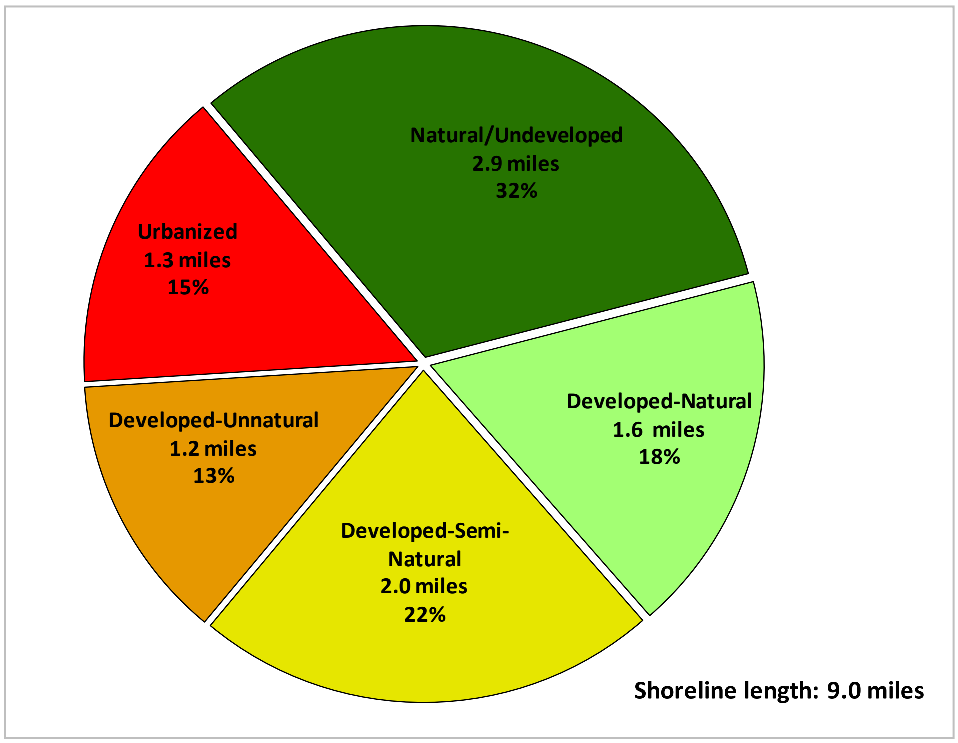


Figure 8.1.3-1. Rest Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Rest Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Rest 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, or clusters of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no

branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 59 total pieces of coarse woody habitat were observed along 9.0 miles of shoreline (Rest Lake Map 2), which gives Rest Lake a coarse woody habitat to shoreline mile ratio of 7:1 (Figure 8.1.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Thirty pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, twenty-nine pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Rest Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Rest Lake falls well below the 25th percentile of these 98 lakes (Figure 8.1.3-2).

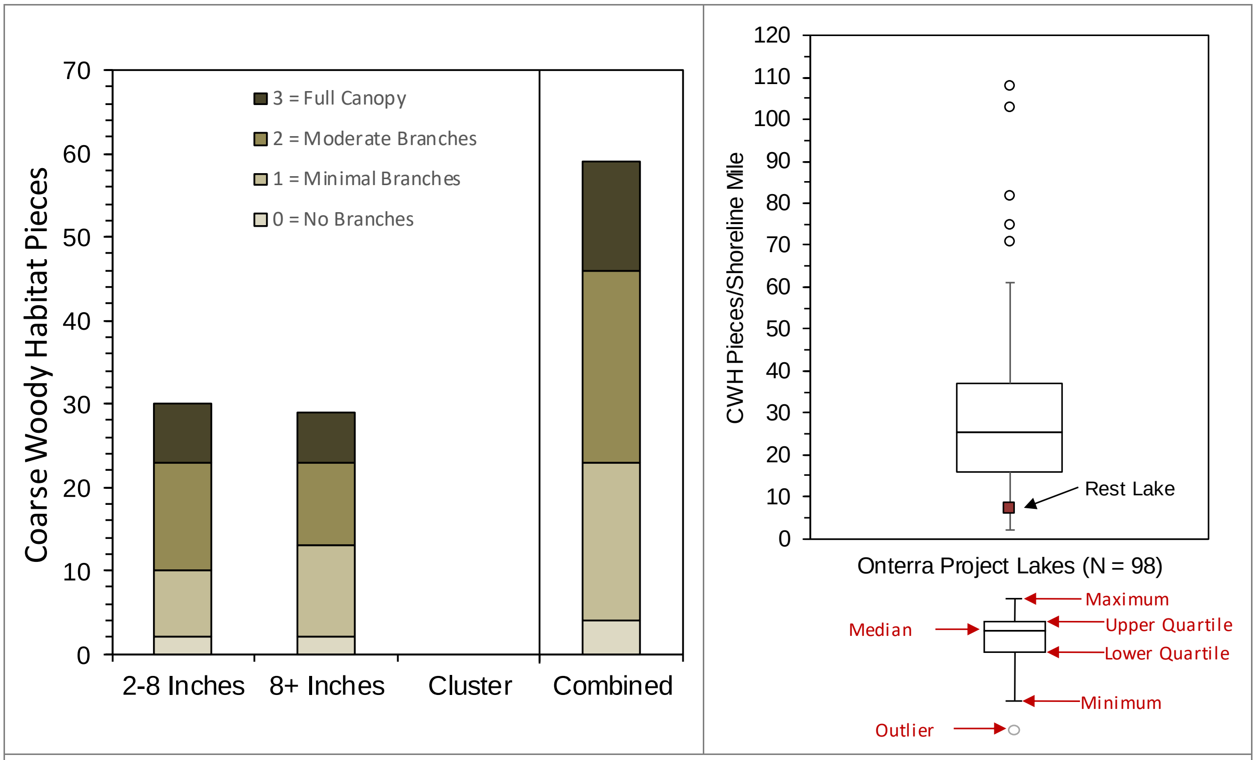


Figure 8.1.3-2. Rest Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of the Rest Lake coarse woody habitat can be found on Rest Lake Map 2.

8.1.4 Rest Lake Aquatic Vegetation

Note: Rest Lake consists of what some consider two waterbodies – Rest Lake and a bay at the north end called Papoose Bay. Papoose Bay and Rest Lake were surveyed in a similar manner with regards to the aquatic plant community; however, some aspects of the aquatic plant community are analyzed separately as discussed below.

An early season aquatic invasive species survey was conducted on Rest Lake and Papoose Bay on May 29, 2012. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species.

The aquatic plant point-intercept survey was conducted on Rest Lake and Papoose Bay on July 24, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on July 25, 2012 to map these community types. During all surveys, 37 species of native aquatic plants were located in Rest Lake (Table 8.1.4-1). Twenty-one of these species were sampled directly on the rake during the point-intercept survey and are used in the analysis that follows, while the remaining 16 species were observed incidentally. Three exotic species, pale yellow iris (*Iris speudacorus*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*) were observed along the shores of Rest Lake also. Exotic species inventories and management actions are discussed within the Chain-wide plan document. A total of 24 native aquatic plant species were located in Papoose Bay in 2012, 17 of which were sampled directly during the point-intercept survey (Table 8.1.4-2). No exotic species were located in Papoose Bay in 2012. Table 8.1.4-1 and Table 8.1.4-2 also include a list of aquatic plant species located in Rest Lake and Papoose Bay during whole-lake point-intercept surveys conducted by members of WDNR in 2008.

Aquatic plants were found growing to a depth of 15 feet in Rest Lake and to the maximum depth of Papoose Bay, 7 feet, in 2012. A WDNR 2008 survey found aquatic plants growing to a depth of 11.5 feet in Rest Lake and 6.5 feet in Papoose Bay. Of the 415 point-intercept sampling locations that fell at or below the maximum depth of plant growth (littoral zone) in Rest Lake in 2012, 18% contained aquatic vegetation, indicating Rest Lake's littoral zone is not highly vegetated. As illustrated on Rest Lake Map 3, aquatic vegetation was most abundant in shallow areas within the northern and southwestern areas of the lake. Papoose Bay, being relatively shallow, was highly vegetated with 84% of the point-intercept sampling locations sampled containing aquatic vegetation in 2012. Papoose Bay-Map 1 displays the point-intercept locations that contained aquatic vegetation in 2012, and that many of the point-intercept sampling locations were not sampled and were listed as "non-navigable" due to dense emergent vegetation.

On Rest Lake, approximately 60% of the point-intercept sampling locations where sediment data were collected (<14 feet) were sand, 35% consisted of a fine, soft sediments (muck) and 5% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5). Most (76%) of the point-intercept sampling locations in Papoose Bay held fine, soft sediments, while 21% contained sand and 3% contained a rocky substrate.

Table 8.1.4-1. Aquatic plant species located in Rest Lake during Onterra 2012 surveys and WDNR 2008 point-intercept survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatsim (C)	WDNR (2008)	Onterra (2012)
Emergent	*Carex crinita*	Fringed sedge	6		I
	Carex lacustris	Lake sedge	6		I
	Carex retrorsa	Retrorse sedge	6		I
	Eleocharis palustris	Creeping spikerush	6		I
	Equisetum fluviatile	Water horsetail	7	X	I
	Glyceria canadensis	Rattlesnake grass	7		I
	Iris pseudacorus	Pale yellow iris	Exotic		I
	Iris versicolor	Northern blue flag	5		I
	Juncus effusus	Soft rush	4		I
	Lythrum alatum	Winged loosestrife	6		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Phalaris arundinacea	Reed canary grass	Exotic		I
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus pungens	Three-square rush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Scirpus cyperinus	Wool grass	4		I
	Sium suave	Water parsnip	5	X	I
	Typha sp.	Cattail sp.	1	X	I
	Zizania palustris	Northern wild rice	8	X	X
FL	*Nymphaea odorata*	White water lily	6		I
	Nuphar variegata	Spatterdock	6		X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	X	X
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara sp.	Muskgrasses	7		X
	Elodea canadensis	Common waterweed	3	X	X
	Elodea nuttallii	Slender waterweed	7	X	
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Najas guadalupensis	Southern naiad	7		X
	Nitella sp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton foliosus	Leafy pondweed	6	X	X
	Potamogeton friesii	Fries' pondweed	8	X	X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	Potamogeton strictifolius	Stiff pondweed	9	X	
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Utricularia intermedia	Flat-leaf bladderwort	9	X	
	Utricularia vulgaris	Common bladderwort	7		X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria cristata*	Crested arrowhead	9	X	
	Schoenoplectus subterminalis	Water bulrush	9	X	

FL = Floating-leaf; FL/E = Floating-leaf/Emergent; S/E = Submergent/Emergent
X = Located on rake during point-intercept survey; I = Incidentally located

Table 8.1.4-2. Aquatic plant species located in Papoose Bay during Onterra 2012 surveys and WDNR 2008 point-intercept survey.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatsim (C)	WDNR (2008)	Onterra (2012)
Emergent	*Carex* sp.	Sedge sp.	N/A	X	
	Cicuta maculata	Water hemlock	6	X	
	Equisetum fluviatile	Water horsetail	7	X	I
	Juncus effusus	Soft rush	4	X	
	Leersia sp.	Sawgrass sp.	N/A	X	
	Sagittaria rigida	Stiff arrowhead	8	X	
	Sagittaria sp.	Arrowhead sp.	N/A	X	
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Scirpus cyperinus	Wool grass	4		I
	Sium suave	Water parsnip	5		I
	Typha spp.	Cattail spp.	1		I
	Zizania palustris	Northern wild rice	8		X
FL	*Nuphar variegata*	Spatterdock	6		I
	Nymphaea odorata	White water lily	6	X	
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Callitriche sp.	Water starwort sp.	N/A	X	
	Ceratophyllum demersum	Coontail	3	X	X
	Chara sp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella sp.	Stoneworts	7		X
	Potamogeton foliosus	Leafy pondweed	6	X	
	Potamogeton friesii	Fries' pondweed	8	X	
	Potamogeton gramineus	Variable pondweed	7	X	X
	Potamogeton gramineus	Variable pondweed	7	X	
	Potamogeton obtusifolius	Blunt-leaf pondweed	9		X
	Potamogeton pusillus	Small pondweed	7	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Ranunculus aquatilis	White water-crowfoot	8	X	
	Utricularia vulgaris	Common bladderwort	7		X
	Vallisneria americana	Wild celery	6		X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	
	Sagittaria cuneata	Arum-leaved arrowhead	7	X	X
FF	*Lemna trisulca*	Forked duckweed	6	X	X

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

Figure 8.1.4-1 displays the littoral frequency of occurrence of aquatic plant species in Rest Lake from the 2012 point-intercept survey. Common waterweed, fern pondweed, and slender naiad were the three-most frequently encountered species in 2012. Common waterweed can be found in lakes throughout Wisconsin and North America. It is usually found growing in soft substrates, and possesses long stems with whorls of three, slender leaves. This species can tolerate and thrive in lakes with lower water clarity, and can often grow to nuisance levels forming large mats on the water's surface. Common waterweed provides excellent structural habitat for aquatic organisms and is an important food source for animals such as muskrats.

Fern pondweed, a common plant of lakes in northern Wisconsin, was the second-most abundant plant in Rest Lake in 2012. This plant generally grows in dense beds which creep along the bottom of the lake, where they provide excellent structural habitat for aquatic invertebrates and fish. The third-most abundant plant in 2012, slender naiad, is a common annual species in Wisconsin, and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). Their numerous seeds, leaves, and stems all provide sources of food, while the small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

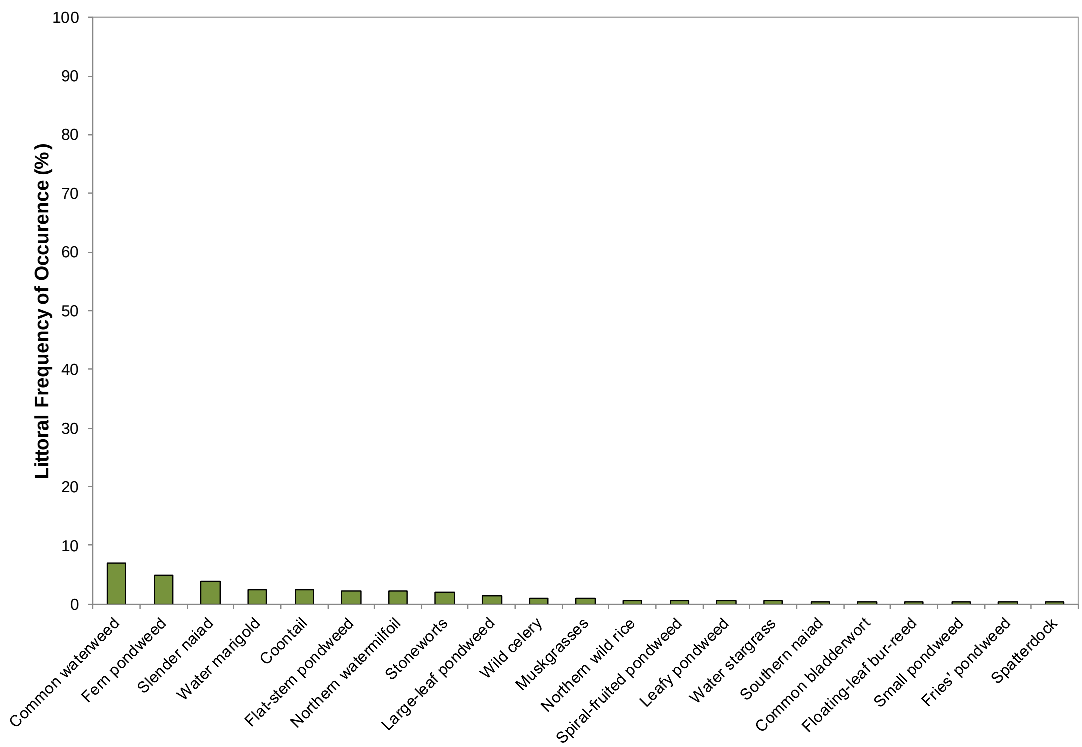


Figure 8.1.4-1. Rest Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

Figure 8.1.4-2 displays the littoral frequency of occurrence of select aquatic plant species from both the Onterra 2012 and WDNR 2008 point-intercept surveys. Like in 2012, common waterweed and fern pondweed were the most frequently encountered aquatic plants. As indicated on Figure 8.1.4-2, northern wild rice was the only aquatic plant species to exhibit a statistically valid reduction in its littoral occurrence from 2008 to 2012 (Chi-square $\alpha = 0.05$). However, this is due to additional point-intercept sampling locations that were sampled in 2008 within the northwest bay of Rest Lake that were non-navigable due to dense northern wild rice in 2012. No other aquatic plant species exhibited statistically valid changes in their occurrence over this time period.

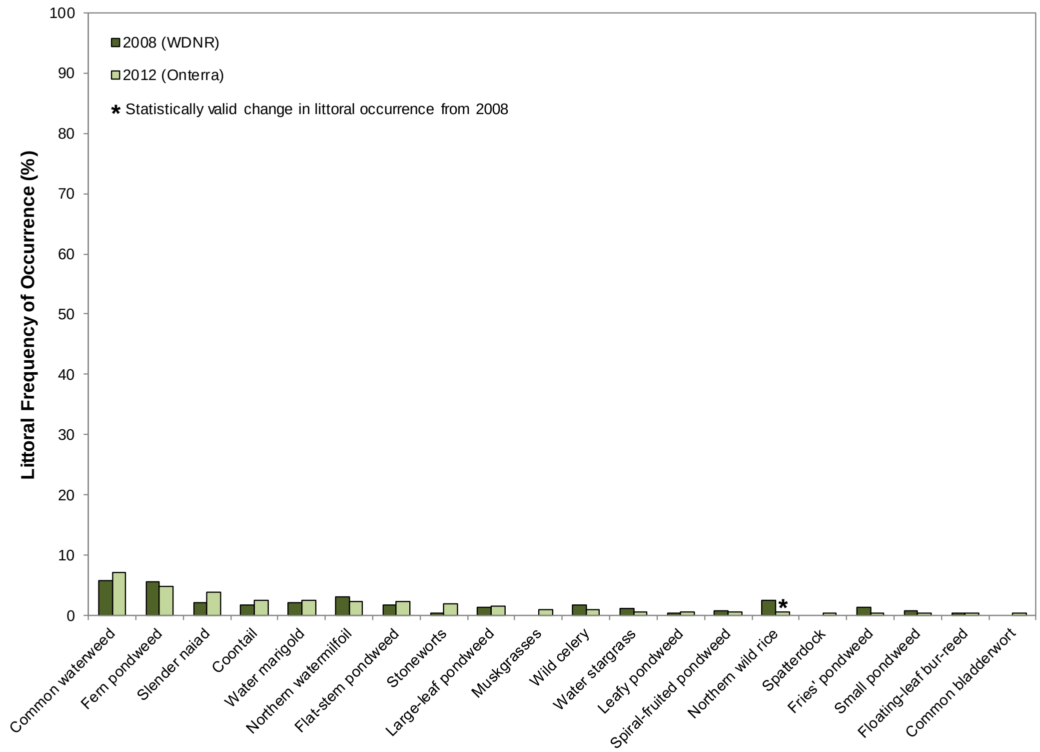


Figure 8.1.4-2. Rest Lake select aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

The 2012 littoral frequency chart for Papoose Bay (Figure 8.1.4-3) illustrates that coontail, common waterweed, and flat-stem pondweed were the three-most frequently encountered aquatic plant species during the 2012 point-intercept survey. However, only about half of the point-intercept sampling locations were able to be sampled, the remaining were located in dense, emergent vegetation, mostly comprised of northern wild rice. Had these points been able to be sampled, these data would likely show that northern wild rice is the most dominant plant within Papoose Bay.

Coontail, like common waterweed, is found throughout lakes in Wisconsin and North America. It produces long stems that contain whorls of stiff leaves, lacks true roots, and obtains the majority of its essential nutrients directly from the water. Coontail is usually found in lakes of higher productivity where there are sufficient nutrients within the water to support it. Its dense growth removes excess nutrients from the water, and provides aquatic wildlife with excellent structural habitat. Flat-stem pondweed, as its name indicates, possesses a conspicuously flattened stem. Like coontail, flat-stem pondweed is usually found in more productive lakes, and provides valuable structural habitat and sources of food for wildlife.

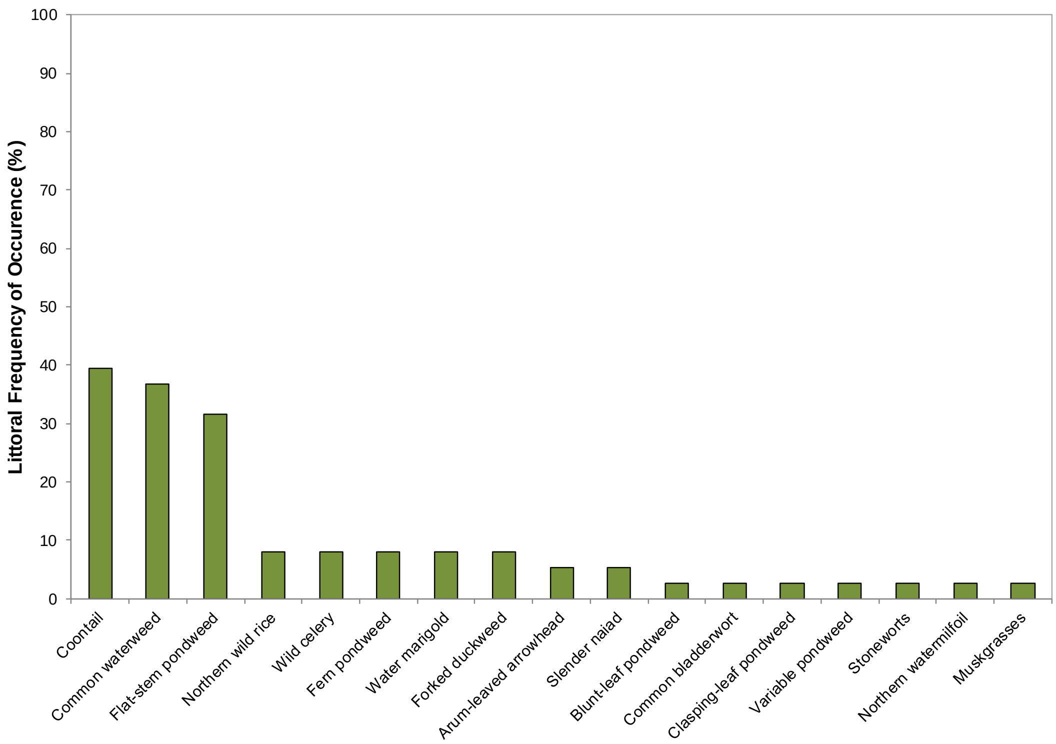


Figure 8.1.4-3. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

Figure 8.1.4-4 displays the littoral frequency of occurrence of aquatic plants from the 2012 and WDNR 2008 point-intercept surveys in Papoose Bay. As illustrate, a number of aquatic plants, including muskgrasses, northern watermilfoil, Fries' pondweed, arrowhead sp., small pondweed, coontail, and flat-stem pondweed, saw statistically valid changes in occurrence from 2008 to 2012. While some of these may reflect natural community dynamics of Papoose Bay over time, these changes are likely due to the difference in the number of point-intercept locations sampled between 2008 and 2012. Nearly all the points (83) were able to be sampled in 2008, while less than half (38) were able to be sampled in 2012. As discussed in the chain-wide section, northern wild rice populations tend fluctuate naturally on an annual basis. It is likely that the northern wild rice in Papoose Bay was less dense in 2008 allowing surveyors to access areas that were non-navigable in 2012.

As discussed in the chain-wide section, the calculations used for the Floristic Quality Index (FQI) for a lake's aquatic plant community are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. These species encountered on the rake and their conservatism values were used to calculate the FQI of Rest Lake's and Papoose Bay's aquatic plant communities in 2008 and 2012 (Figure 8.1.4-5). The number of native species encountered on the rake declined from 2008 to 2012 in both Rest Lake and Papoose Bay. The large reduction in the number of species encountered in Papoose Bay in 2012 is likely due to the previously discussed reduced sampling effort. The number of native species for both Rest Lake and Papoose Bay falls above the median value for both lakes in the Northern Lakes and Forests Lakes (NLFL) Ecoregion and for lakes throughout Wisconsin.

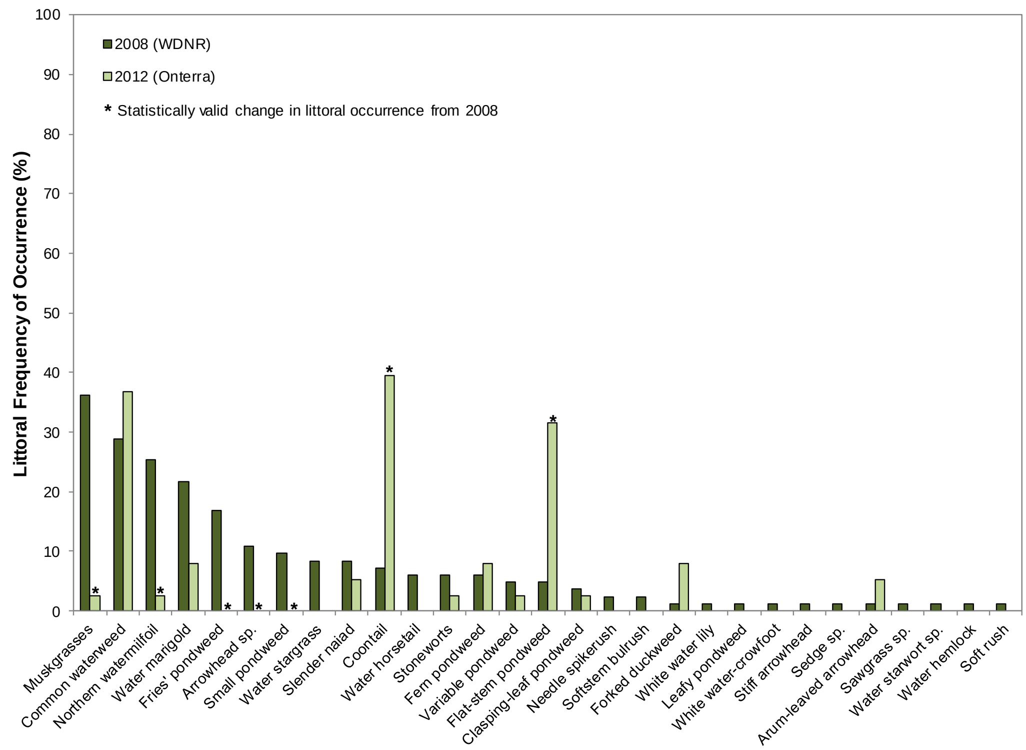


Figure 8.1.4-4. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

The average conservatism values decreased slightly in Rest Lake from 2008 to 2012, and increased slightly in Papoose Bay (Figure 8.1-4-5). The average conservatism values for Rest Lake and Papoose Bay in 2012 fall below the median value for lakes in the NLFL Ecoregion, but above the median for lakes throughout Wisconsin. The Floristic Quality Index values for both Rest Lake and Papoose Bay declined from 2008 to 2012, but both waterbodies were higher than the median values for lakes in NLFL Ecoregion and lakes in Wisconsin in 2012. These data indicate that the aquatic plant community of Rest Lake is of comparable quality to other lakes in NLFL Ecoregion and of higher quality than the majority of lakes in Wisconsin, and the plant community has changed little since 2008. The plant community of Papoose Bay is of comparable to slightly lower quality than other lakes in the NLFL Ecoregion but of higher quality than most of the lakes in Wisconsin.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while common waterweed was found at 7% of the littoral sampling locations in Rest Lake in 2012, its relative frequency of occurrence is 21%. Explained another way, if 100 plants were randomly sampled from Rest Lake, 21 of them would be common waterweed. This distribution can be observed in Figures 8.1.4-6 and 8.1.4-7.

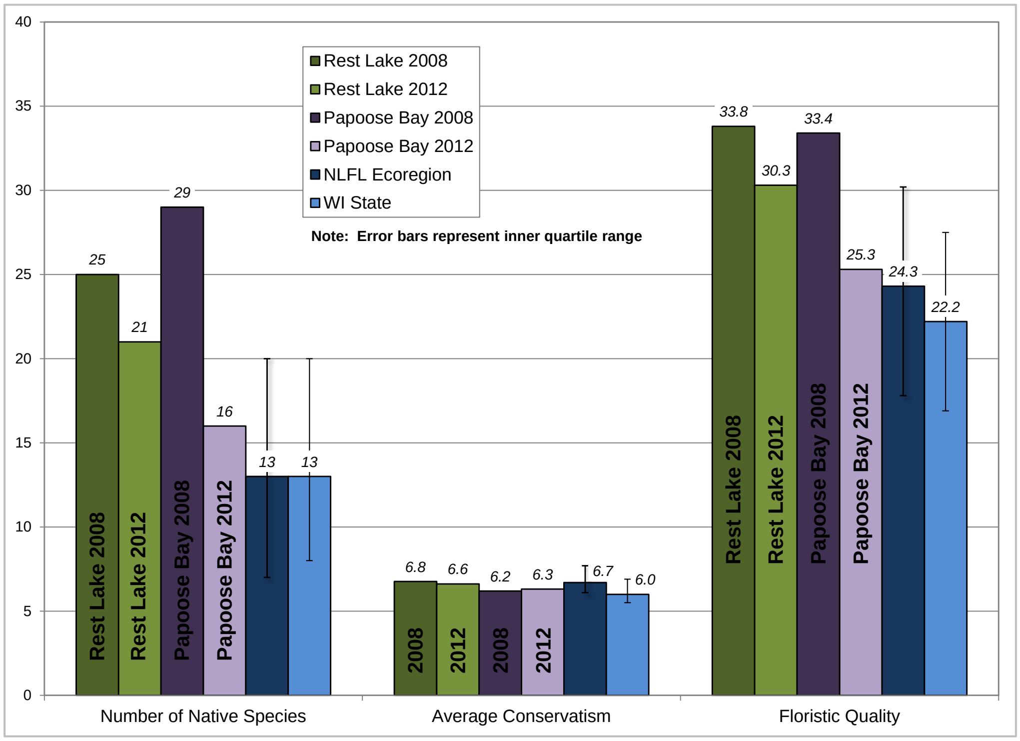


Figure 8.1.4-5. Rest Lake and Papoose Bay 2008 and 2012 Floristic Quality Analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys. Analysis following Nichols (1999).

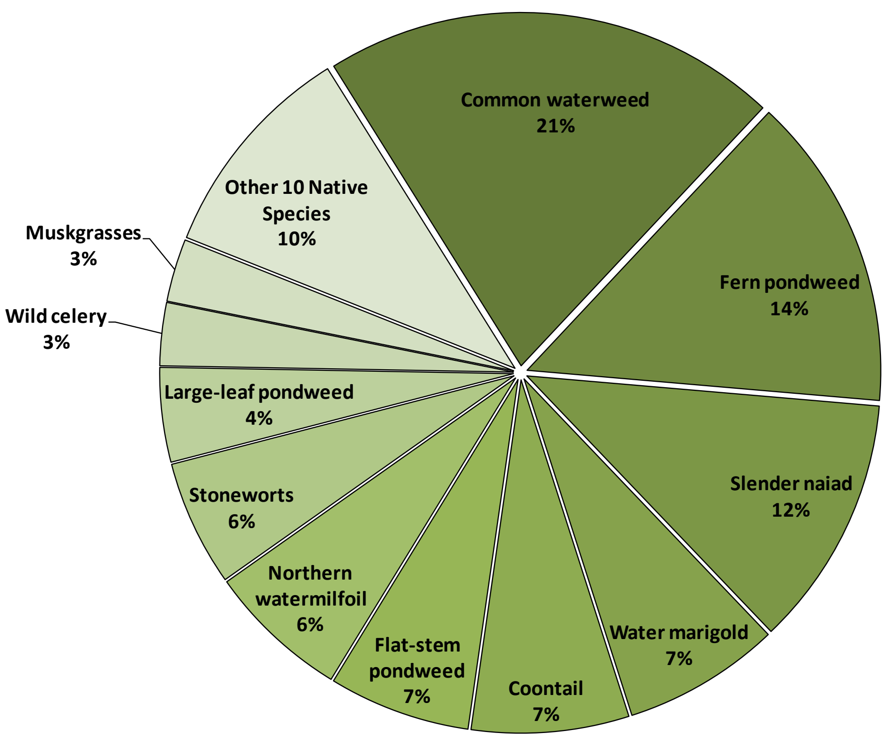


Figure 8.1.4-6. Rest Lake 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

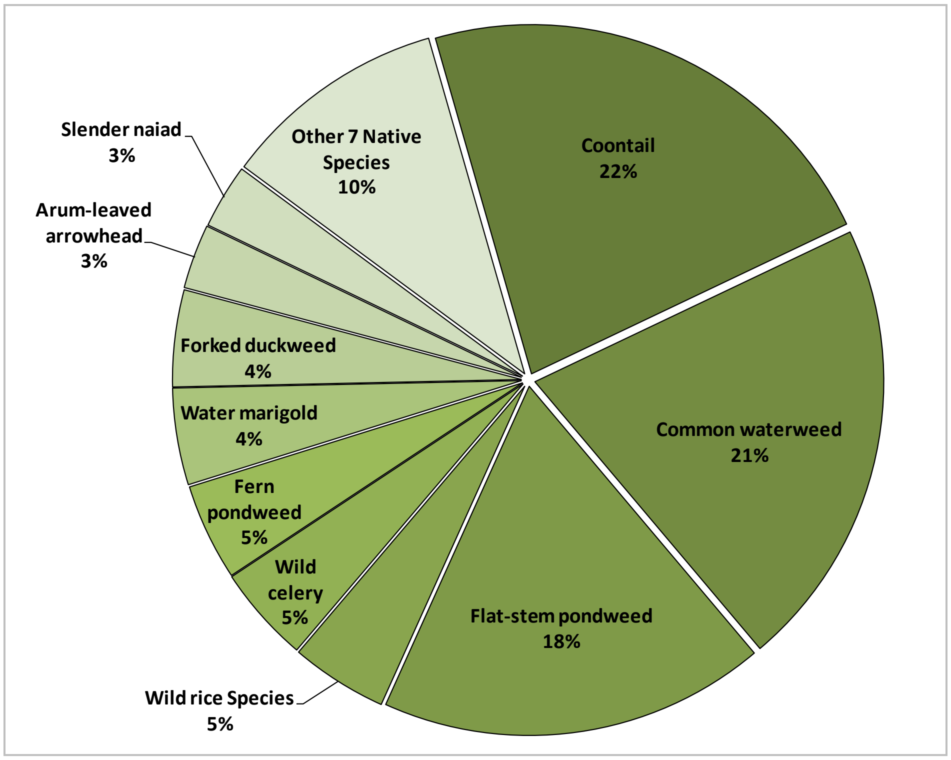


Figure 8.1.4-7. Papoose Bay 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

The quality of Rest Lake and Papoose Bay are also indicated by the presence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 11.1 acres of Rest Lake and 9.1 acres of Papoose Bay contain these types of plant communities (Rest Lake Map 4, Papoose Bay-Map 2, Table 8.1.4-3). Fourteen native floating-leaf and emergent species were located on Rest Lake and Papoose Bay (Table 8.1.4-1, 8.1.4-2), all of which provide valuable wildlife habitat.

Table 8.1.4-3. Rest Lake and Papoose Bay acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Rest Lake Acres	Papoose Bay Acres
Emergent	10.3	9.0
Floating-leaf	0.1	0.1
Mixed Emergent & Floating-leaf	0.7	0.0
Total	11.1	9.1
Grand Total	**20.2**	

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

Papoose Creek

Papoose Creek consists of a tributary stream and a small bay at the north end of Rest Lake. Some consider the bay a separate waterbody from Rest Lake and the remaining Manitowish Waters Chain of Lakes. The Papoose Bay Association (PBA) is heavily involved with the Manitowish Waters Lake Association, North Lakeland Discovery Center and other stakeholders in management of this waterbody. Specifically, the PBA is involved with management of abundant aquatic plant populations, which bring about navigational issues in this bay.

Mechanical Harvesting in Papoose Bay

Papoose Bay riparian property owners, many who are members of the Papoose Bay Association, experience navigational issues brought about by abundant aquatic plant populations within the bay. The association has sponsored mechanical harvesting to maintain navigational lanes to increase navigability annually since 2002. In 2012, approximately 2 acres of aquatic plants were mechanically harvested. Papoose Bay-Map 3 shows that a 30-foot wide navigational lane was harvested down the center of the bay, while 15-foot wide riparian access lanes were harvested to maintain access to the main navigational channel. Within the Implementation Plan, Management Goal 7 addresses future harvesting permitting and activities.

Non-Native Aquatic Plants in Rest Lake

Pale-yellow iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along the shoreline areas on the lake during the early-season aquatic invasive species survey. The single location of pale-yellow iris on Rest Lake's western shore can be viewed on Rest Lake Map 4. This exotic plant is typically controlled with hand-removal and in cases of heavy infestations, the use of herbicides.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

In Rest Lake, purple loosestrife was located along the shoreline of the southern portion of the lake (Rest Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Rest Lake.

Reed canary grass

Reed canary grass (*Phalaris arundinacea*) is a large, coarse perennial grass that can reach six feet in height. Often difficult to distinguish from native grasses, this species forms dense, highly productive stands that vigorously outcompete native species. Unlike native grasses, few wildlife species utilize the grass as a food source, and the stems grow too densely to provide cover for small mammals and waterfowl. It grows best in moist soils such as wetlands, marshes, stream banks and lake shorelines. Reed canary grass was observed in several areas in the south half of Rest Lake (Rest Lake – Map 4). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Rest Lake during 2015. Through 2019, the infrequent occurrences of this exotic were managed through volunteer and professional hand-harvesting. As a part of the Manitowish Waters Comprehensive Management Plan, Rest Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.1.5 Rest Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here and within each lake's individual report section as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Rest Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.1.5-1). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Rest Lake has been stocked from 1973 to 2016 with walleye and muskellunge (Table 8.1.5-1).

Photograph 8.1.5-1. Fingerling Muskellunge.

Table 8.1.5-1. Stocking data available for Rest Lake (1974-2016).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in
1976	Walleye	Unspecified	Fingerling	32,000	3
1973	Muskellunge	Unspecified	Fingerling	1,000	11
1977	Muskellunge	Unspecified	Fingerling	700	9
1983	Muskellunge	Unspecified	Fingerling	300	11
1985	Muskellunge	Unspecified	Fingerling	600	10
1987	Muskellunge	Unspecified	Fingerling	1,800	12
1989	Muskellunge	Unspecified	Fingerling	600	11
1991	Muskellunge	Unspecified	Fingerling	300	12
1992	Muskellunge	Unspecified	Fingerling	300	10
1993	Muskellunge	Unspecified	Fingerling	300	12.4
1996	Muskellunge	Unspecified	Fingerling	300	10.8
1998	Muskellunge	Unspecified	Large Fingerling	600	12
2000	Muskellunge	Unspecified	Large Fingerling	600	10.3
2002	Muskellunge	Unspecified	Large Fingerling	203	10.1
2004	Muskellunge	Unspecified	Large Fingerling	203	10.5
2006	Muskellunge	Upper Wisconsin River	Large Fingerling	203	10.5
2008	Muskellunge	Upper Wisconsin River	Large Fingerling	202	10.1
2010	Muskellunge	Upper Wisconsin River	Large Fingerling	203	12.8
2012	Muskellunge	Upper Wisconsin River	Large Fingerling	203	10.2
2014	Muskellunge	Upper Wisconsin River	Large Fingerling	212	10.4
2016	Muskellunge	Upper Wisconsin River	Large Fingerling	183	10.9

Rest Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.1.5-1 from 1999 to 2017. As many as 209 walleye have been harvested from the lake in the past (2015), but the average harvest is roughly 127 fish in a given year. Spear harvesters on average have taken 97% of the declared quota. Additionally, on average 8% of walleye harvested have been female.

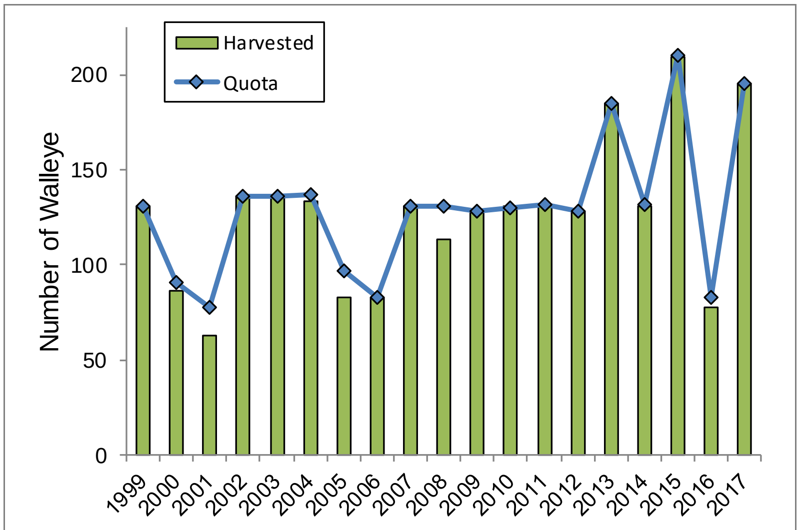


Figure 8.1.5-1. Rest Lake walleye spear harvest data. (GLIFWC 1999-2017).

Muskellunge open water spear harvest records are provided in Figure 8.1.5-2 from 1999 to 2017. As many as six muskellunge have been harvested from the lake in the past (2012), however the average harvest is two fish in a given year. Spear harvesters on average have taken 16% of the declared quota. Additionally, on average 27% of muskellunge harvested have been female.

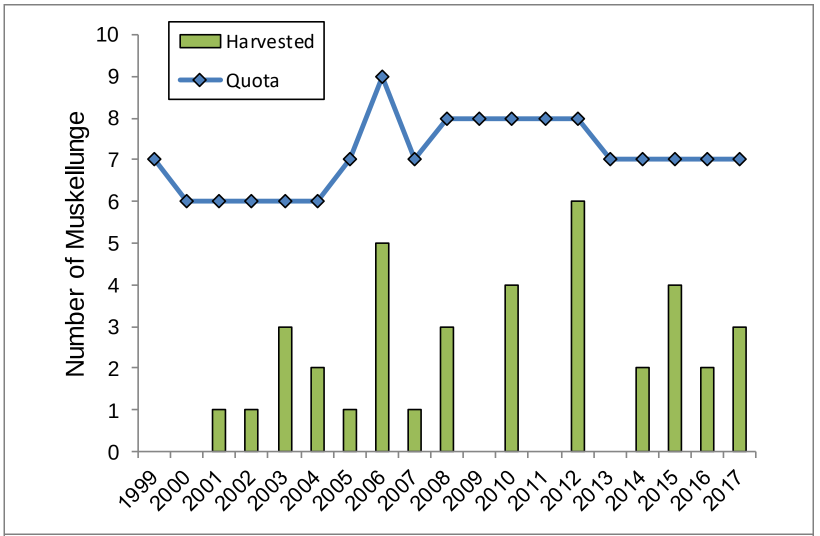
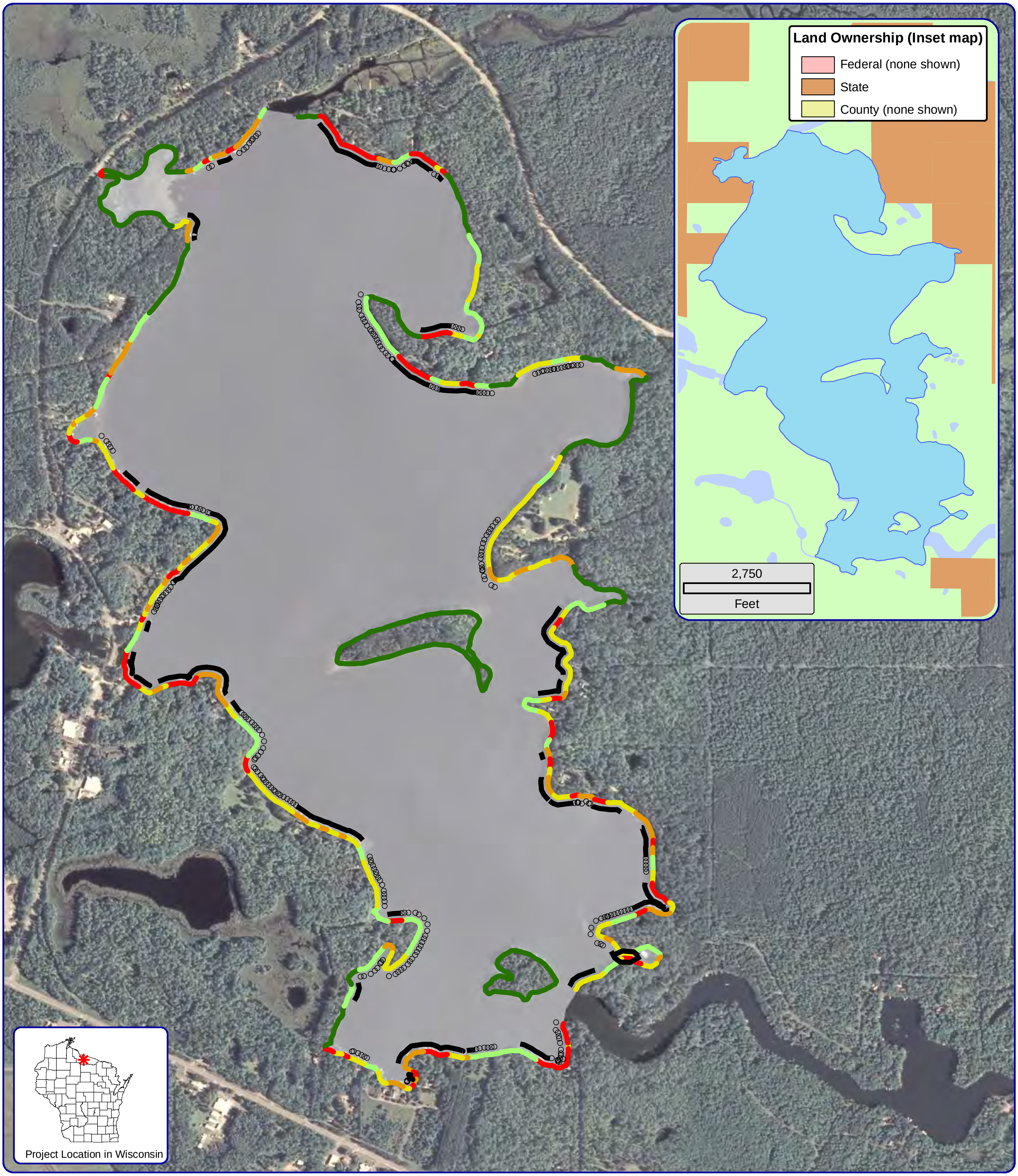


Figure 8.1.5-2. Rest Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



N
W E
S

1,250
Feet

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

Sources:
Shoreline Assessment: Onterra, 2013
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Rest_Map1_SA_2012.mxd

Legend

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

Seawall

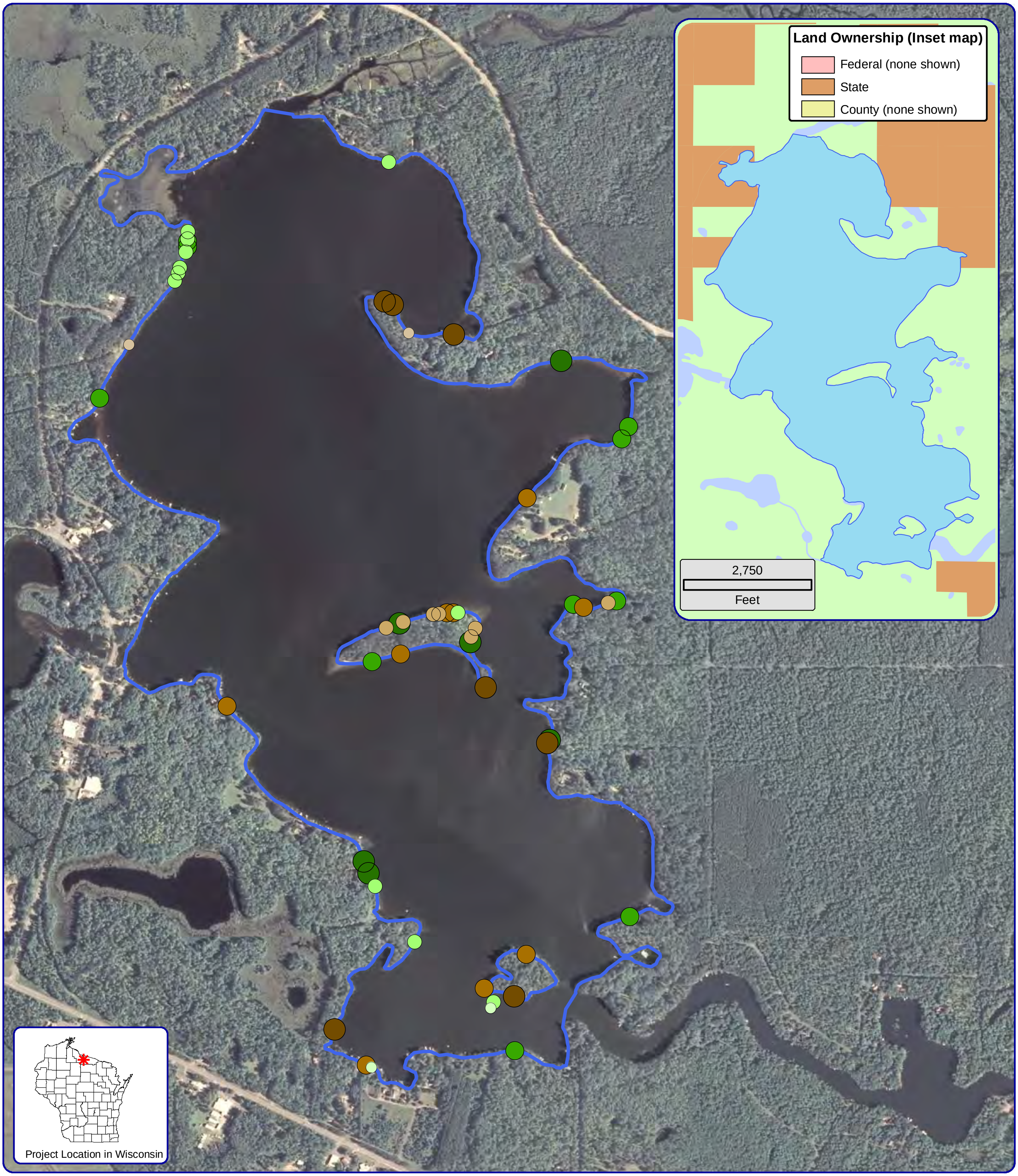
- Masonary/Wood
- Rip-Rap

Rest Lake - Map 1

Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Shoreline Condition



1,250
Feet

Legend

2-8 Inches, No Branches	>8 Inches, No Branches
2-8 Inches, Minimal Branches	>8 Inches, Minimal Branches (none)
2-8 Inches, Moderate Branches	>8 Inches, Moderate Branches
2-8 Inches, Full Canopy (none)	>8 Inches, Full Canopy
	Cluster

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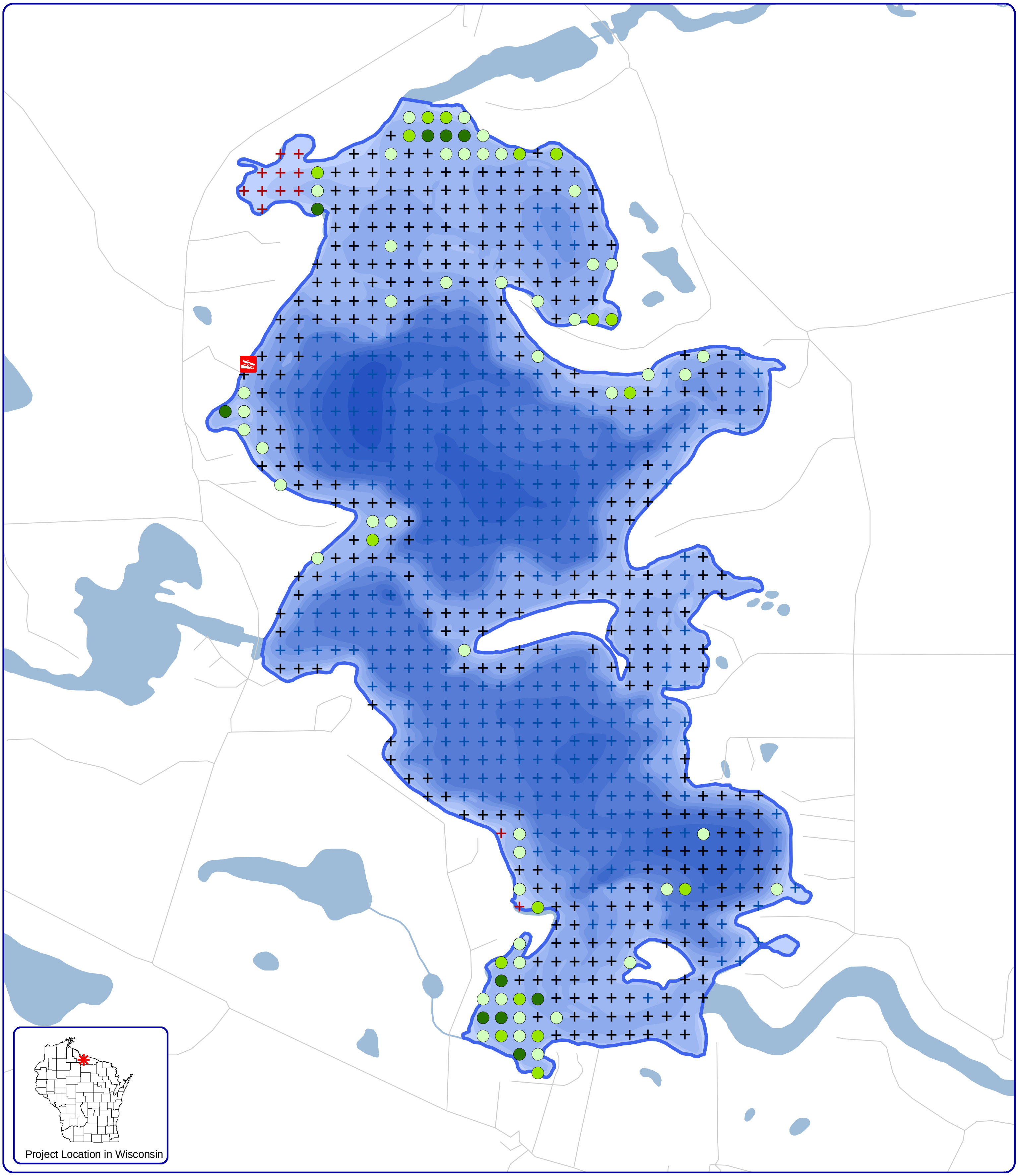
Sources:
Shoreline Assessment: Onterra, 2013
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Rest_Map2_CWH_2012.mxd

Rest Lake - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Course Woody Habitat



N
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1,250
Feet

Legend

2012 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

Rest Lake - Map 3

Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Aquatic Vegetation Distribution

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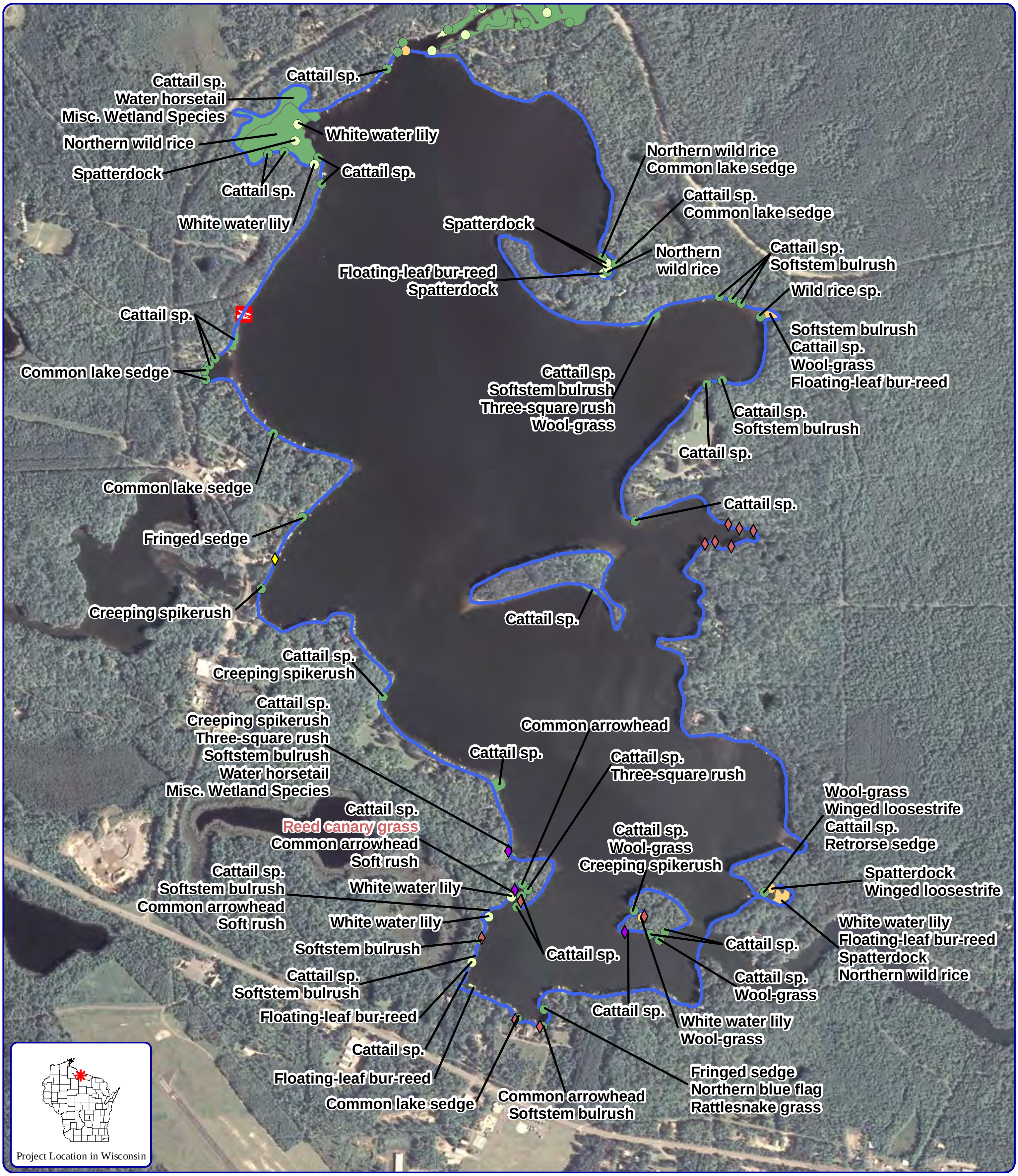
Sources:
Roads and Hydro: WDNR
Aquatic Plant Survey: Onterra, 2012
Map Date: September 24, 2013
Filename: Rest_Map3_TRFPI_2012.mxd



Legend

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

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

Exotic Plant Communities
- Purple Loosestrife
- Pale Yellow Iris
- Reed Canary Grass

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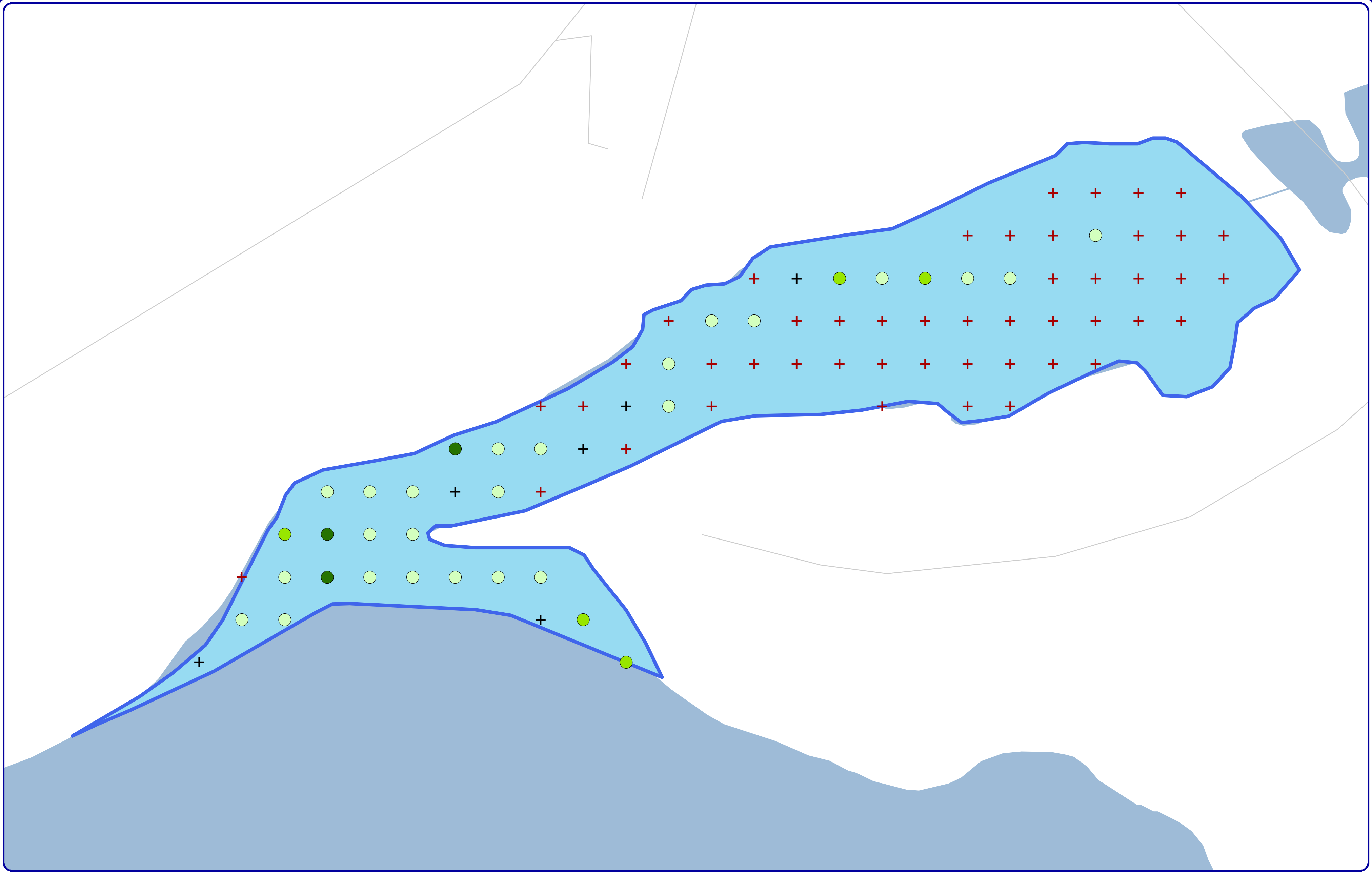
Sources:
Hydro: WDNR
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 11, 2012
Filename: Rest_Comm_2012.mxd

Rest Lake - Map 4
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities



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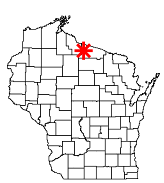
Sources:
Aquatic Plant Surveyt: Onterra, 2012
Roads and Hydro: WDNR
Map Date: September 24, 2013
Filename: PapooseBay_Map1_TRFPI_2012.mxd



Project Location in Wisconsin

Legend

2012 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

Papoose Bay - Map 1
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Aquatic Plant Distribution

N
W E
S
325
Feet

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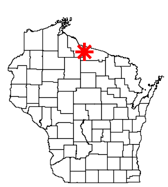
Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 11, 2012
Filename: PapooseBay_Map2_Comm_2012.mxd



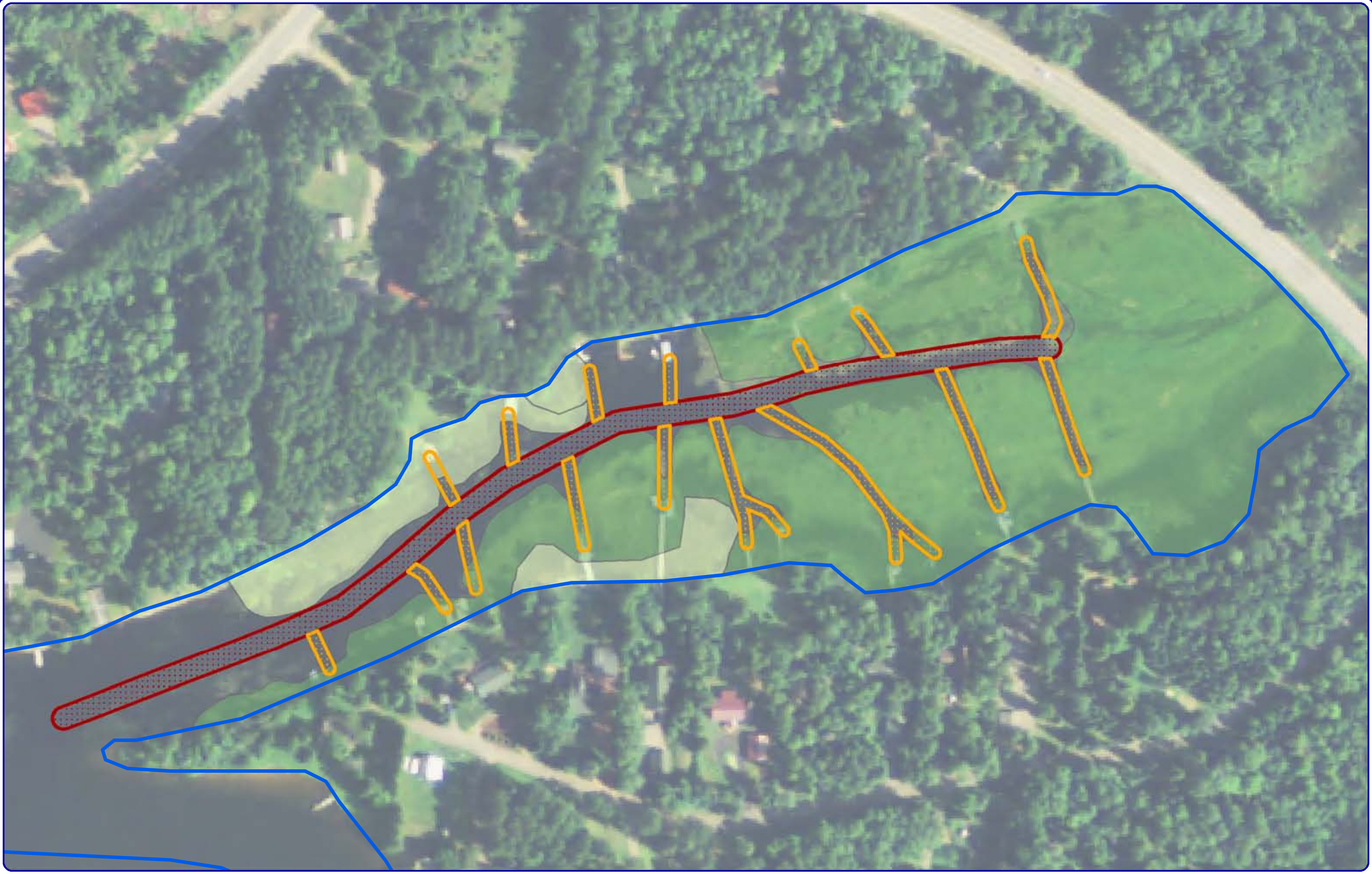
Project Location in Wisconsin

Legend

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

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

Papoose Bay - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities



N
W E
S

175
Feet

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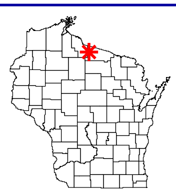
Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: October 8, 2013
Filename: Rest_Map5_MechanicalHarvestPlan.mxd



Project Location in Wisconsin

Legend

Mechanical Harvest Plan

- Common Use Lane *(30-ft width, 1.0 total acres)*
- Riparian Acess Lane *(15-ft width, 0.7 total acres)*

Northern Wild Rice

- Dense Plant Community
- Sparse Plant Community

Papoose Bay - Map 3
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Current Mechanical Harvest Plan

Note: Methodology, explanation of analysis and biological background on Island Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.2 Island Lake

An Introduction to Island Lake

Island Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 35 feet, a mean depth of 13 feet, and a surface area of approximately 918 acres. The lake is fed via Rice Creek to the northwest and Island Creek and the Manitowish River to the southwest, and empties into downstream Spider Lake. The lake is currently in a mesotrophic state, and its watershed encompasses approximately 79,573 acres. In a 2011 WDNR study and studies conducted by Onterra in 2012, 40 native aquatic plant species were located in the lake, of which fern pondweed (*Potamogeton robbinsii*) was the most common. Four non-native plants, curly-leaf pondweed, pale yellow iris, purple loosestrife, and common forget-me-not were observed growing in or along the shorelines of Island Lake in 2012.

Field Survey Notes

Shallower areas encountered along the eastern side of the lake, many logs and branches found. Abundant rice fields mapped during project studies – these areas provide great wildlife habitat.

Photo 8.2. Island Lake, Vilas County

Lake at a Glance* – Island Lake

Morphology	
Acreage	918
Maximum Depth (ft)	35
Mean Depth (ft)	13
Volume (acre-feet)	11,934
Shoreline Complexity	10.2
Vegetation	
Curly-leaf Survey Date	May 30, 2012
Comprehensive Survey Date	July 5 & 8, 2011 (WDNR), July 24, 2012 (Onterra)
Number of Native Species	40
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Curly-leaf pondweed; Pale yellow iris; Purple loosestrife; Common forget-me-not
Simpson's Diversity	0.93
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	86:1

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

8.2.1 Island Lake Water Quality

Water quality data was collected from Island Lake on six occasions in 2012/2013. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2012/2013, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2012, average summer phosphorus concentrations (20.5 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.2.1-1). The value is also less than to the median value for all lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Good* for a deep, lowland drainage lake.

Total phosphorus surface values from 2012 are compared with bottom-lake samples collected during this same time frame in Figure 8.2.1-2. As displayed in this figure, on several occasions surface and bottom total phosphorus concentrations were similar. However, on some occasions, namely during July and August of 2012, the bottom phosphorus concentrations were much greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.2.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain of Lakes-wide document. While this process may be contributing some phosphorus to Island Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Island Lake's surface water total phosphorus values are slightly lower than the median value for comparable lakes in Wisconsin.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (5.3 µg/L) were slightly higher than the median value (5.0 µg/L) for other lakes of this type (Figure 8.2.1-3), yet slightly lower than the median for all lakes in the ecoregion. Both of these parameters indicate that the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2012 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

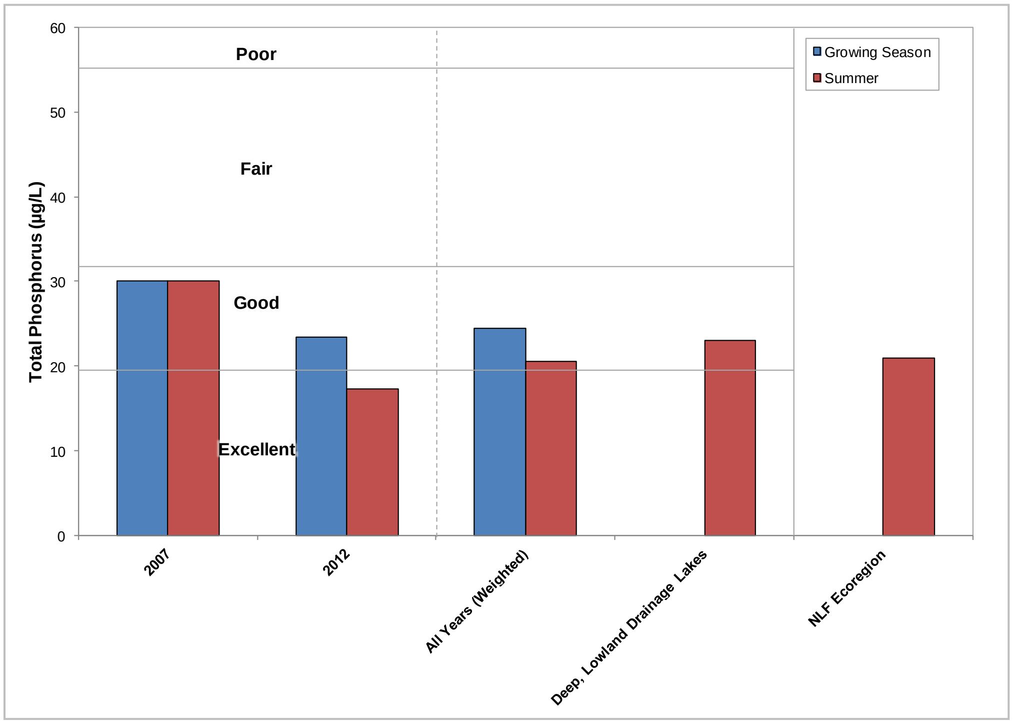


Figure 8.2.1-1. Island Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

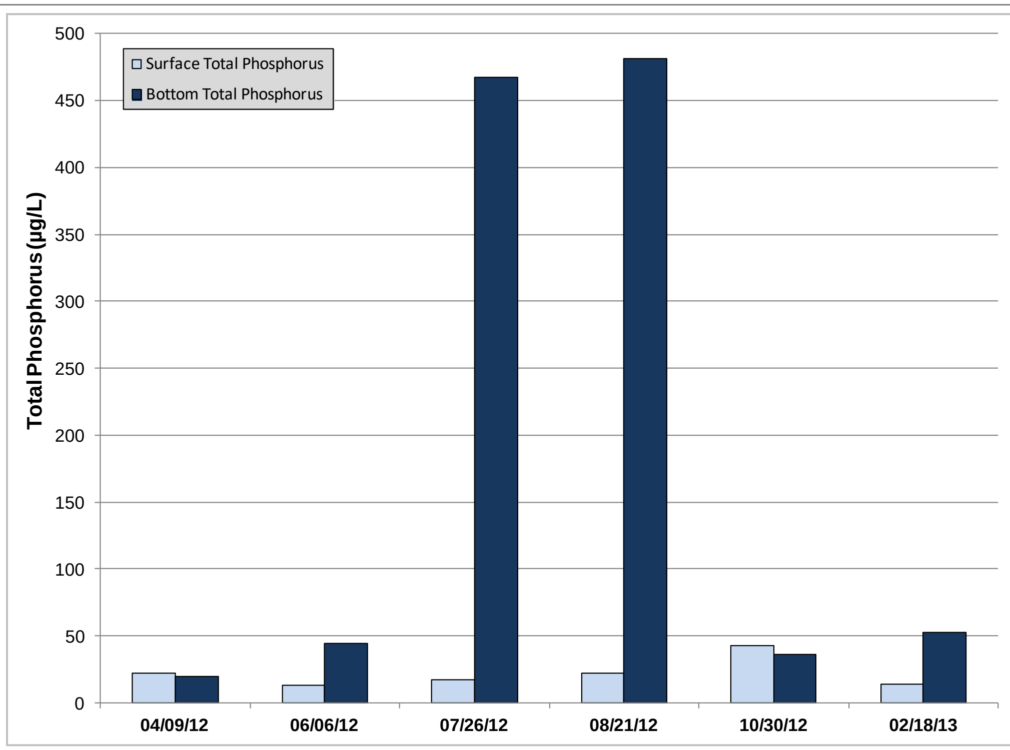


Figure 8.2.1-2. Island Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

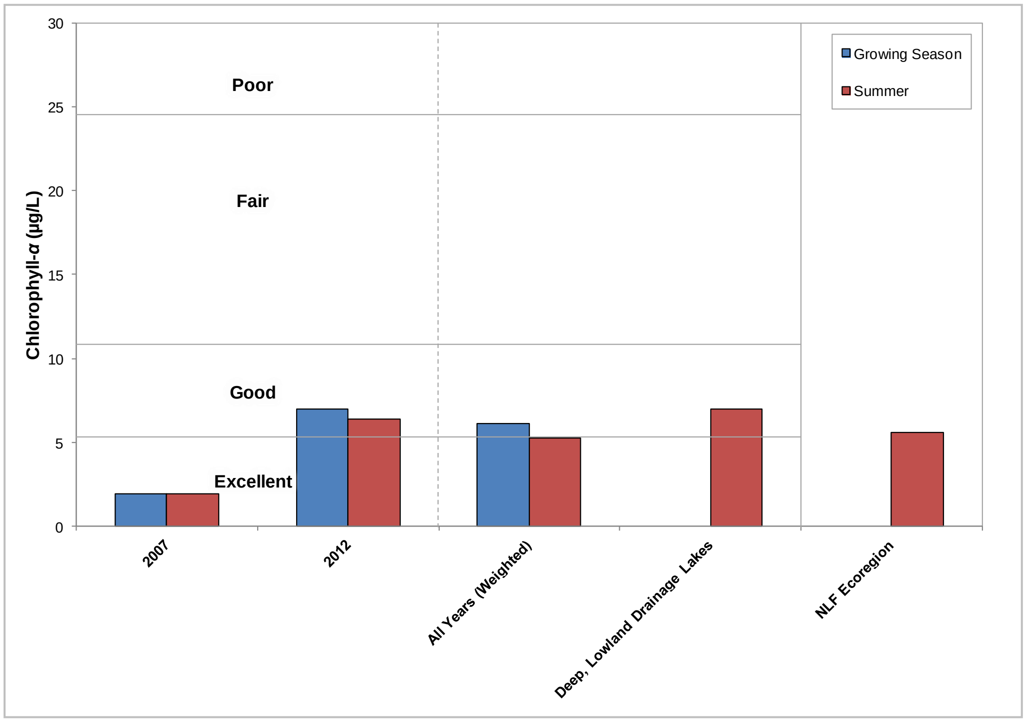


Figure 8.2.1-3. Island Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of nearly two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Island Lake's water can be described as *Good* or *Excellent* (Figure 8.1.1-4). A weighted average over this timeframe is less than the median value for other deep, lowland drainage lakes in the state. Secondly, there is no apparent trend in the clarity of the water in Island Lake; the data indicate that clarity may differ from one year to the next, but has not gotten "worse" or "better" over this time period. Annual variation is however apparent.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Island Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Island Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in April and July of 2012 were measured for this parameter, and were found to be 20 and 15 Platinum-cobalt units (Pt-co units, or PCU), respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

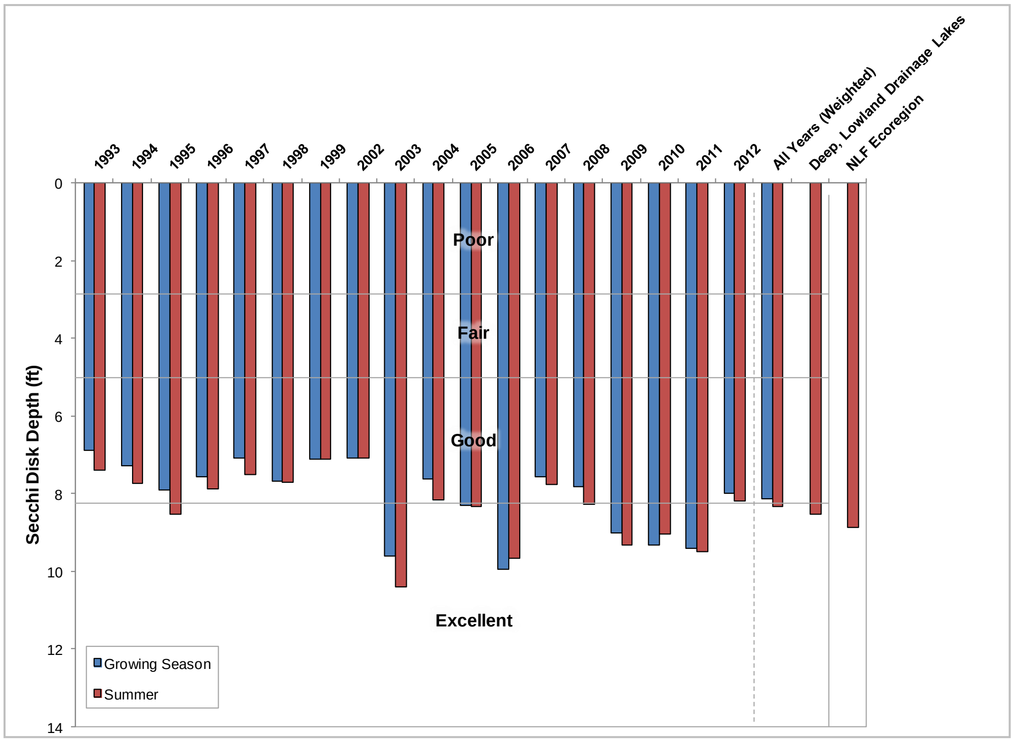


Figure 8.2.1-4. Island Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Island Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.2.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Island Lake is in a mesotrophic state.

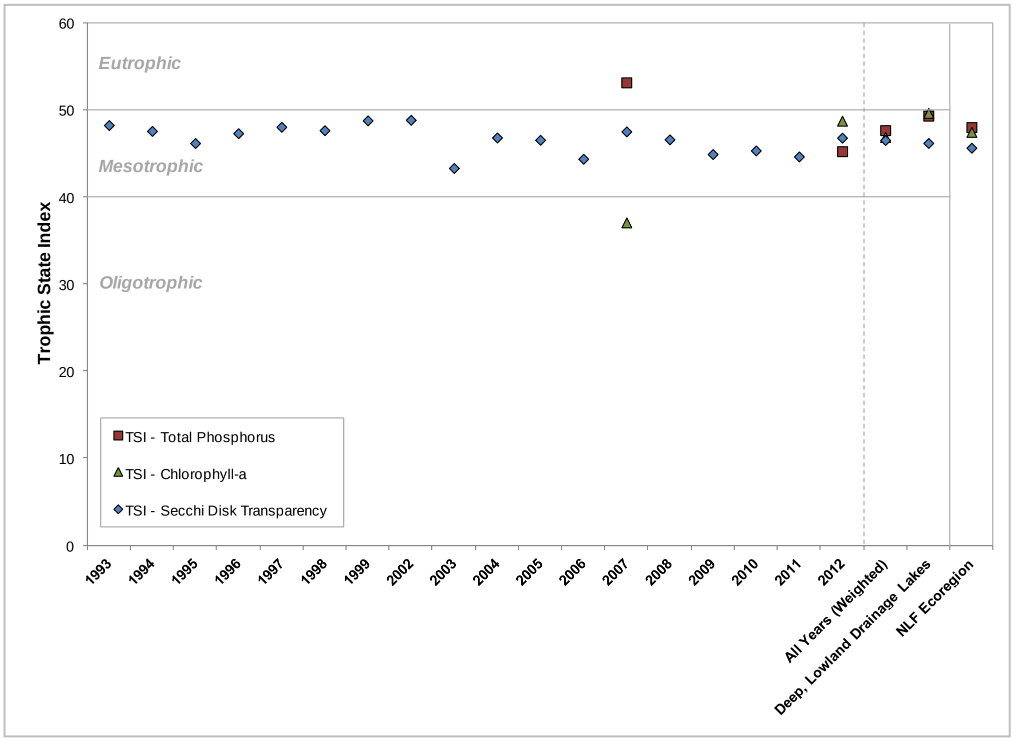


Figure 8.2.1-5. Island Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Island Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Island Lake by Onterra staff. Graphs of those data are displayed in Figure 8.2.1-6 for all sampling events.

Island Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

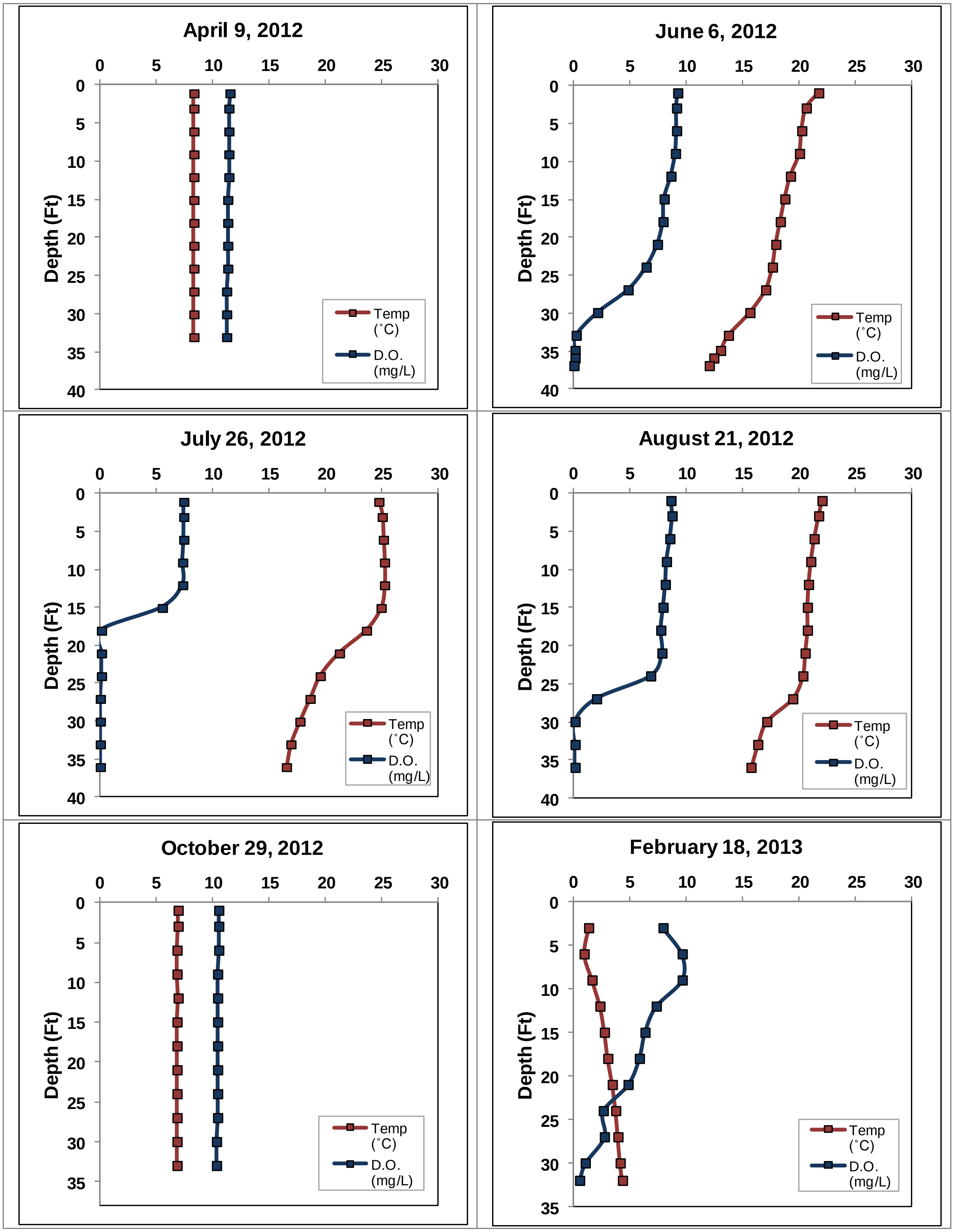


Figure 8.2.1-6. Island Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Island Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Island Lake's surface water pH was measured at roughly 8.6 during April and 7.1 during July of 2012. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Island Lake was measured at 45-46 mg/L as $CaCO_3$ in April and July of 2012. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Island Lake during 2012. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Island Lake's pH of 7.1 – 8.6 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Island Lake was found to be 13.0 mg/L in April and 12.5 mg/L in July of 2012, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval stage of zebra mussels) were observed within these samples.

8.2.2 Island Lake Watershed Assessment

Island Lake's watershed is 81,887 acres in size. Compared to Island Lake's size of 918 acres, this makes for a large watershed to lake area ratio of 88:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lakes immediately upstream. For Island Lake this means that 49,788 acres (61%) of the lake's watershed is the Boulder Lake subwatershed and 15,700 acres (19%) of the watershed is the Big Lake subwatershed while 4% is the Big Crooked and Whitney lakes subwatersheds. The rest of the Island Lake's watershed is comprised of land cover types including forest (7%), wetlands (7%), and smaller amounts of other land uses (Figure 8.2.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Island Lake's residence time is approximately 51 days, or the water within the lake is completely replaced 7.2 times per year.

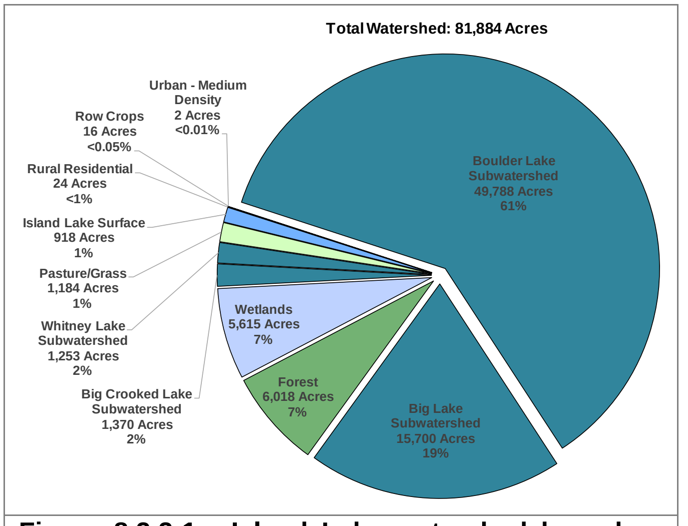


Figure 8.2.2-1. Island Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

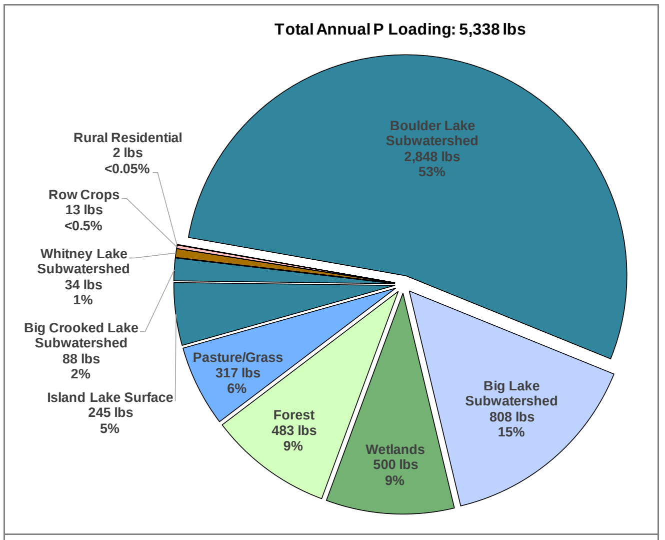


Figure 8.2.2-2. Island Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Of the estimated 5,338 pounds of phosphorus being delivered to Island Lake on an annual basis, approximately 2,848 pounds (53%) originates from the Boulder Lake subwatershed, 808 pounds (15%) from the Big Lake subwatershed, 500 pounds (9%) from wetlands, 483 pounds (9%) from wetlands, 317 pounds (6%%) from areas of pasture/grass/rural open space, 245 pounds (5%) through direct atmospheric deposition onto the lake, 88 pounds (2%) from the Big Crooked Lake subwatershed, 34 pounds (1%) from the Whitney Lake subwatershed, 13 pounds (<0.5%), and 2 pounds (<0.05%) from rural residential (Figure 8.2.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 18 µg/L, which is essentially the same as the measured growing season average total phosphorus concentration of 24 µg/L. This means the model works reasonably well for Island Lake.

Because the large majority of the phosphorus that enters Island Lake comes from the upstream lakes, especially Boulder Lake, efforts to reduce phosphorus levels in Fawn Lake should concentrate on reducing phosphorus inputs to the upstream lakes.

8.2.3 Island Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Island Lake's immediate shoreline was assessed in terms of its development. Island Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 6.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.2.3-1). This constitutes about 52% of Island Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.1 miles of urbanized and developed–unnatural shoreline (17%) was observed. If restoration of the Island Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Island Lake Map 1 displays the location of these shoreline lengths around the entire lake.

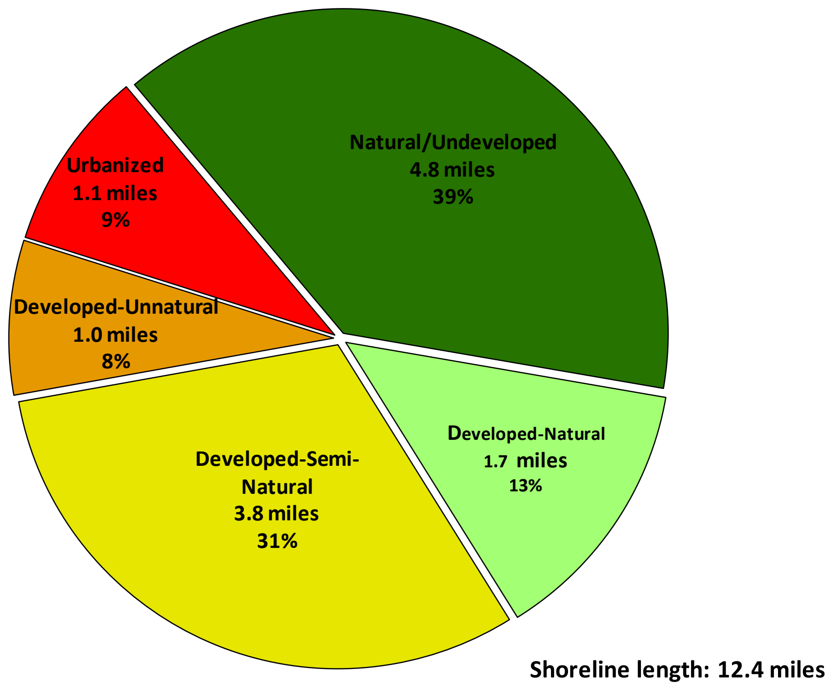


Figure 8.2.3-1. Island Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Island Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Island 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, or clusters of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no

branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 75 total pieces of coarse woody habitat were observed along 12.4 miles of shoreline (Island Lake Map 2), which gives Island Lake a coarse woody habitat to shoreline mile ratio of 6:1 (Figure 8.2.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Sixty-three pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, twelve pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Island Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Island Lake falls well below the 25th percentile of these 98 lakes (Figure 8.2.3-2).

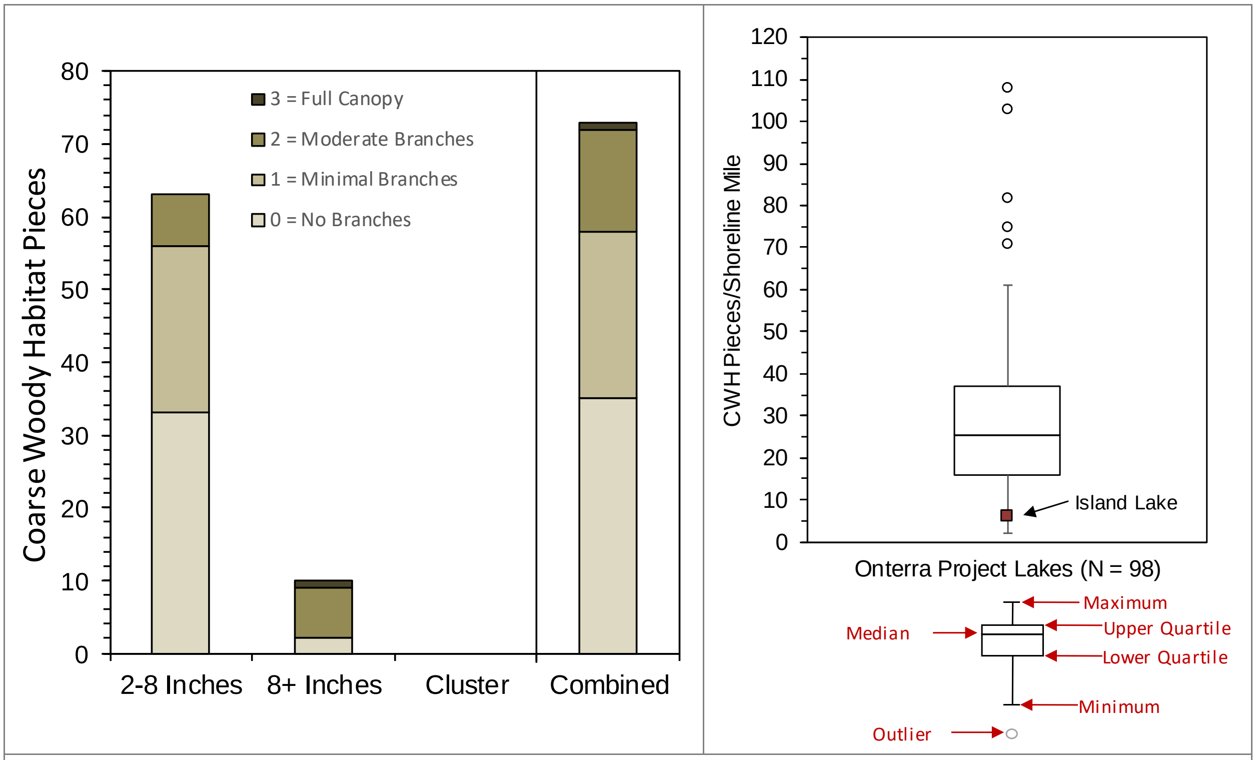


Figure 8.2.3-2. Island Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of the Island Lake coarse woody habitat can be found on Island Lake Map 2.

8.2.4 Island Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Island Lake on May 30, 2012. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species. While curly-leaf pondweed was not located during May 30, 2012 survey, earlier and subsequent surveys completed by professionals and volunteers did locate this exotic. This is elaborated on at the end of this section.

The aquatic plant point-intercept survey was conducted on Island Lake on July 5 and July 8, 2011 by the WDNR. The floating-leaf and emergent plant community mapping survey was completed on July 24, 2012 by Onterra to map these community types. During all surveys, 40 species of native aquatic plants were located in Island Lake (Table 8.2.4-1). 24 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while 16 species were observed incidentally during visits to Island Lake. Four exotic species, pale yellow iris (*Iris speudacorus*), purple loosestrife (*Lythrum salicaria*), common forget-me-not (*Myosotis scorpioides*) and curly-leaf pondweed (*Potamogeton crispus*) were observed within and along Island Lake also. Exotic species inventories and management actions are discussed within the Chain-wide plan document.

Aquatic plants were found growing to a depth of 10 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Island Lake Map 3 indicates that the majority of the aquatic vegetation found during the WDNR 2011 point-intercept survey was located in the shallow bay areas of the western and southeastern portions of the lake. Of the 230 point-intercept locations sampled within the littoral zone, roughly 26% contained aquatic vegetation. Approximately 26% of these point-intercept sampling locations where sediment data was collected at were sand, 62% consisted of a fine, organic substrate (muck) and 12% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.2.4-1. Aquatic plant species located in Island Lake during 2012 plant surveys.

Growth Form	Scientific Name	Common Name	Coefficient of Conservatism (C)	WDNR 2011 & Onterra 2012
Emergent	*Carex crinita*	Fringed sedge	6	I
	Carex retrorsa	Retrorse sedge	6	I
	Carex vesicaria	Blister sedge	7	I
	Eleocharis palustris	Creeping spikerush	6	I
	Iris pseudacorus	Pale-yellow iris	Exotic	I
	Iris versicolor	Northern blue flag	5	I
	Juncus effusus	Soft rush	4	I
	Leersia oryzoides	Rice cut grass	3	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Myosotis scorpioides	Common forget-me-not	Exotic	I
	Sagittaria latifolia	Common arrowhead	3	I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I
	Scirpus cyperinus	Wool grass	4	I
	Sparganium sp.	Bur-reed species	N/A	X
	Typha sp.	Cattail sp.	1	I
	Zizania palustris	Northern wild rice	8	X
FL	*Nuphar microphylla***	Yellow pond-lily	9	
	Nuphar variegata	Spatterdock	6	X
	Nuphar x *rubrodisca***	Intermediate pond-lily	9	
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium americanum*	Eastern bur-reed	8	I
	Sparganium angustifolium	Narrow-leaf bur-reed	9	I
	Sparganium eurycarpum	Common bur-reed	5	I
	Sparganium fluctuans	Floating-leaf bur-reed	10	I
Submergent	*Bidens beckii*	Water marigold	8	X
	Ceratophyllum demersum	Coontail	3	X
	Ceratophyllum echinatum	Spiny hornwort	10	X
	Chara sp.	Muskgrasses	7	X
	Elodea canadensis	Common waterweed	3	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Najas flexilis	Slender naiad	6	X
	Nitella sp.	Stoneworts	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X
	Potamogeton foliosus	Leafy pondweed	6	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton robbinsii	Fern pondweed	8	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
S/E	*Sagittaria graminea*	Grass-leaved arrowhead	9	I
FF	*Wolffia* sp.	Watermeal species	N/A	X

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent; FF = Free Floating
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as 'special concern' in Wisconsin*
*** = Species incidentally located in Rice Creek in 2012*

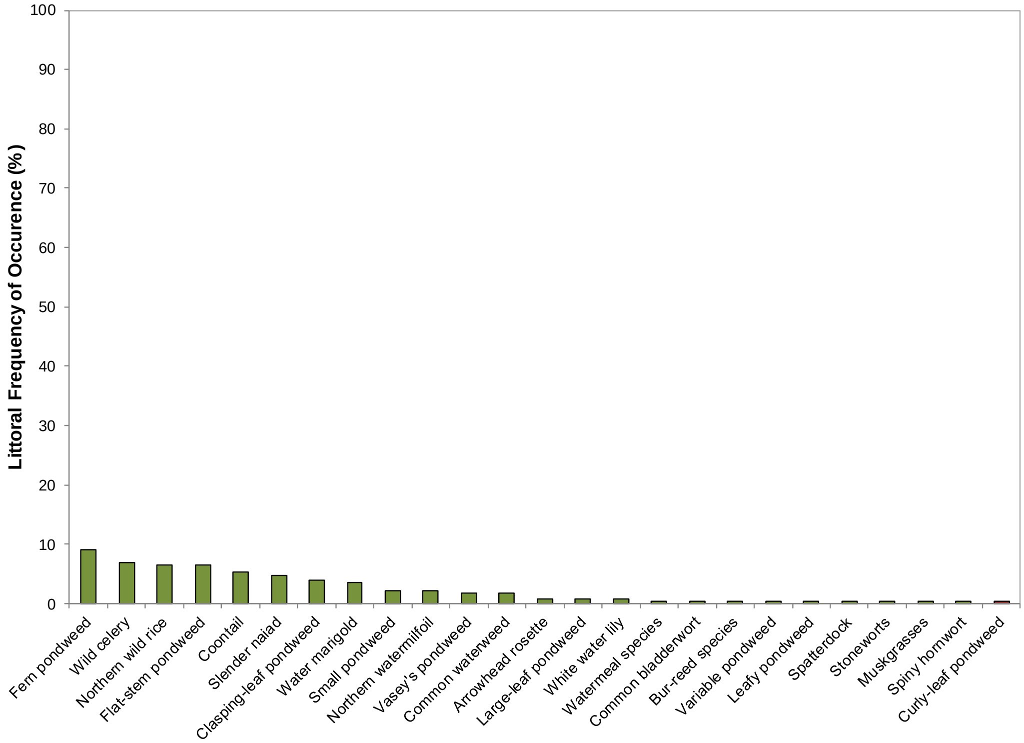


Figure 8.2.4-1. Island Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2011 WDNR point-intercept survey. Exotic species indicated in red.

Figure 8.2.4-1 (above) shows that fern pondweed, wild celery and northern wild rice were the most frequently encountered plants within Island Lake. Fern pondweed is a low-growing plant that was likely named after its palm-frond or fern-like appearance. This plant is known to provide habitat for smaller aquatic animals that are used as food by larger, predatory fishes. Wild celery is a long, limp, ribbon-leaved turbidity-tolerant species that is a premiere food source for ducks, marsh birds, shore birds and muskrats. Animals may eat the entire plant, including the tubers that reside within the sediment. Northern wild rice is an emergent annual plant that grows along the fringes of some lakes within relatively shallower water (up to 4-5 ft). Because of its significance to Native American communities and to management of the Manitowish Waters Chain of Lakes, extensive discussion of northern wild rice is included within the Chain-wide management plan document.

One species discovered during 2011 and 2012 studies, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory as a species of special concern in Wisconsin due to uncertainty regarding its distribution and abundance in Wisconsin. Vasey's pondweed is typically found in bays of large soft-water lakes as well as in rivers and ponds.

During aquatic plant inventories, 40 species of native aquatic plants (including incidentals) were found in Island Lake, along with one non-native plant. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Island Lake's plant community (0.93) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while fern pondweed was found at 9% of the sampling locations, its relative frequency of occurrence is 15%. Explained another way, if 100 plants were randomly sampled from Island Lake, 15 of them would be fern pondweed. This distribution can be observed in Figure 8.2.4-2, where together 12 species account for 89% of the aquatic plant population within Island Lake, while the other 12 native (and one non-native – curly-leaf pondweed) species account for the remaining 10%. Sixteen additional species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.2.4-1 as incidentals.

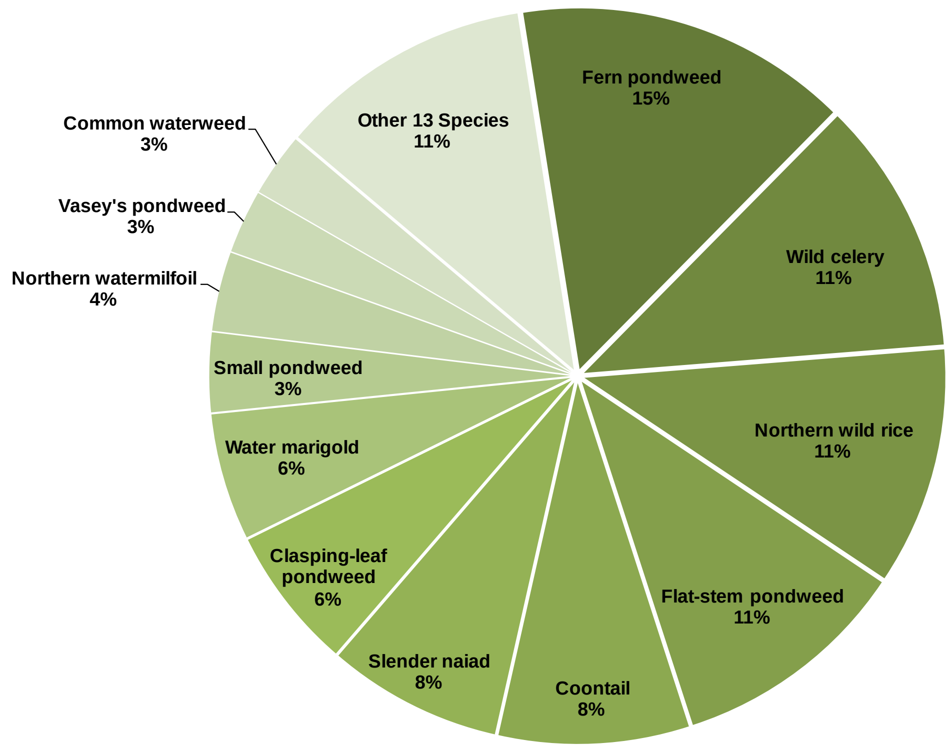


Figure 8.2.4-2. Island Lake aquatic plant relative frequency of occurrence analysis. Created using data from a 2011 WDNR point-intercept survey.

Island Lake's average conservatism value (6.7) is higher than the state (6.0) and equal to the Northern Lakes and Forests ecoregion (6.7) median. This indicates that the plant community of Island Lake is indicative of a moderately disturbed system. Combining Island Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 32.7 which is above the median values of the ecoregion and state.

The quality of Island Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 298 acres of the lake contains these types of plant communities (Island Lake Map 4, Table 8.2.4-2). Twenty-two floating-leaf and emergent species were located on Island Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

Table 8.2.4-2. Island Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Acres
Emergent	97.9
Floating-leaf	0.7
Mixed Floating-leaf and Emergent	9.7
Subtotal	**108.3**
Adjacent Wetland Area	189.8
Total	**298.1**

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

Non-Native Aquatic Plants in Island Lake

Pale-yellow iris

Pale-yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers. Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. This species was observed flowering along the shoreline areas on the lake during the early-season aquatic invasive species survey. The locations of pale-yellow iris in Island Lake Lake can be viewed on Island Lake Map 4. This exotic plant is typically controlled with hand-removal and in cases of heavy infestations, the use of herbicides.

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

In Island Lake, purple loosestrife was located along the shoreline of the lake (Island Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Island Lake.

Common Forget-me-not

Common forget-me-not (*Myosotis scorpioides*) is a relatively small, semi-aquatic wetland plant that produces clusters of small bluish flowers. Native to Eurasia, like pale-yellow iris, common forget-me-not has escaped cultivation and invaded wetland habitats across Wisconsin and creates a monotypic ground cover. A small colony of common forget-me-not was located by Onterra on the southern shoreline of Island Lake's southern end (Island Lake – Map 4). Manual removal by pulling the plants and their roots is likely the best option for control of this plant at this time on Island Lake.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Island Lake during 2010. Through 2019, the infrequent occurrences of this exotic, in Island Lake proper, were managed through volunteer and professional hand-harvesting. A more significant population located in the Spider-Island channel was closely monitored and managed with a combination of herbicide treatments and hand-harvesting. This is described in Section 3.4. As a part of the Manitowish Waters Comprehensive Management Plan, Island Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.2.5 Island Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here and within each lake's individual report section as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Island Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.2.5-1). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Island Lake has been stocked from 1974 to 2016 with muskellunge (Table 8.2.5-1).

Photograph 8.2.5-1. Fingerling Muskellunge.

Table 8.2.5-1. Stocking data available for muskellunge in Island Lake (1974 2016).

Lake	Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
Island Lake	1974	Unspecified	Fingerling	2,100	3
Island Lake	1977	Unspecified	Fingerling	1,698	7
Island Lake	1978	Unspecified	Fingerling	1,500	10
Island Lake	1981	Unspecified	Fingerling	760	12
Island Lake	1983	Unspecified	Fingerling	397	9
Island Lake	1985	Unspecified	Fingerling	800	9
Island Lake	1987	Unspecified	Fingerling	2,400	12
Island Lake	1988	Unspecified	Fingerling	410	11
Island Lake	1989	Unspecified	Fingerling	800	11
Island Lake	1991	Unspecified	Fingerling	400	11
Island Lake	1992	Unspecified	Fingerling	400	10
Island Lake	1993	Unspecified	Fingerling	1,000	11
Island Lake	1997	Unspecified	Large Fingerling	500	10.7
Island Lake	1999	Unspecified	Large Fingerling	500	11.8
Island Lake	2002	Unspecified	Large Fingerling	400	10.1
Island Lake	2004	Unspecified	Large Fingerling	400	10.5
Island Lake	2006	Upper Wisconsin River	Large Fingerling	397	9.9
Island Lake	2008	Upper Wisconsin River	Large Fingerling	400	10.1
Island Lake	2010	Upper Wisconsin River	Large Fingerling	331	13.1
Island Lake	2012	Upper Wisconsin River	Large Fingerling	400	10.2
Island Lake	2014	Upper Wisconsin River	Large Fingerling	398	10.4
Island Lake	2016	Upper Wisconsin River	Large Fingerling	360	10.9

Island Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.2.5-1 from 1999 to 2017. As many as 344 walleye have been harvested from the lake in the past (2014), but the average harvest is roughly 231 fish in a given year. Spear harvesters on average have taken 97% of the declared quota. Additionally, on average 7% of walleye harvested have been female.

Muskellunge open water spear harvest records are provided in Figure 8.2.5-2 from 1999 to 2017. As many as 1 muskellunge has been harvested from the lake in the past (2005-2007 and 2010), however the average harvest is 0 fish in a given year. Spear harvesters on average have taken 2% of the declared quota.

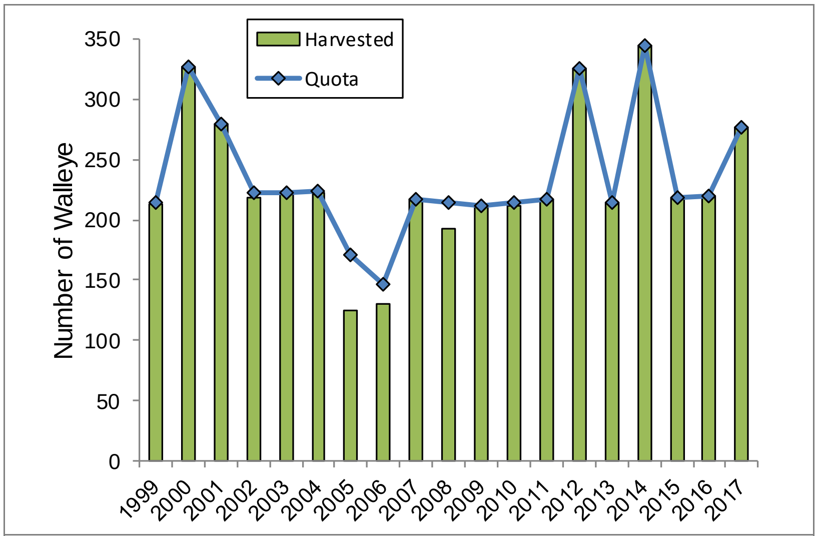


Figure 8.2.5-1. Island Lake walleye spear harvest data. (GLIFWC 1999-2017).

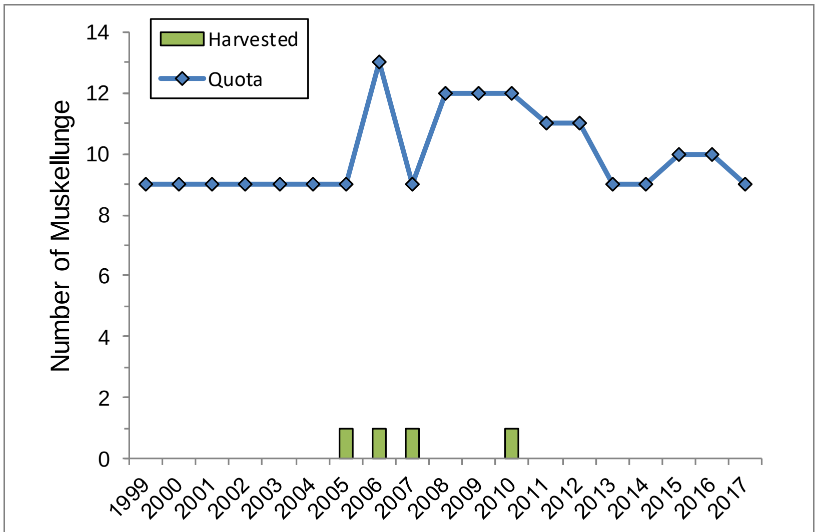
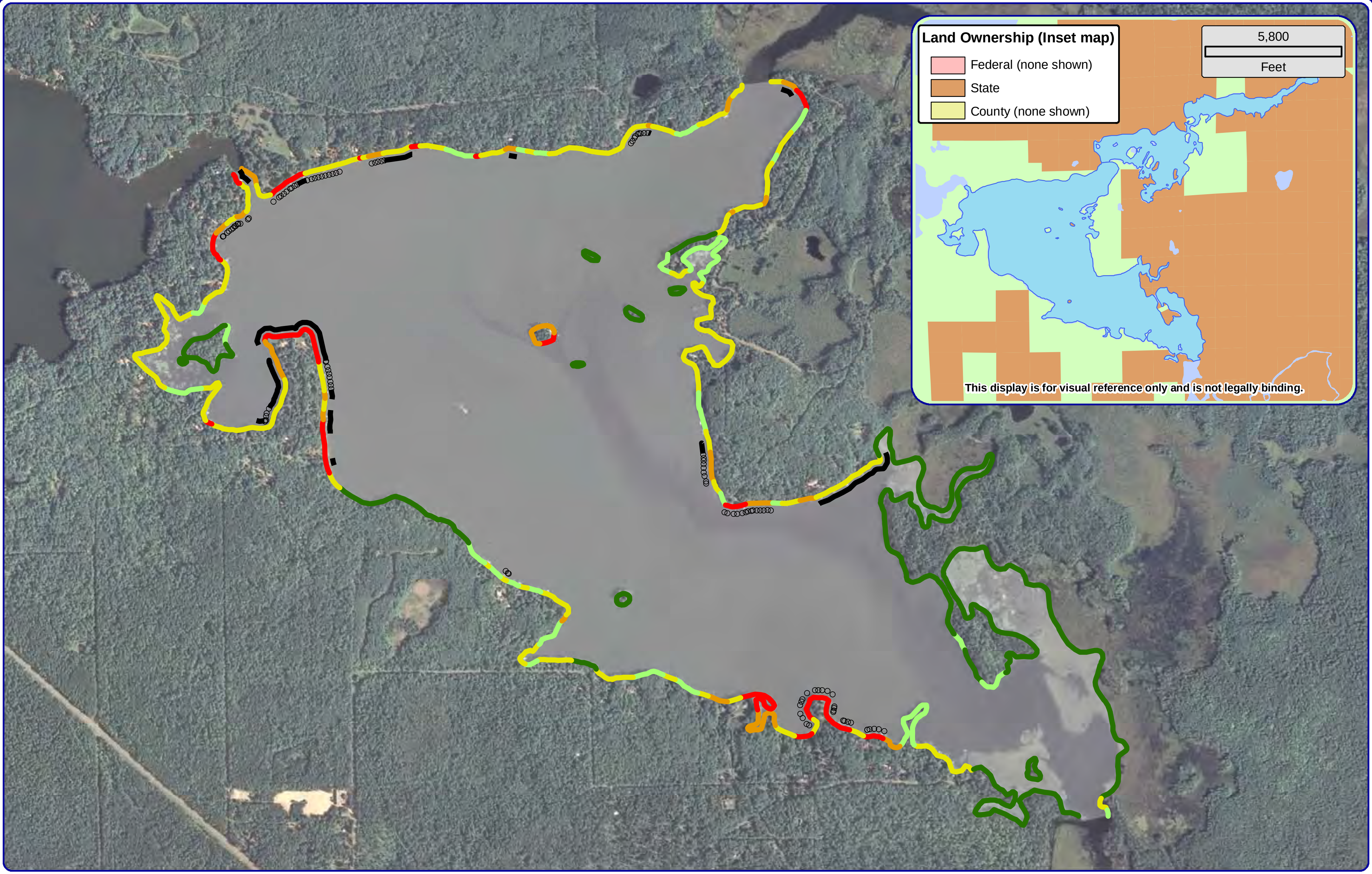


Figure 8.2.5-2. Island Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



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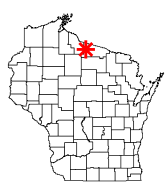
1,500
Feet

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

Sources:
Shoreline Assessment: Onterra, 2012
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Island_Map1_SA_2012.mxd


Project Location in Wisconsin

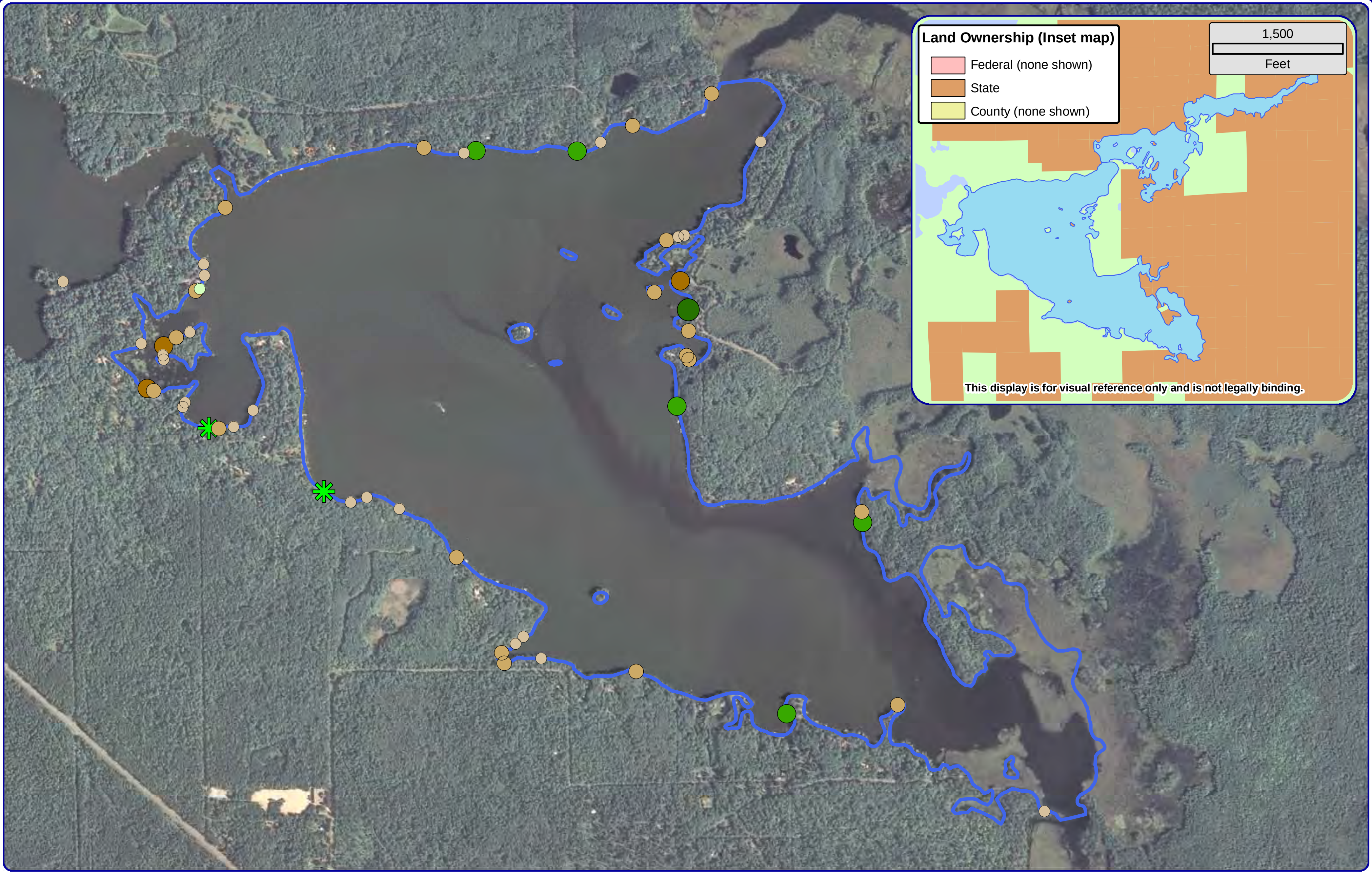
Legend

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

Seawall

Masonary/Metal/Wood
Rip-Rap

Island Lake - Map 1
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Shoreline Condition



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815 Prosper Road
De Pere, WI 54115
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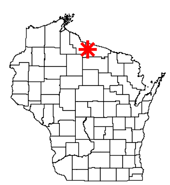
www.onterra-eco.com

Sources:
Shoreline Assessment: Onterra, 2012
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Island_Map2_CWH_2012.mxd



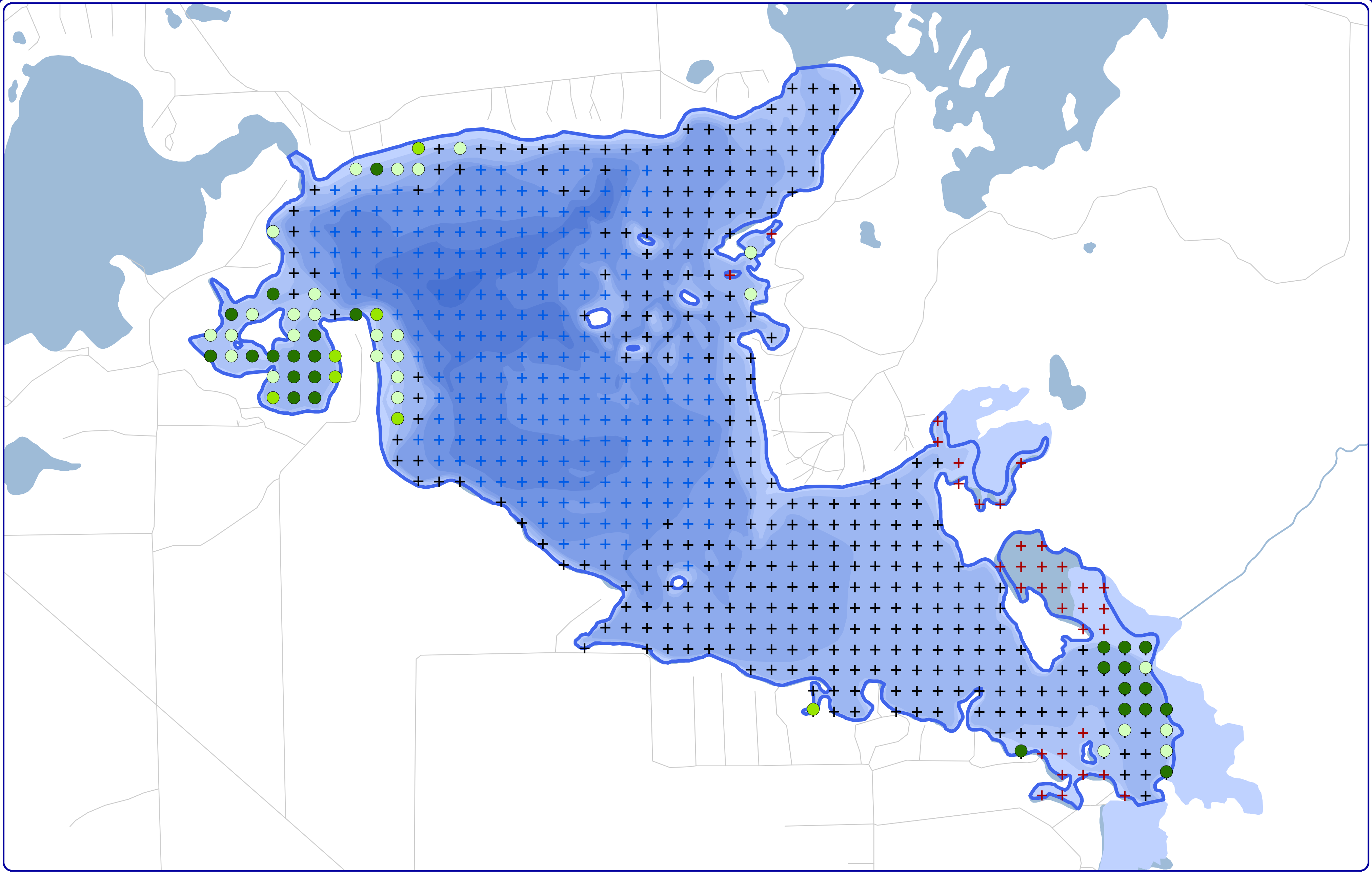
Project Location in Wisconsin

Legend

- 2-8 Inches, No Branches
- 2-8 Inches, Minimal Branches
- 2-8 Inches, Moderate Branches
- 2-8 Inches, Full Canopy (none)
- >8 Inches, No Branches
- >8 Inches, Minimal Branches (none)
- >8 Inches, Moderate Branches
- >8 Inches, Full Canopy
- Cluster

Island Lake - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Course Woody Habitat



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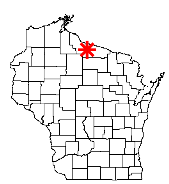
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Aquatic Plant Survey: WDNR, 2011
Roads and Hydro: WDNR
Map Date: September 24, 2013
Filename: Island_Map3_TRFPI_2012.mxd

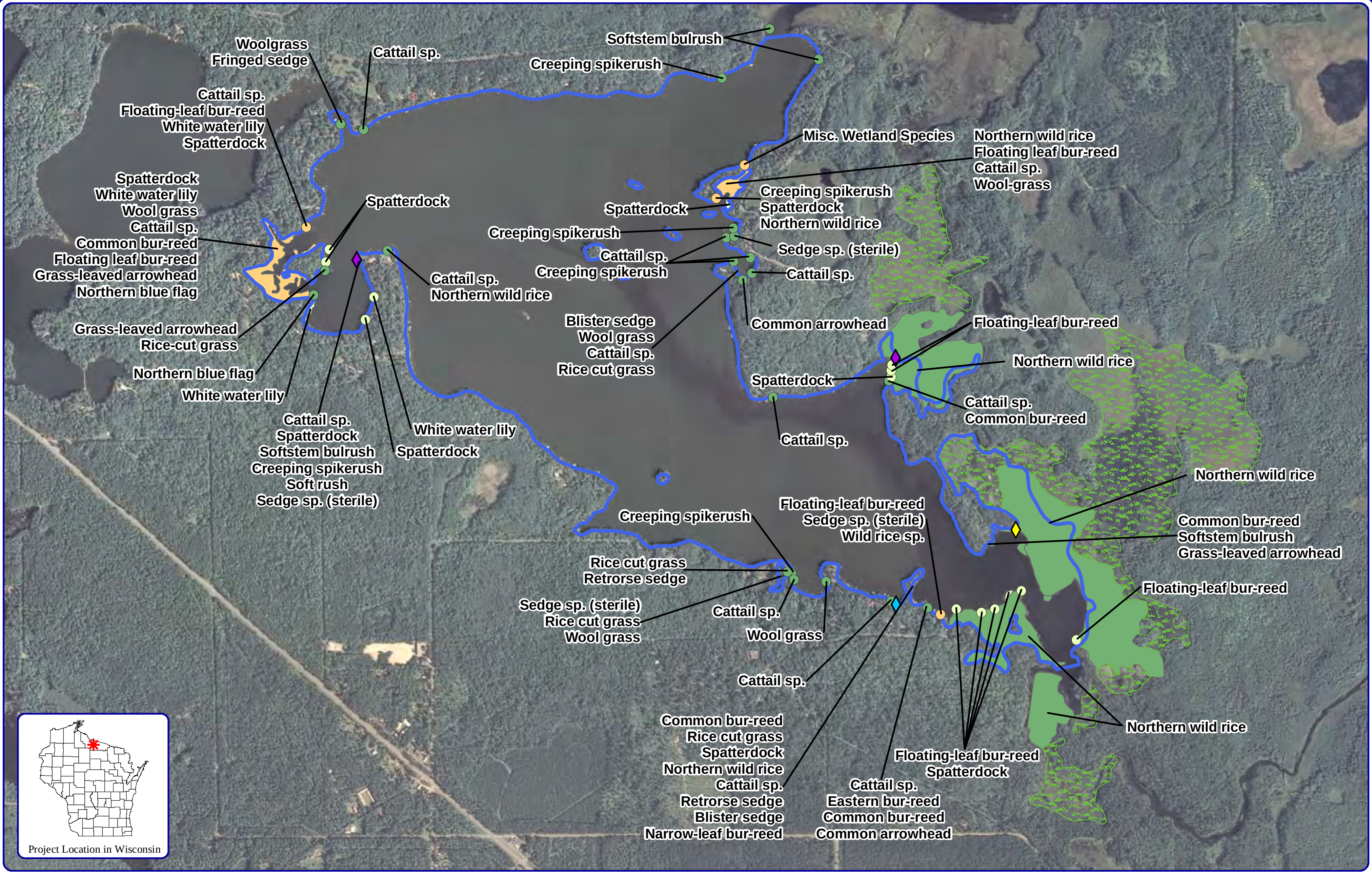


Project Location in Wisconsin

Legend
2011 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

Island Lake - Map 3
Manitowish Waters Chain of Lakes
Vilas County, Wisconsin
Aquatic Plant Distribution



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1,750

Feet

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www.onterra-eco.com

Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 12, 2012
Filename: Island_Map4_Comm_2012.mxd

Legend

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

Large Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Adjacent Wetland Habitat

Exotic Plant Communities
- Purple loosestrife
- Pale Yellow Iris
- Common forget-me-not

Island Lake - Map 4

Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Spider Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.3 Spider Lake

An Introduction to Spider Lake

Spider Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 43 feet, a mean depth of 20 feet, and a surface area of approximately 283 acres. The lake is fed via Island Lake to the east and Manitowish Lake to the south, and empties into downstream Stone Lake. The lake is currently in a mesotrophic state, and its watershed encompasses approximately 134,039 acres. In 2012, 40 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. Three non-native plants, curly-leaf pondweed, purple loosestrife, and common forget-me-not were observed growing in or along the shorelines of Island Lake in 2012.

Field Survey Notes

Fairly dense curly-leaf pondweed observed between Spider and Island Lakes, within a narrow channel.

Photo 8.3. Spider Lake, Vilas County

Lake at a Glance* – Spider Lake

Morphology	
Acreage	283
Maximum Depth (ft)	43
Mean Depth (ft)	20
Volume (acre-feet)	5,660
Shoreline Complexity	6.5
Vegetation	
Curly-leaf Survey Date	May 30, 2012
Comprehensive Survey Date	July 25, 2012
Number of Native Species	40
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Curly-leaf pondweed; Purple loosestrife; Common forget-me-not
Simpson's Diversity	0.92
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	472:1

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

8.3.1 Spider Lake Water Quality

Water quality data was collected from Spider Lake on six occasions in 2012/2013. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2012/2013, any historical data was researched and are included within this report as available.

Unfortunately, very limited data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2012, average summer phosphorus concentrations (11.7 µg/L) were less than the median value (23.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.3.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Excellent* for a deep, lowland drainage lake.

Total phosphorus surface values from 2012 are compared with bottom-lake samples collected during this same time frame in Figure 8.3.1-2. As displayed in this figure, on several occasions surface and bottom total phosphorus concentrations were similar. However, on some occasions, namely during July and August of 2012, the bottom phosphorus concentrations were much greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.3.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain of Lakes-wide document. While this process may be contributing some phosphorus to Spider Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Spider Lake's surface water total phosphorus values are slightly lower than the median value for comparable lakes in Wisconsin, and rank as *Excellent* overall.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (4.3 µg/L) were slightly lower than the median value (7.0 µg/L) for other lakes of this type (Figure 8.3.1-3), as well as lower than the median for all lakes in the ecoregion. Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Excellent*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2012 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

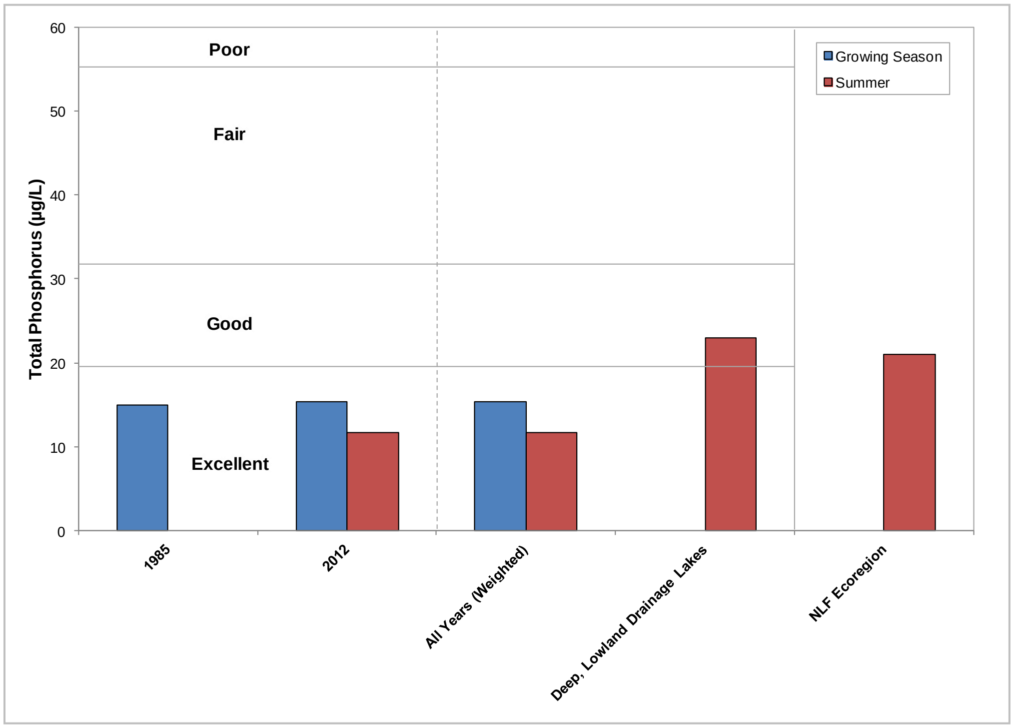


Figure 8.3.1-1. Spider Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

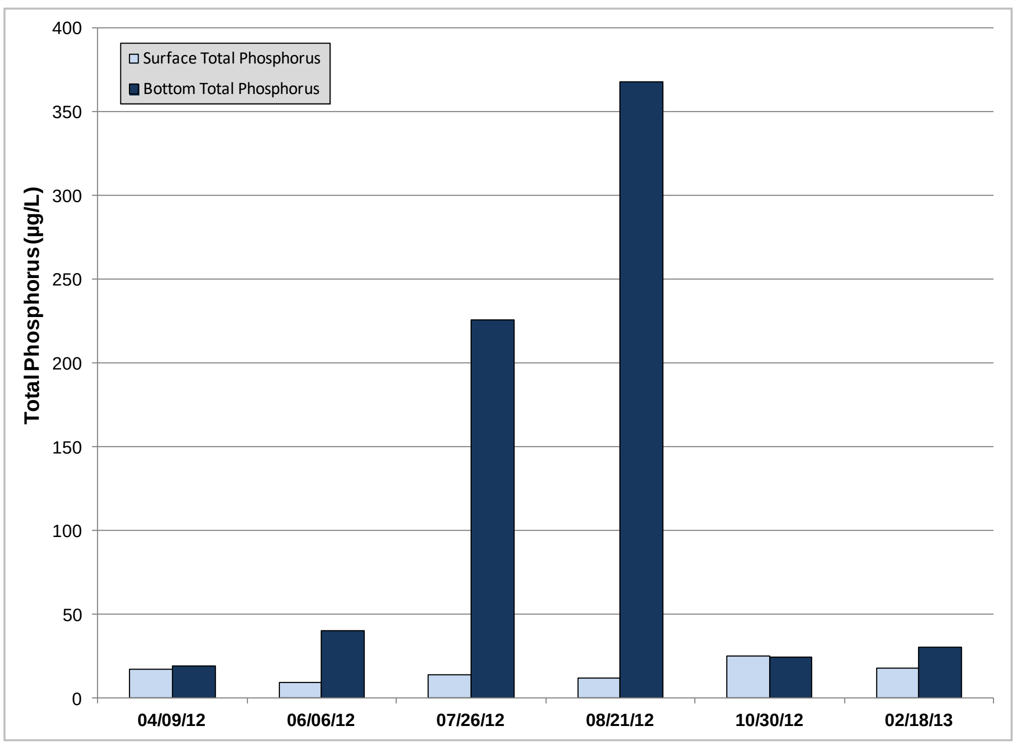


Figure 8.3.1-2. Spider Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

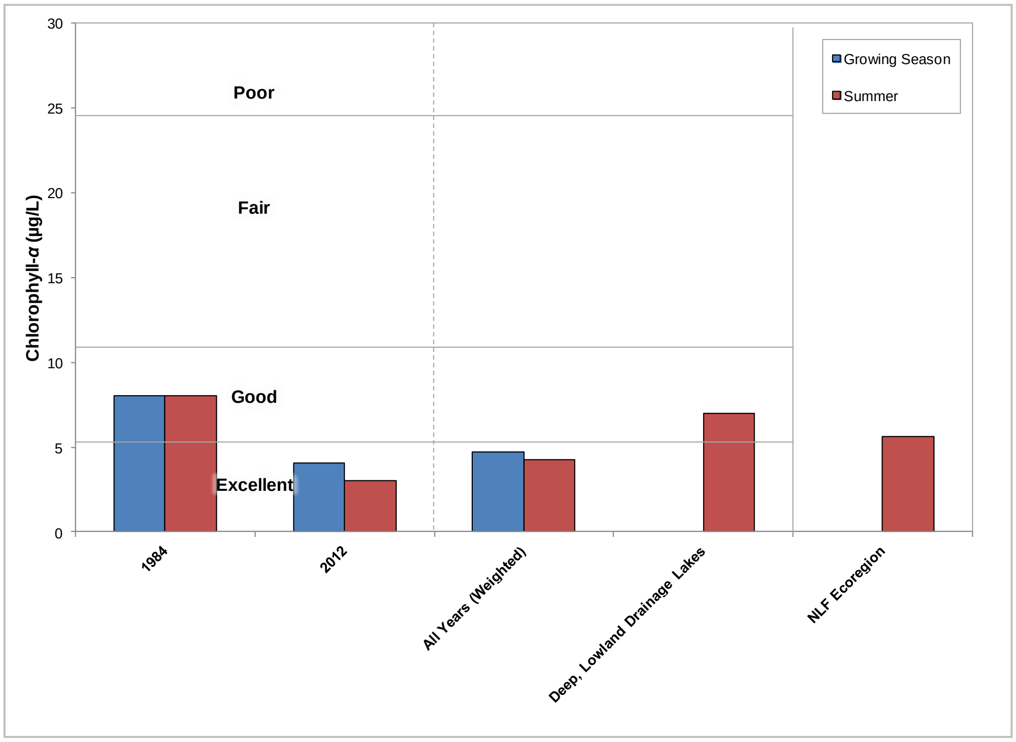


Figure 8.3.1-3. Spider Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of the available Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Spider Lake's water can be described as *Excellent* during the summer months in which data has been collected (Figure 8.3.1-4). A weighted average over this timeframe is greater than the median value for other deep, lowland drainage lakes in the state and is also larger than the regional median. Secondly, there is no apparent trend in the clarity of the water in Spider Lake; the data indicate that clarity may differ from one year to the next, but has not gotten "worse" or "better" over this time period.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Spider Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Spider Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake.

"True color" measures the dissolved organic materials in water. Water samples collected in April and July of 2012 were measured for this parameter, and were found to be 15 and 10 Platinum-cobalt units (Pt-co units, or PCU), respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

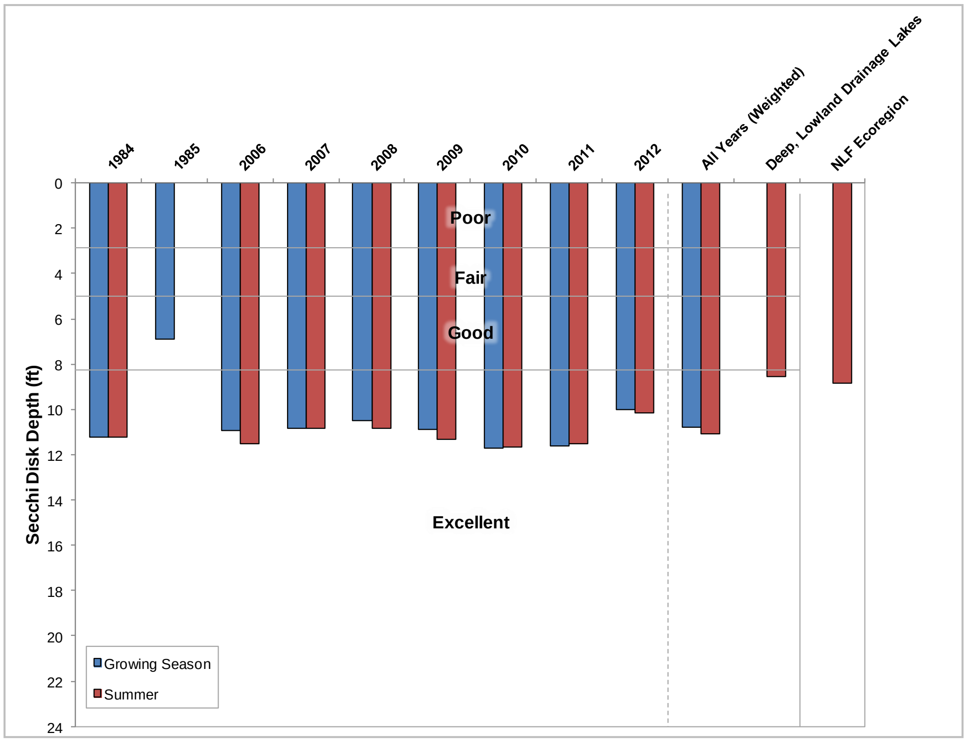


Figure 8.3.1-4. Spider Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Spider Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.3.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Spider Lake is in a mesotrophic state.

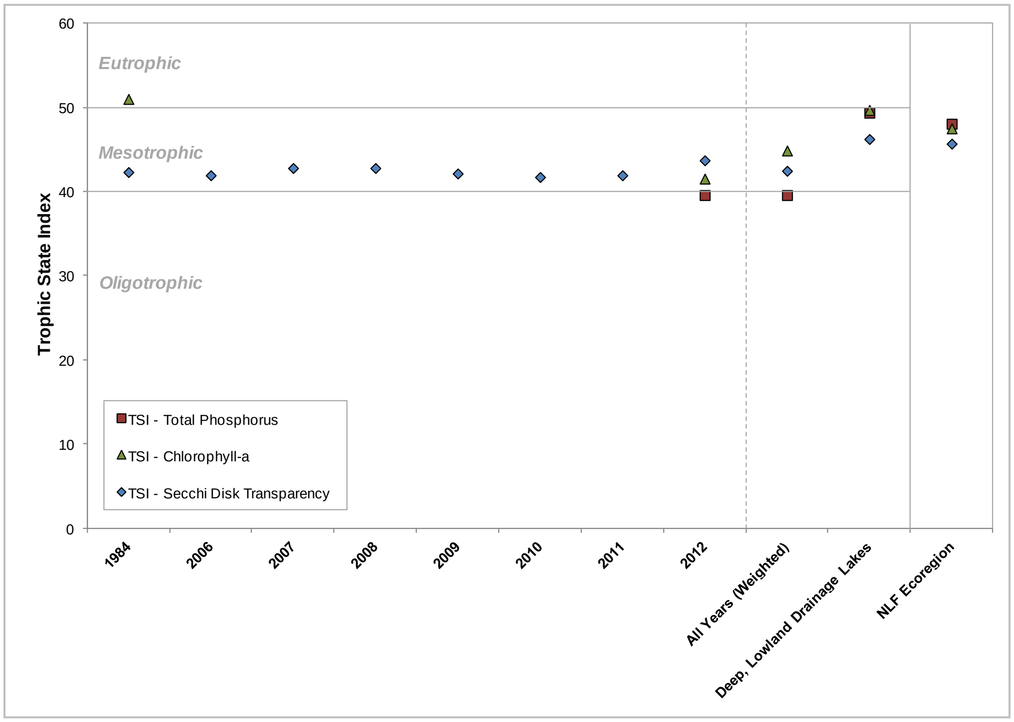


Figure 8.3.1-5. Spider Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Spider Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Spider Lake by Onterra staff. Graphs of those data are displayed in Figure 8.3.1-6 for all sampling events.

Spider Lake mixes thoroughly during the spring and fall, when changing air temperatures and gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in deep Wisconsin lakes, where wind energy is not sufficient during the summer to mix the entire water column – only the upper portion. During this time, bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

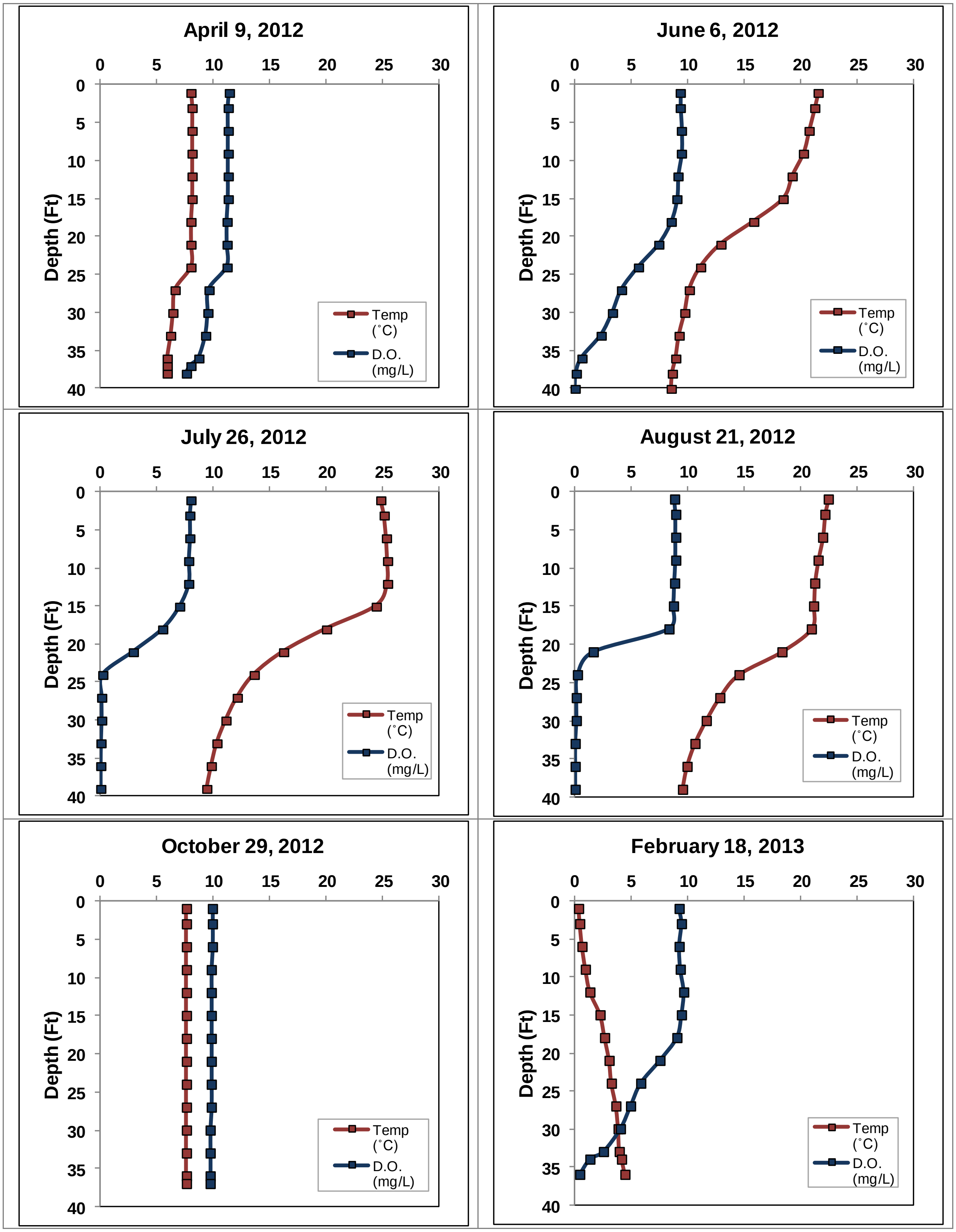


Figure 8.3.1-6. Spider Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Spider Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Spider Lake's surface water pH was measured at roughly 8.8 during April and 7.7 during July of 2012. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Spider Lake was measured at 47 and 45 mg/L as $CaCO_3$ in April and July of 2012, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Spider Lake during 2012. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Spider Lake's pH of 7.7 – 8.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Spider Lake was found to be 12.9 mg/L in April and 12.6 mg/L in July of 2012, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2012 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval stage of zebra mussels) were observed within these samples.

8.3.2 Spider Lake Watershed Assessment

8.3.2 Spider Lake Watershed Assessment

Spider Lake's watershed is 134,041 acres in size. Compared to Spider Lake's size of 283 acres, this makes for a very large watershed to lake area ratio of 472:1. Similar to most lakes that are downstream of other lakes, the large majority of the lake's watershed consists of the lakes immediately upstream. For Spider Lake this means that 81.877 acres (61%) of the lake's watershed is the Island subwatershed and 51,048 acres (39%) of the watershed is the Manitowish Lake subwatershed. The rest of the Spider Lake's watershed is comprised of small amounts of various land cover types (Figure 8.3.2-1). Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Spider Lake's residence time is approximately 15 days, or the water within the lake is completely replaced 26 times per year.

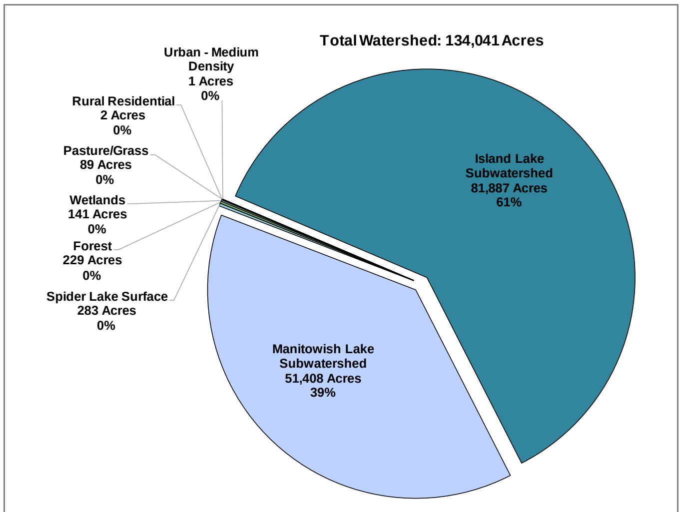


Figure 8.3.2-1. Island Lake watershed boundary (red line) and proportion of land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

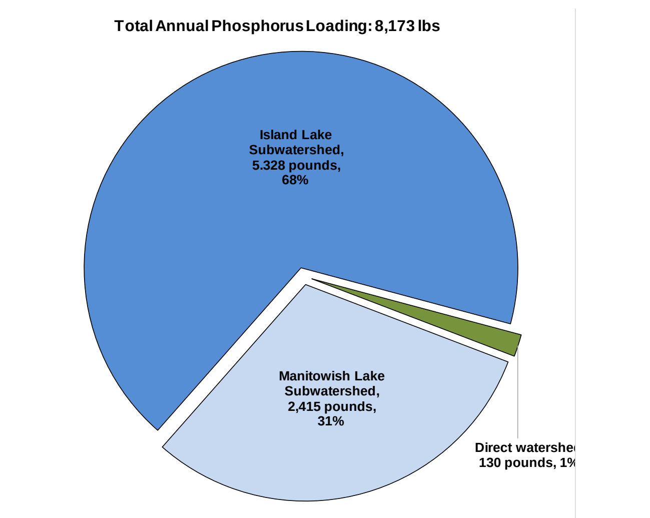


Figure 8.3.2-2. Spider Lake estimated potential annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Of the estimated 8,173 pounds of phosphorus being delivered to Spider Lake on an annual basis, approximately 5.328 pounds (68%) originates from the Island Lake subwatershed, 2,415 pounds (31%) from the Manitowish Lake subwatershed, and the rest comes from the direct (Figure 8.3.2-2). Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 19 µg/L, which is essentially the same as the measured growing season average total phosphorus concentration of 12 µg/L. It is not clear why the model overestimates the phosphorus concentration in Spider Lake. This does indicate that internal loading is not an issue in the lake.

Because the large majority of the phosphorus that enters Spider Lake comes from the upstream lakes, especially Island Lake, efforts to reduce phosphorus levels in Spider Lake should concentrate on reducing phosphorus inputs to the upstream lakes.

8.3.3 Spider Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Spider Lake's immediate shoreline was assessed in terms of its development. Spider Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.0 mile of natural/undeveloped and developed-natural shoreline was observed during the survey (Figure 8.3.3-1). This constitutes about 17% of Spider Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.0 miles of urbanized and developed–unnatural shoreline (34%) was observed. If restoration of the Spider Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Spider Lake Map 1 displays the location of these shoreline lengths around the entire lake.

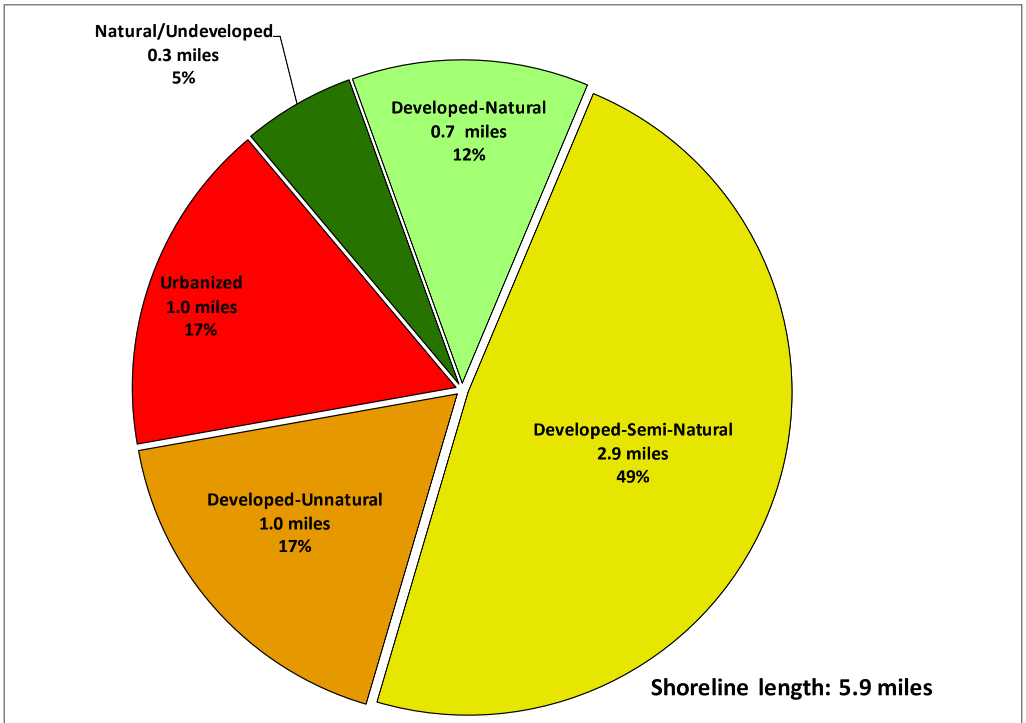


Figure 8.3.3-1. Spider Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Spider Lake Map 1.

Coarse Woody Habitat

As part of the shoreland condition assessment, Spider 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, or clusters of pieces) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed earlier, research indicates that fish species prefer some branching as opposed to no

branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005).

During this survey, 27 total pieces of coarse woody habitat were observed along 5.9 miles of shoreline (Spider Lake Map 2), which gives Spider Lake a coarse woody habitat to shoreline mile ratio of 5:1 (Figure 8.3.3-2). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey. Twenty-four pieces of 2-8 inches in diameter pieces of coarse woody habitat were found, three pieces of 8+ inches in diameter pieces of coarse woody habitat were found, and no instances of clusters of coarse woody habitat were found.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on Spider Lake and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat.

Onterra has completed coarse woody habitat surveys on 98 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile in Spider Lake falls well below the 25th percentile of these 98 lakes (Figure 8.3.3-2).

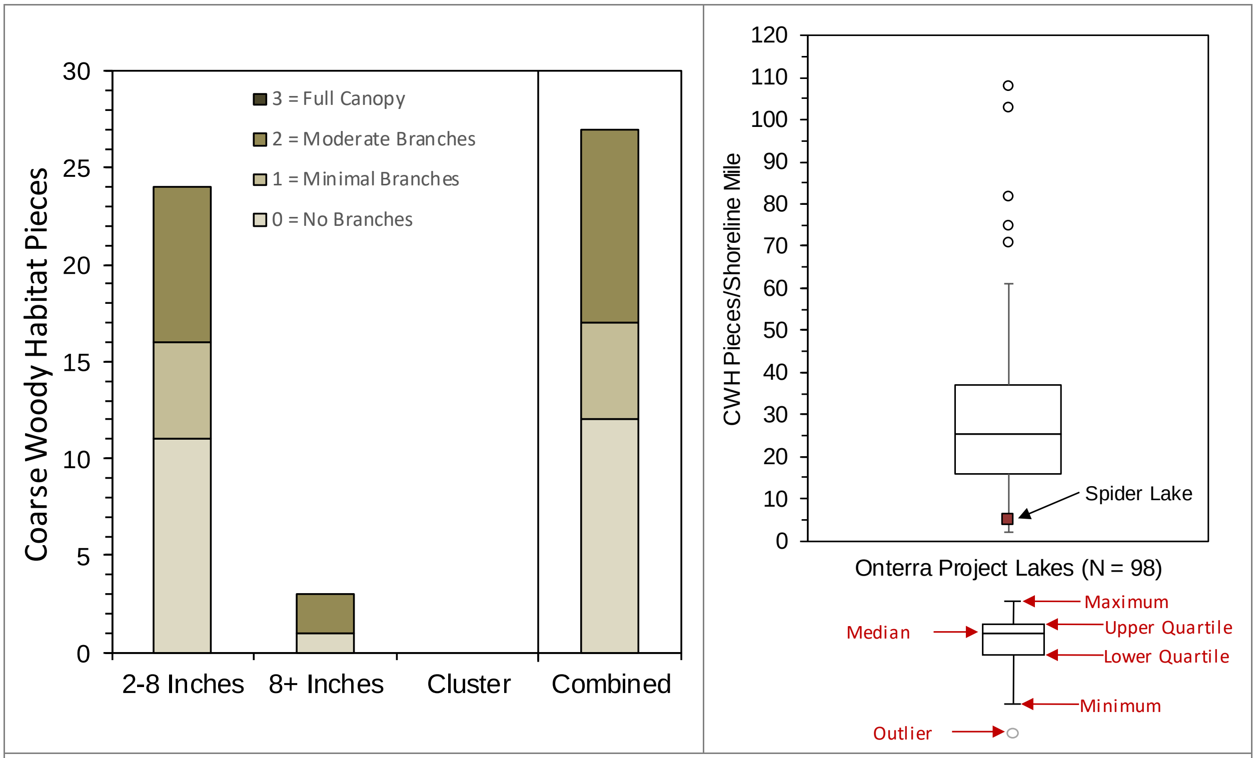


Figure 8.3.3-2. Spider Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of the Spider Lake coarse woody habitat can be found on Spider Lake Map 2.

8.3.4 Spider Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Spider Lake on May 30, 2012. While the intent of this survey is to locate *any* potential non-native species within the lake, the primary focus is to locate occurrences of curly-leaf pondweed which should be at or near its peak growth at this time. During this meander-based survey of the littoral zone, Onterra ecologists did not locate any occurrences of curly-leaf pondweed or any other submersed non-native aquatic plant species. While curly-leaf pondweed was not located during May 30, 2012 survey, earlier and subsequent surveys completed by professionals and volunteers did locate this exotic. This is elaborated on at the end of this section.

The aquatic plant point-intercept survey was conducted on Spider Lake on July 25, 2012 by Onterra. The floating-leaf and emergent plant community mapping survey was completed on that same day to map these community types. During all surveys, 40 species of native aquatic plants were located in Spider Lake (Table 8.3.4-1). 32 of these species were sampled directly during the point-intercept survey and are used in the analysis that follows, while eight species were observed incidentally during visits to Spider Lake. Four exotic species, purple loosestrife (*Lythrum salicaria*), common forget-me-not (*Myosotis scorpioides*) and curly-leaf pondweed (*Potamogeton crispus*) were observed within and along Spider Lake also. Exotic species inventories and management actions are discussed within the Chain-wide plan document.

Aquatic plants were found growing to a depth of 14 feet. As discussed later on within this section, many of the plants found in this survey indicate that the overall community is healthy, diverse and in one species case somewhat rare. Of the 281 point-intercept locations sampled within the littoral zone, roughly 45% contained aquatic vegetation. Spider Lake Map 3 indicates that most of the point-intercept locations that contained aquatic vegetation are located in shallow bays that are more likely to hold organic substrates. Approximately 63% of the point-intercept sampling locations where sediment data was collected at were sand, 17% consisted of a fine, organic substrate (muck) and 20% were determined to be rocky (Chain-wide Fisheries Section, Table 3.5-5).

Table 8.3.4-1. Aquatic plant species located in Spider Lake during 2012 plant surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	2012 Onterra
Emergent	*Carex retrorsa*	Retrorse sedge	6	I
	Carex crinita	Fringed sedge	6	I
	Carex vesicaria	Blister sedge	7	I
	Eleocharis palustris	Creeping spikerush	6	X
	Equisetum fluviatile	Water horsetail	7	X
	Juncus effusus	Soft rush	4	I
	Lythrum salicaria	Purple loosestrife	Exotic	I
	Myosotis scorpioides	Common forget-me-not	Exotic	I
	Scirpus cyperinus	Wool grass	4	I
	Sagittaria rigida	Stiff arrowhead	8	X
	Schoenoplectus acutus	Hardstem bulrush	5	X
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X
	Typha spp.	Cattail spp.	1	I
	Zizania sp.	Wild rice Species	8	I
FL	*Nuphar variegata*	Spatterdock	6	X
	Nymphaea odorata	White water lily	6	X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	I
	Sparganium eurycarpum	Common bur-reed	5	X
Submergent	*Bidens beckii*	Water marigold	8	X
	Callitriche palustris	Common water starwort	8	X
	Chara spp.	Muskgrasses	7	X
	Ceratophyllum demersum	Coontail	3	X
	Elatine minima	Waterwort	9	X
	Elodea canadensis	Common waterweed	3	X
	Heteranthera dubia	Water stargrass	6	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X
	Nitella sp.	Stoneworts	7	X
	Najas flexilis	Slender naiad	6	X
	Potamogeton pusillus	Small pondweed	7	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X
	Potamogeton vaseyi	Vasey's pondweed	10	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X
	Potamogeton crispus	Curly-leaf pondweed	Exotic	X
	Potamogeton strictifolius	Stiff pondweed	8	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X
	Potamogeton gramineus	Variable pondweed	7	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X
	Potamogeton robbinsii	Fern pondweed	8	X
	Sagittaria cristata	Crested arrowhead	9	X
	Utricularia vulgaris	Common bladderwort	7	X
	Vallisneria americana	Wild celery	6	X
SE	*Eleocharis acicularis*	Needle spikerush	5	X
	Sagittaria cuneata	Arum-leaved arrowhead	7	X

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

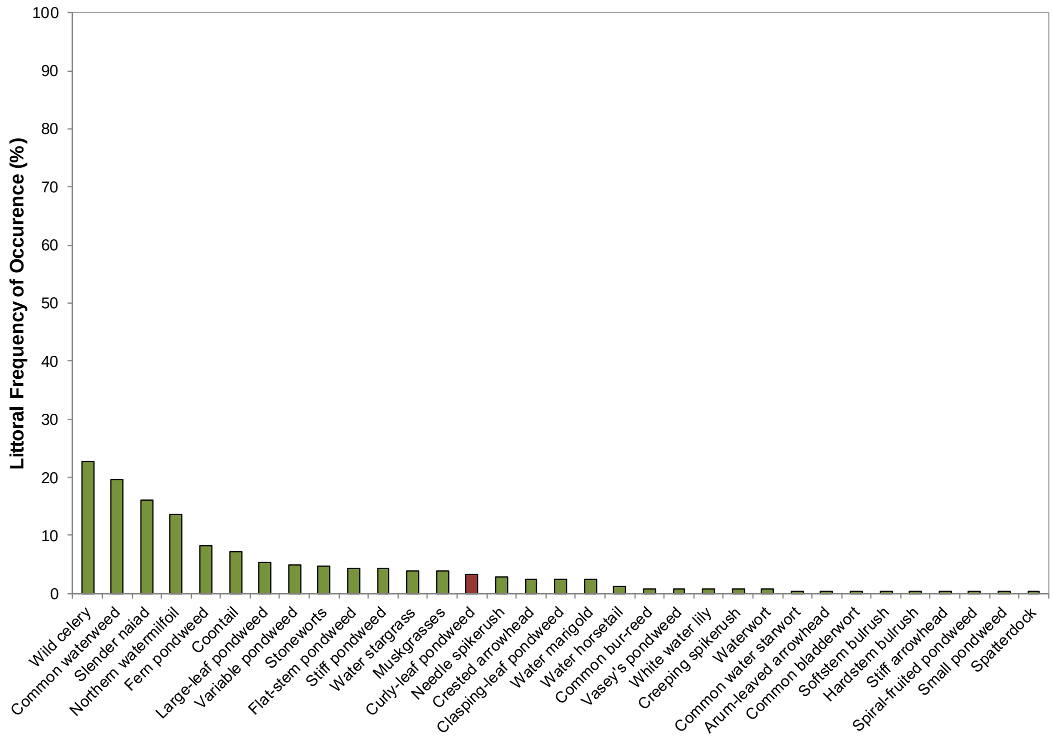


Figure 8.3.4-1. Spider Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey. Exotic species indicated in red.

Figure 8.3.4-1 (above) shows that wild celery, common waterweed and slender naiad were the most frequently encountered plants within Spider Lake. Wild celery is a submerged aquatic plant with ribbon-shaped floating leaves that may grow to as long as two meters, depending on water depth. It is a preferred food choice by numerous species of waterfowl and aquatic invertebrates. Common waterweed is an interesting plant in that although it sometimes produces root-like structures that bury themselves into the sediment, it is largely an unrooted plant that can obtain nutrients directly from the water. As a result, this plant's location in a lake can be dependent upon water movement. Naiad species are branching plants that are eaten by waterfowl and provides excellent shelter for aquatic insects and small fish. As its name implies, slender naiad is a slender, low-growing species with narrow, short pale green leaves.

One species discovered during 2011 and 2012 studies, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory as a species of special concern in Wisconsin due to uncertainty regarding its distribution and abundance in Wisconsin. Vasey's pondweed is typically found in bays of large soft-water lakes as well as in rivers and ponds.

During aquatic plant inventories, 40 species of native aquatic plants (including incidentals) were found in Spider Lake, along with three non-native plant species. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Spider Lake's plant community (0.92) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

As explained earlier in the Manitowish Waters Chain of Lakes-wide document, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at 23% of the sampling locations, its relative frequency of occurrence is 16%. Explained another way, if 100 plants were randomly sampled from Spider Lake, 16 of them would be wild celery. This distribution can be observed in Figure 8.3.4-2, where together 15 native (and one non-native) species account for 89% of the aquatic plant population within Spider Lake, while the other 18 species account for the remaining 10%. Eight additional native and two non-native species were located from the lake but not from of the point-intercept survey, and are indicated in Table 8.3.4-1 as incidentals.

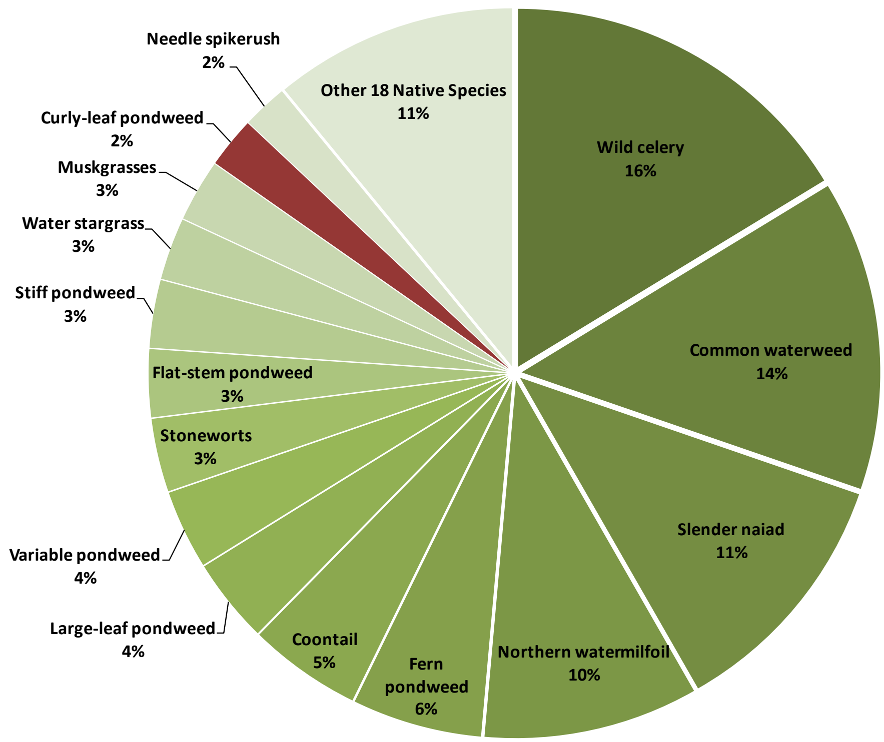


Figure 8.3.4-2. Spider Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

Spider Lake's average conservatism value (6.5) is higher than the state (6.0) but slightly under the Northern Lakes and Forests ecoregion (6.7) median. This indicates that the plant community of Spider Lake is indicative of a moderately disturbed system. Combining Spider Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 36.9 which is above the median values of the ecoregion and state.

The quality of Spider Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 2.4 acres of the lake contains these types of plant communities (Spider Lake Map 4, Table 8.3.4-2). Eighteen floating-leaf and emergent species were located on Spider Lake (Table 8.3.4-1), all of which provide valuable wildlife habitat.

Table 8.3.4-2. Spider Lake acres of emergent and floating-leaf plant communities from the 2012 community mapping survey.

Plant Community	Acres
Emergent	1.4
Floating-leaf	-
Mixed Floating-leaf and Emergent	1.0
Total	2.4

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

Non-Native Aquatic Plants in Spider Lake

Purple loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe and was likely brought over to North America as a garden ornamental. This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it has now spread to 70 of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments.

In Spider Lake, purple loosestrife was located along the shoreline of the lake in several locations (Spider Lake – Map 4). There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. Due to the low occurrence and distribution of plants, hand removal by volunteers is likely the best option as it would decrease costs significantly. Additional purple loosestrife monitoring would be required to ensure the eradication of the plant from the shorelines and wetland areas around Spider Lake.

Common Forget-me-not

Common forget-me-not (*Myosotis scorpioides*) is a relatively small, semi-aquatic wetland plant that produces clusters of small bluish flowers. Native to Eurasia, like pale-yellow iris, common forget-me-not has escaped cultivation and invaded wetland habitats across Wisconsin and creates a monotypic ground cover. A small colony of common forget-me-not was located by Onterra on the far western shoreline of Spider Lake's southern basin (Spider Lake – Map 4). Manual removal by pulling the plants and their roots is likely the best option for control of this plant at this time on Spider Lake.

Curly-leaf Pondweed

Curly-leaf pondweed (*Potamogeton crispus*) is discussed in detail at the end of the Aquatic Plant Section 3.4. Monitoring results, control actions, and a description of the plant's lifecycle are contained in that section.

Curly-leaf pondweed was first discovered in Spider Lake during 2010. Through 2019, the infrequent occurrences of this exotic, in Spider Lake proper, were managed through volunteer and professional hand-harvesting. A more significant population located in the Spider-Island channel was closely monitored and managed with a combination of herbicide treatments and hand-harvesting. This is described in Section 3.4. As a part of the Manitowish Waters Comprehensive Management Plan, Spider Lake's curly-leaf pondweed population will be monitored by volunteers and professionals with control actions being implemented as appropriate.

8.3.5 Spider Lake Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as a reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the fisheries biologists overseeing Spider Lake. The goal of this section is to provide an overview of some of the data that exists. Although current fish data were not collected as a part of this project, the following information was compiled based upon data available from the Wisconsin Department of Natural Resources (WDNR) the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and personal communications with DNR Fisheries Biologist Hadley Boehm (WDNR 2018 & GLIFWC 2017).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may stock fry, fingerling or adult fish in a waterbody that were raised in nearby permitted hatcheries (Photograph 8.3.5-1). Stocking of a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Spider Lake has been stocked from 1991 to 2016 with muskellunge (Table 8.3.5-1).

Photograph 8.3.5-1. Fingerling Muskellunge.

Table 8.3.5-1. Stocking data available for muskellunge in Spider Lake (1991-2016).

Year	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
1991	Unspecified	Fingerling	250	11
1992	Unspecified	Fingerling	250	10
1993	Unspecified	Fingerling	500	10
1997	Unspecified	Large Fingerling	268	10.5
1999	Unspecified	Large Fingerling	250	11.8
2002	Unspecified	Large Fingerling	400	10.1
2004	Unspecified	Large Fingerling	400	10.5
2006	Upper Wisconsin River	Large Fingerling	400	10.5
2008	Upper Wisconsin River	Large Fingerling	400	10.1
2010	Upper Wisconsin River	Large Fingerling	240	12.5
2012	Upper Wisconsin River	Large Fingerling	400	10.2
2014	Upper Wisconsin River	Large Fingerling	400	10.4
2016	Upper Wisconsin River	Large Fingerling	438	11.07

Spider Lake Spear Harvest Records

Walleye open water spear harvest records are provided in Figure 8.3.5-1 from 1999 to 2017. As many as 66 walleye have been harvested from the lake in the past (2014), but the average harvest is roughly 31 fish in a given year. Spear harvesters on average have taken 58% of the declared quota. Additionally, on average 12% of walleye harvested have been female.

Muskellunge open water spear harvest records are provided in Figure 8.3.5-2 from 1999 to 2017. As many as two muskellunge have been harvested from the lake in the past (1999, 2007 and 2008), however the average harvest is zero fish in a given year. Spear harvesters on average have taken 7% of the declared quota.

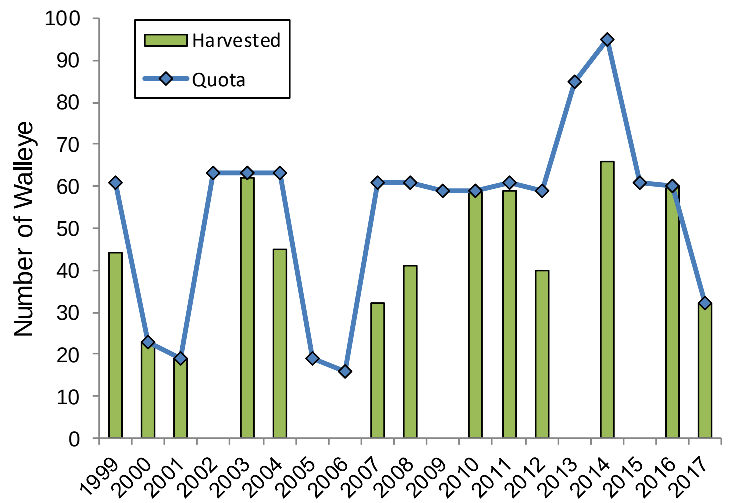


Figure 8.3.5-1. Spider Lake walleye spear harvest data. (GLIFWC 1999-2017).

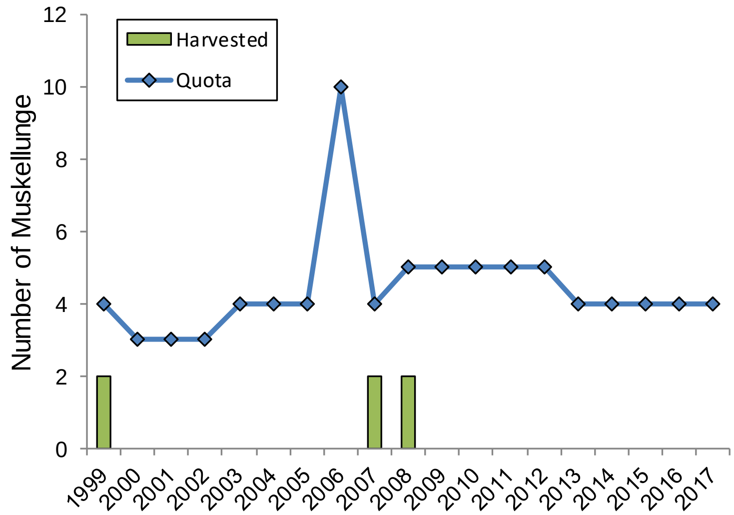
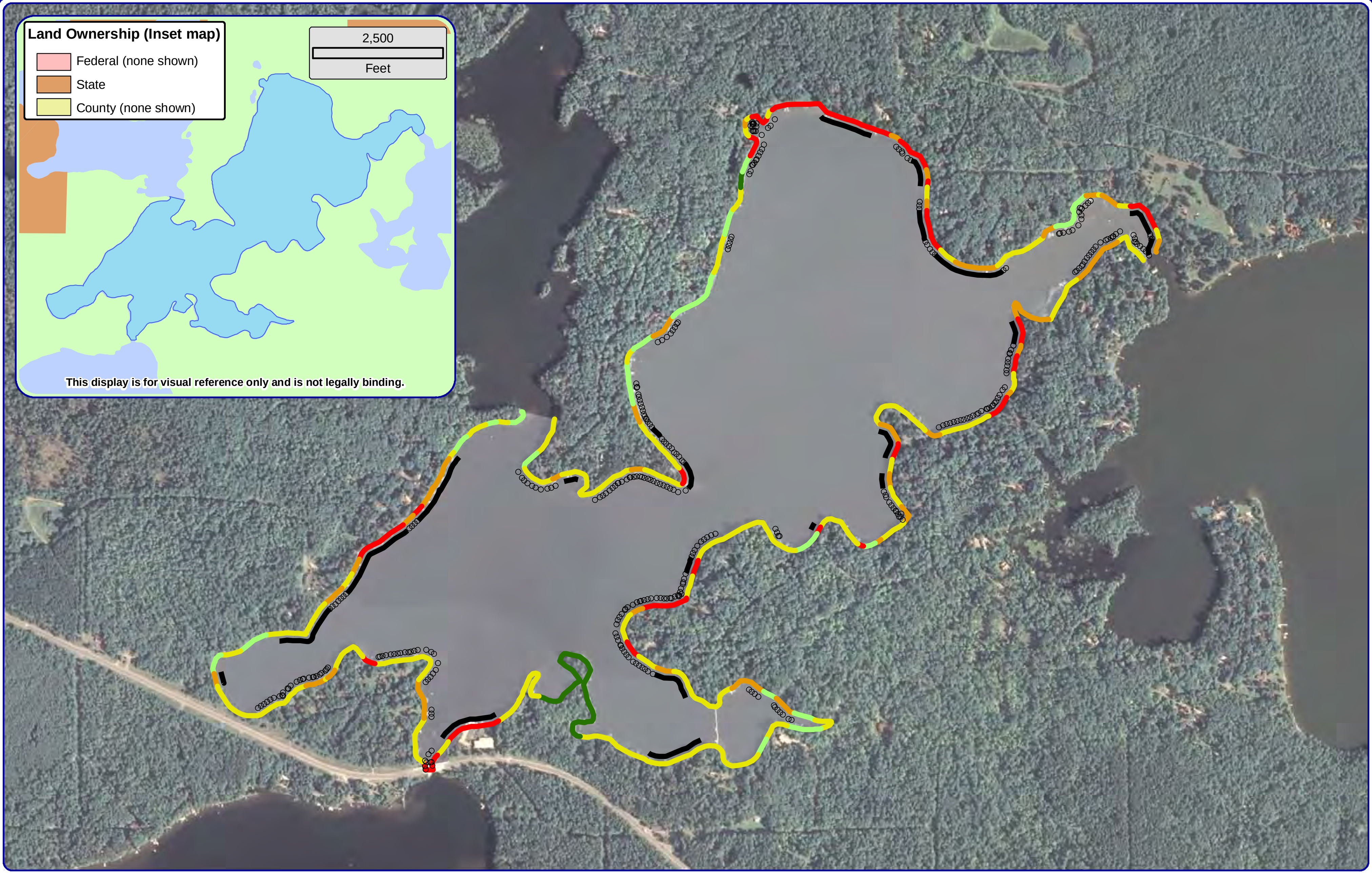


Figure 8.3.5-2. Spider Lake muskellunge spear harvest data. (GLIFWC 1999-2017).



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

Sources:
Shoreline Assessment: Onterra, 2012
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Spider_Map1_SA_2012.mxd

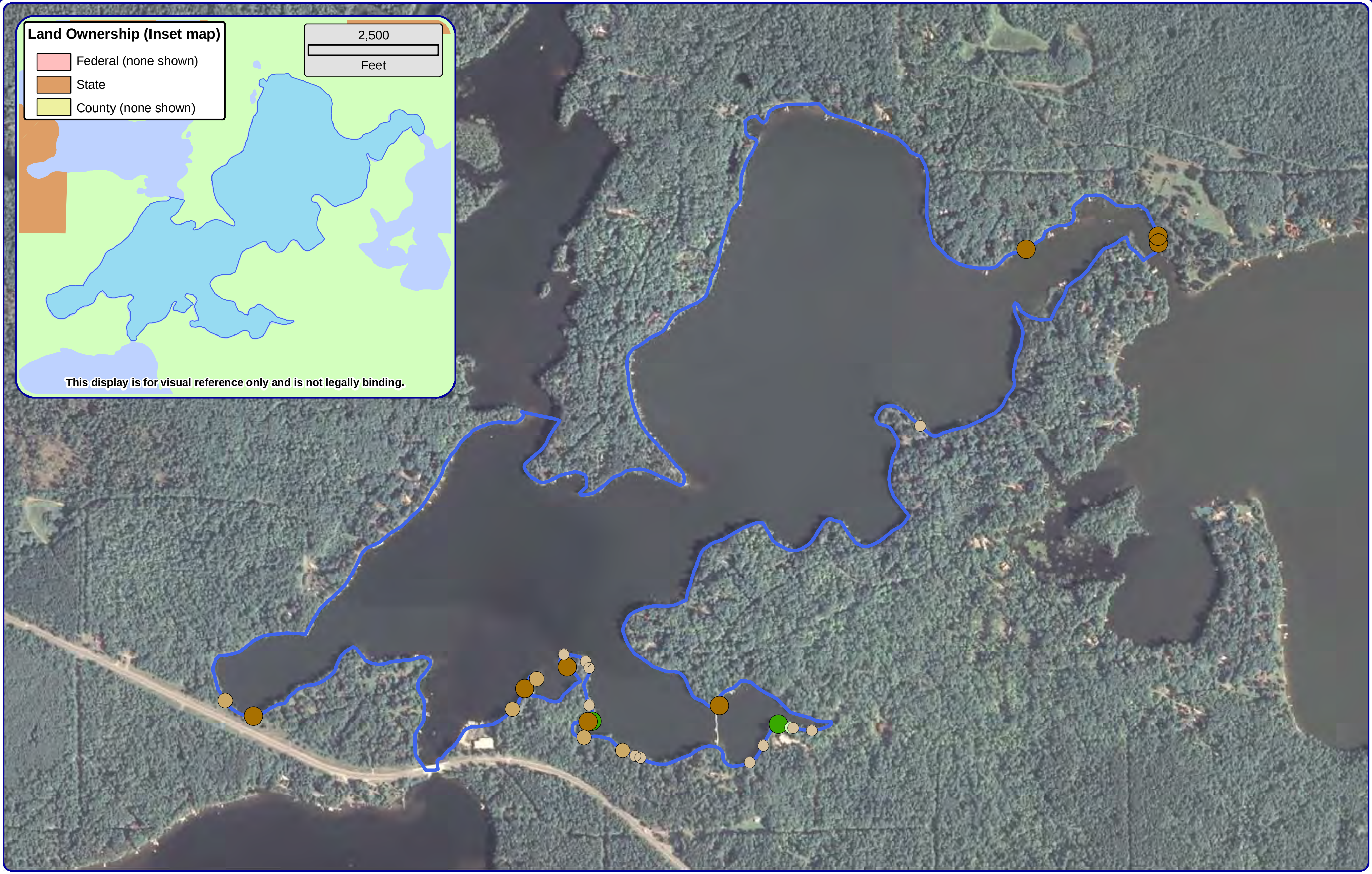
Project Location in Wisconsin

Legend

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

Seawall
Masonary/Metal/Wood
Rip-Rap

Spider Lake - Map 1
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin
Shoreline Condition



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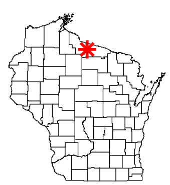
Sources:
Shoreline Assessment: Onterra, 2012
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Spider_Map2_CWH_2012.mxd



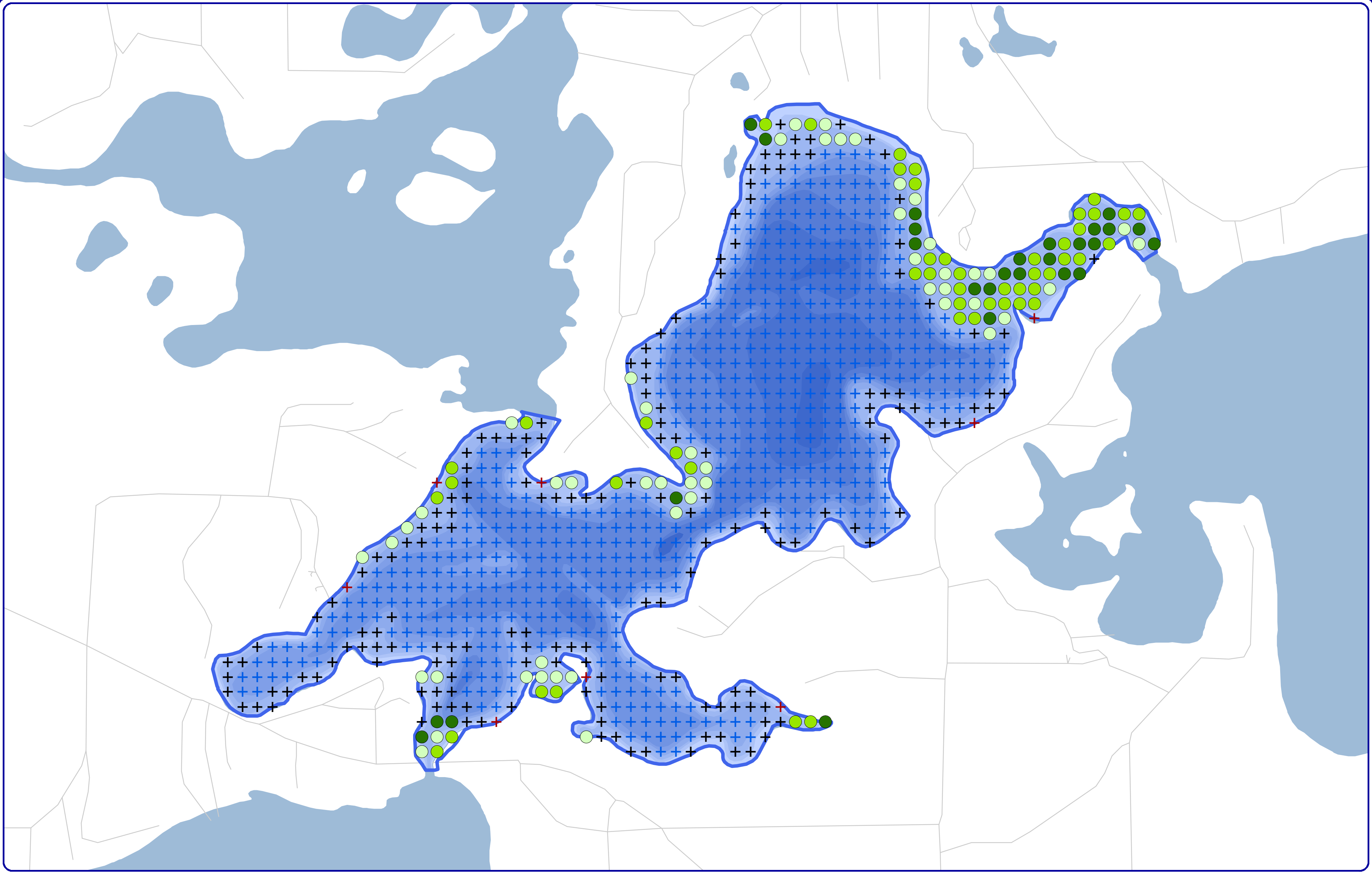
Project Location in Wisconsin

Legend

- 2-8 Inches, No Branches
- 2-8 Inches, Minimal Branches
- 2-8 Inches, Moderate Branches
- 2-8 Inches, Full Canopy (none)
- >8 Inches, No Branches
- >8 Inches, Minimal Branches (none)
- >8 Inches, Moderate Branches
- >8 Inches, Full Canopy
- Cluster

Spider Lake - Map 2
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Course Woody Habitat



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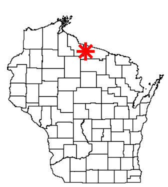
www.onterra-eco.com

Sources:
Aquatic Plant Surveyt: Onterra, 2012
Roads and Hydro: WDNR
Map Date: September 24, 2013
Filename: Spider_Map3_TRFPI_2012.mxd



Project Location in Wisconsin

Legend

2012 Point-intercept Survey

- No Vegetation
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3
- Too Deep (Below Max Depth of Plants)
- Non-navigable

Spider Lake - Map 3
Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Aquatic Plant Distribution

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Feet

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Adjacent Wetland Habitat

Exotic Plant Communities

- Purple loosestrife
- Common forget-me-not

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Sources:
Aquatic Plants: Onterra, 2012
Orthophotography: NAIP, 2010
Map date: December 11, 2012
Filename: Spider_Map4_Comm_2012.mxd

Spider Lake - Map 4

Manitowish Waters
Chain of Lakes
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities

Note: Methodology, explanation of analysis and biological background on Clear Lake studies are contained within the Manitowish Waters Chain of Lakes-wide Management Plan document.

8.4 Clear Lake

An Introduction to Clear Lake

Clear Lake, Vilas County, is a spring lake with a maximum depth of 45 feet, a mean depth of 16 feet, and a surface area of approximately 568 acres. The lake empties into downstream Fawn Lake. The lake is in a mesotrophic state, and its watershed encompasses approximately 3,046 acres. In 2013, 55 native aquatic plant species were located in the lake, of which fern pondweed (*Potamogeton robbinsii*) was the most common. No aquatic invasive plant species were observed growing in or along the shorelines of Clear Lake in 2013.

Field Survey Notes

Abundance of native plants in this clear-watered, minimally developed lake. No exotic plant species found during surveys.

Photo 8.4. Clear Lake, Vilas County

Lake at a Glance* – Clear Lake

Morphology	
Acreage	568
Maximum Depth (ft)	45
Mean Depth (ft)	16
Volume (acre-feet)	9,055
Shoreline Complexity	6.5
Vegetation	
Curly-leaf Survey Date	June 25, 2013
Comprehensive Survey Date	July 31, 2013
Number of Native Species	55
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	-
Simpson's Diversity	0.90
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Deep, Seepage
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	4:1

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

8.4.1 Clear Lake Water Quality

Water quality data was collected from Clear Lake on six occasions in 2013/2014. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, Secchi disk clarity, temperature, and dissolved oxygen. Please note that the data in these graphs represent concentrations and depths taken during the growing season (April-October), summer months (June-August) or winter (February-March) as indicated with each dataset. Furthermore, unless otherwise noted the phosphorus and chlorophyll-*a* data represent only surface samples. In addition to sampling efforts completed in 2013/2014, any historical data was researched and are included within this report as available.

Note that in this report, Clear Lake is compared against water quality variables for deep, seepage lakes. Technically, Clear Lake may be considered a spring lake because of its hydrology; it has no surface inlet stream but does flow to the south into Fawn Lake, so has an outlet stream. For the purposes of the water quality analysis however, Clear Lake will be categorized as a seepage lake as it most closely aligns to this lake type within WisCALM (2014).

A fair amount of historical data is available for Clear Lake due to the efforts of volunteers through Wisconsin's Citizens Lake Monitoring Network. The datasets include nearly 15 years of non-continuous total phosphorus data. In 2013, average summer phosphorus concentrations averaged 14.9 µg/L, which is comparable to the median value (15.0 µg/L) for other deep, lowland drainage lakes in the state (Figure 8.4.1-1). This value is also lower than the value for other lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *Good* for a deep, lowland drainage lake. The 2013 data is similar to phosphorus concentrations measured during the late 1990's and 2000's. From the available data, no changes in annual total phosphorus concentrations can be observed.

Total phosphorus surface values from 2013 are compared with bottom-lake samples collected during this same time frame in Figure 8.4.1-2. As displayed in this figure, during spring and fall turnovers (lake vertical mixing) surface and bottom total phosphorus concentrations were similar. However, during the summer and winter, the bottom phosphorus concentrations were greater than the relatively low surface concentrations. During these periods, anoxic conditions were recorded near the bottom of the lake through measurement of dissolved oxygen (refer to Figure 8.4.1-6 and associated text). This is an indication of hypolimnetic nutrient recycling, or internal nutrient loading, which is a process discussed further in the Manitowish Waters Chain of Lakes-wide document. This is a natural process that most lakes have. While the hypolimnetic concentrations are higher than surface water concentrations, these relatively higher levels are not high enough to negatively impact Clear Lake's surface water quality. Typically, lake managers do not become concerned unless these concentrations near 200 µg/L)

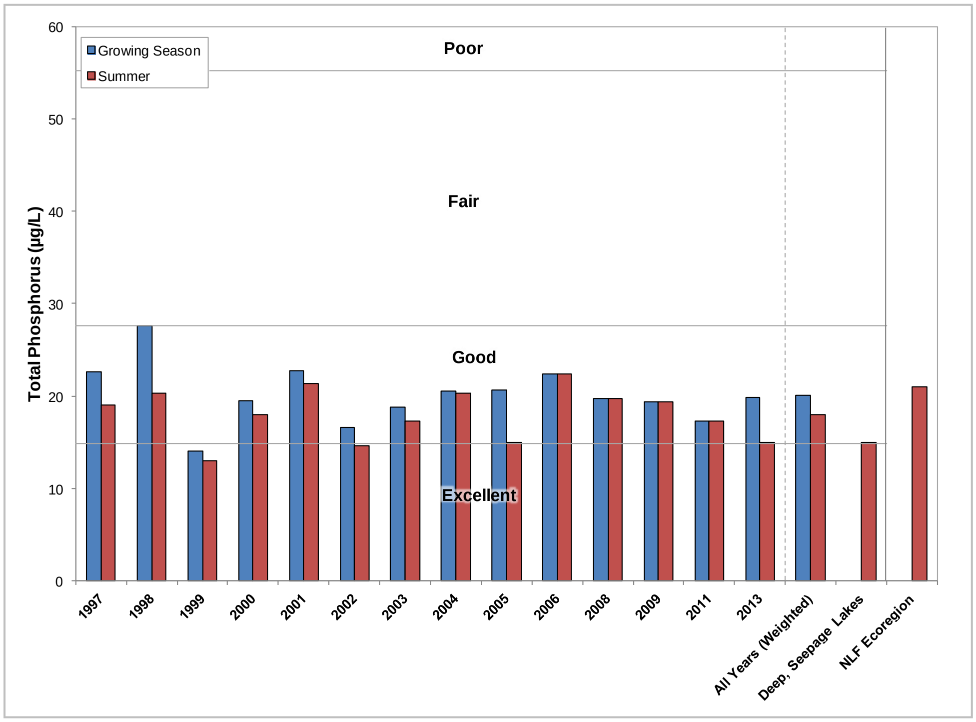

Figure 8.4.1-1. Clear Lake, state-wide deep seepage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

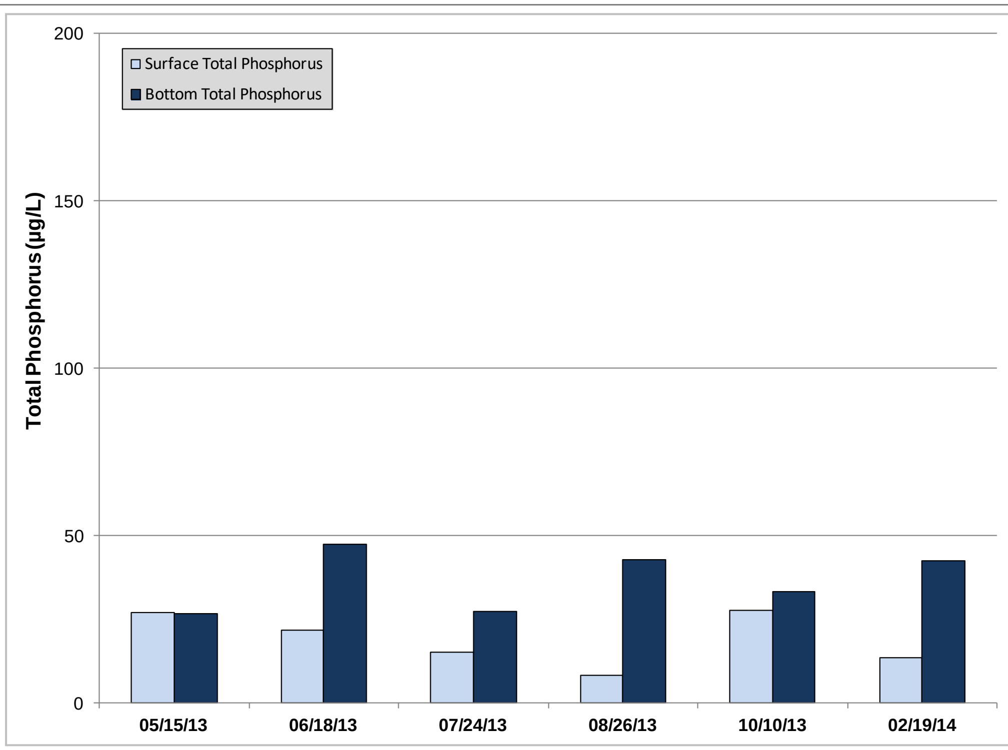

Figure 8.4.1-2. Clear Lake surface and bottom total phosphorus values, 2013-2014. Anoxia was observed in the hypolimnion of the lake during June, July, August and February sampling visits.

Similar to what has been observed with the total phosphorus dataset, summer average chlorophyll-*a* concentrations (3.9 µg/L) were comparable to the median value (3.6 µg/L) for other lakes of this type and are lower than the median for all lakes in the ecoregion (Figure 8.4.1-3). Both of these parameters, total phosphorus and chlorophyll-*a*, rank within a TSI category of *Good*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2013 visits to the lake, Onterra ecologists recorded field notes describing very good water conditions.

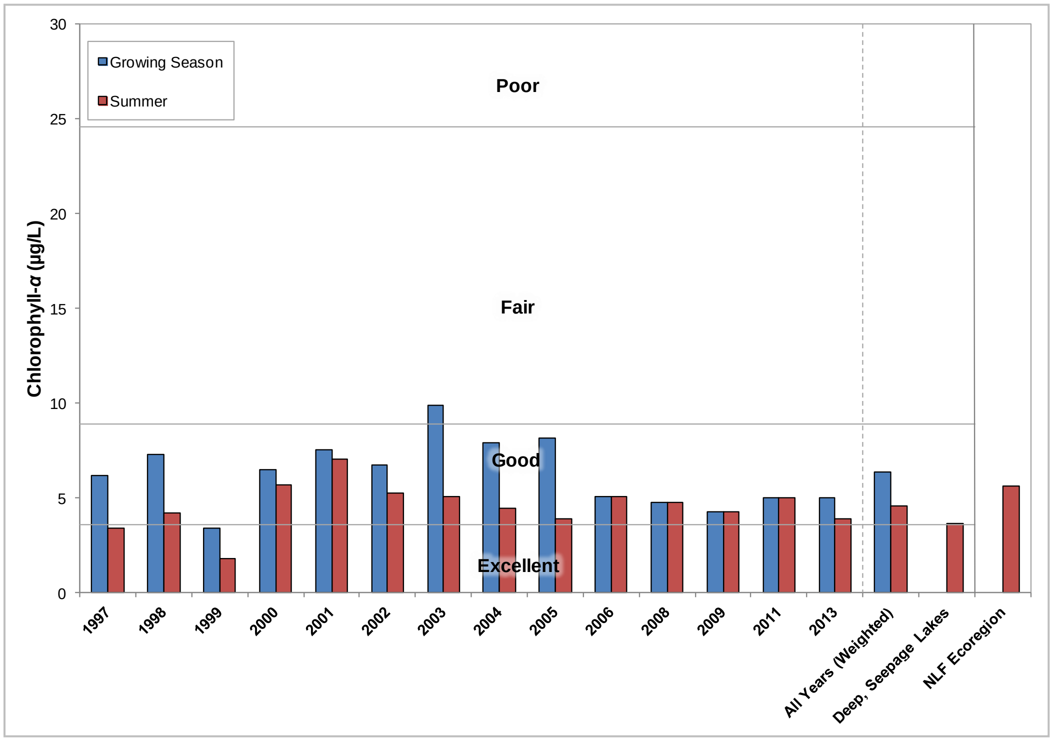

Figure 8.4.1-3. Clear Lake, state-wide deep seepage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of the available Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Clear Lake's water can be described as *Good* to *Excellent* during the summer months in which data has been collected (Figure 8.4.1-4). A weighted average over this timeframe is slightly greater than the median value for other deep seepage lakes in the state and is also greater than the regional median. Secondly, there is no apparent trend in the clarity of the water in Clear Lake; the data indicate that clarity may differ from one year to the next, but has not gotten "worse" or "better" over this time period.

Secchi disk clarity is influenced by many factors, including plankton production and suspended sediments, which themselves vary due to several environmental conditions such as precipitation, sunlight, and nutrient availability. In Clear Lake as well as the other lakes in the Manitowish Waters Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Clear Lake contain naturally occurring organic acids that are washed into the lake from nearby wetlands. The acids are not harmful to humans or aquatic species; they are by-products of decomposing terrestrial and wetland plant species. This natural staining may reduce light penetration into the water column, which reduces visibility and also reduces the growing depth of aquatic vegetation within the lake. Because of its smaller watershed relative to the other Manitowish Waters Chain of Lakes, Clear Lake's water may be less stained.

"True color" measures the dissolved organic materials in water. Water samples collected in April and July of 2013 were measured for this parameter, and were found to be 20 and 10 Platinum-cobalt units (Pt-co units, or PCU), respectively. Lillie and Mason (1983) categorized lakes with 0-40 PCU as having "low" color, 40-100 PCU as "medium" color, and >100 PCU as high color.

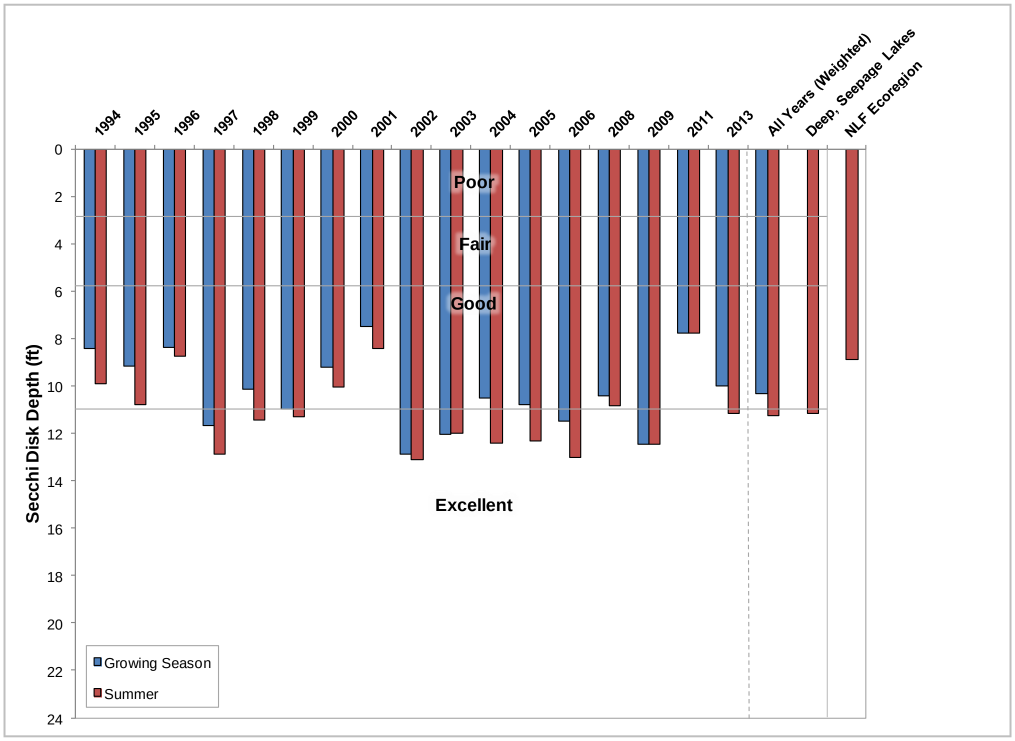

Figure 8.4.1-4. Clear Lake, state-wide deep seepage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Clear Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.4.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Clear Lake is in a mesotrophic state.

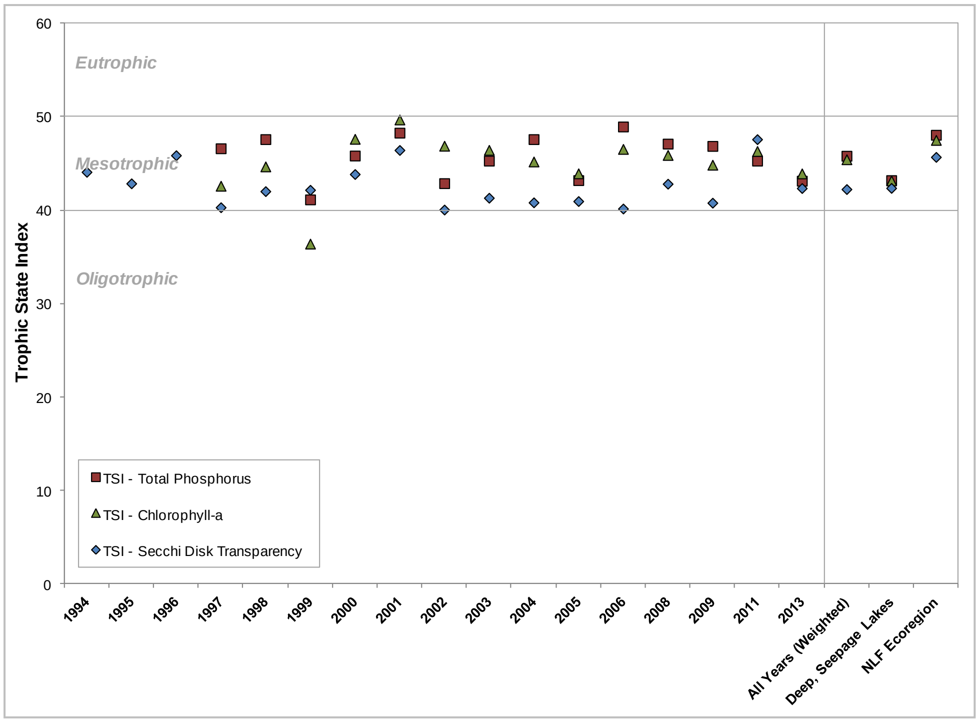

Figure 8.4.1-5. Clear Lake, state-wide deep seepage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Clear Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Clear Lake by Onterra staff. Graphs of those data are displayed in Figure 8.4.1-6 for all sampling events.

Clear Lake mixes thoroughly during the spring and fall, when changing air and water temperatures as well as gusty winds help to mix the water column. During the summer months, the bottom of the lake becomes void of oxygen and temperatures remain fairly cool as they were in the spring months. This occurrence is not uncommon in deep Wisconsin lakes; the sun's warmth is only able to penetrate the upper layer of the water column and wind energy is not sufficient to mix the entire water column either. Dissolved oxygen is mixed within the upper water column through plant respiration and atmospheric exchange. Oxygen may decrease in the hypolimnion, as the oxygenated upper water column is not able to exchange with this region. Additionally, during this time bacteria break down organic matter that has collected at the bottom of the lake and in doing so utilize any available oxygen.

The lake mixes completely again in the fall, re-oxygenating the water in the lower part of the water column. During the winter months, the coldest temperatures are found just under the overlying ice, while oxygen gradually diminishes once again towards the bottom of the lake. In February of 2013, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

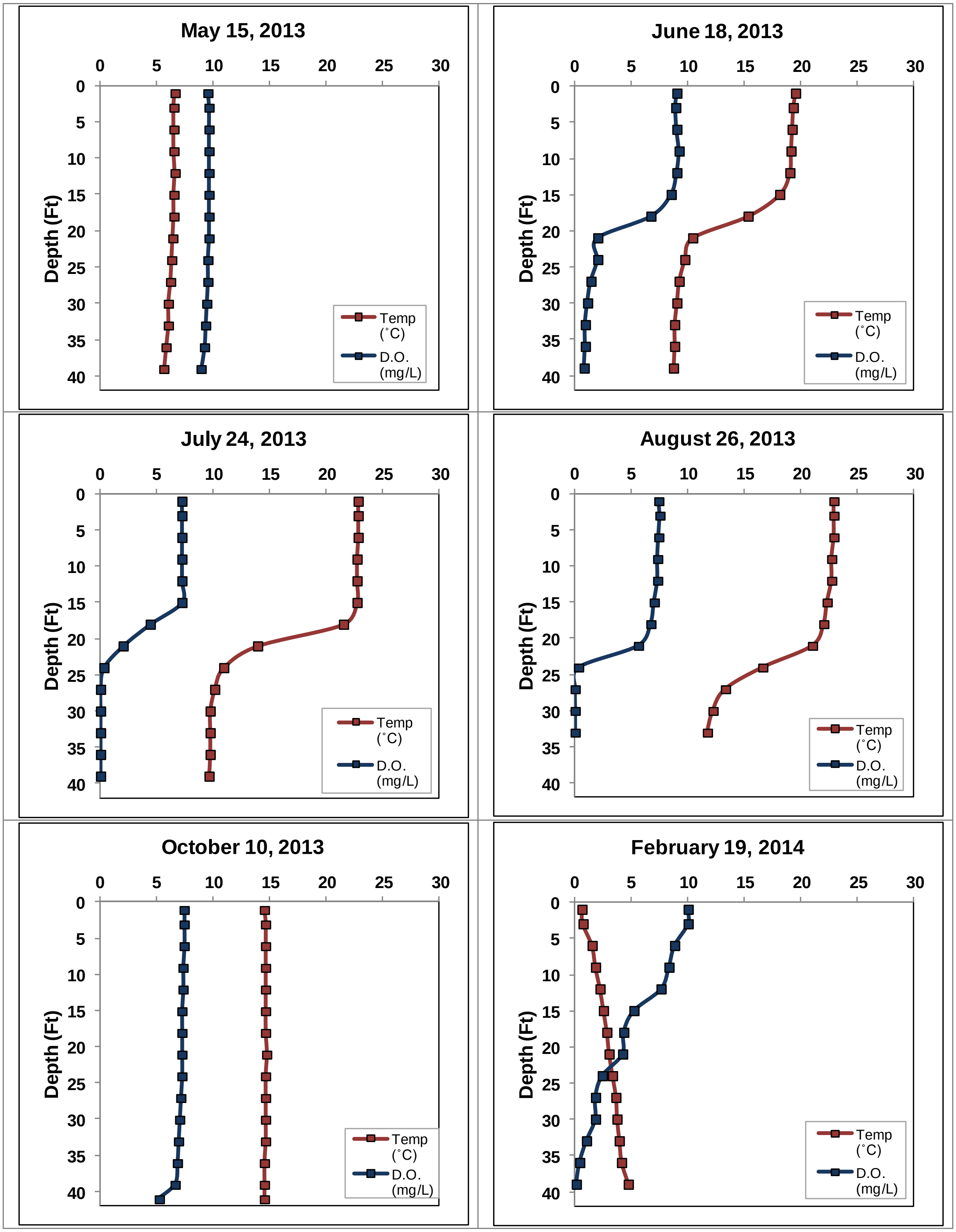

Figure 8.4.1-6. Clear Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Clear Lake

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

As the Chain-wide Water Quality Section explains, the pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is thus an index of the lake's acidity. Clear Lake's surface water pH was measured at roughly 7.5 during May and 7.8 during July of 2013. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^{=}$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Clear Lake was measured at 41.8 and 42.3 mg/L as $CaCO_3$ in May and July of 2013, respectively. This indicates that the lake has a substantial capacity to resist fluctuations in pH and has a low sensitivity to acid rain.

Samples of calcium were also collected from Clear Lake during 2013. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Clear Lake's pH of 7.5 – 7.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Clear Lake was found to be 11.7 mg/L in August of 2013, which is at the bottom end of the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. No veligers (larval stage of zebra mussels) were observed within these samples.