DRAFT 3

Manitowish Waters Chain of Lakes Comprehensive Management Plan

Vilas County, Wisconsin

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

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:

Organization

Town of Manitowish Waters   Town of Boulder Junction

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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 2013 annual report highlighting these projects can be viewed within Appendix A.

The NLDC began the ‘Lake Captain and Deckhand’ aquatic invasive species monitoring program in 2010 to fill an identified need for volunteer aquatic invasive species monitoring on the chain and to supplement the established Clean Boats Clean Waters (CBCW) public access monitoring program. Until 2010, the Manitowish Waters Chain of Lakes were thought to be free of aquatic invasive plant species besides purple loosestrife (*Lythrum salicaria*). On June 17, 2010, the NLDC sponsored the yearly Lake Captain training which was conducted by Ted Ritter (Vilas County AIS Coordinator). Curly-leaf pondweed was first documented on the Manitowish Waters Chain of Lakes in Island Lake on June 18, 2010 by a volunteer Lake Captain who had attended the training session the previous day. In July of that year, subsequent monitoring turned up the presence of curly-leaf pondweed in Rice Creek. Since that time, NLDC staff and Manitowish Waters Chain of Lakes volunteers as well as staff from Onterra, LLC have documented curly-leaf pondweed in Spider Lake, Stone Lake, Manitowish Lake, and the Rest-Stone Lake Channel. Though no rooted curly-leaf pondweed has been found in Rest Lake, volunteers have discovered floating fragments in this waterbody.

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 wishes to create individualized management plans for each chain lake including three lakes below the Rest Lake Dam (Benson, Sturgeon, and Vance Lakes) and all associated river sections, as well as a chain-wide management plan. The creation of individualized management plans fits into both the TAISP’s mission which is *“…to prevent the spread of AIS into the Town’s waters and to monitor and control or eliminate the AIS present in the Town’s waters*” and the association’s purpose, which is “*…to maintain, protect and enhance the quality of the Manitowish Waters Chain of Lakes and other waters in Manitowish Waters township for the benefit of the members and the general public*.” 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 2011-2016. 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 Grant Program for each phase of the project.

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

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

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.

Stakeholder Survey

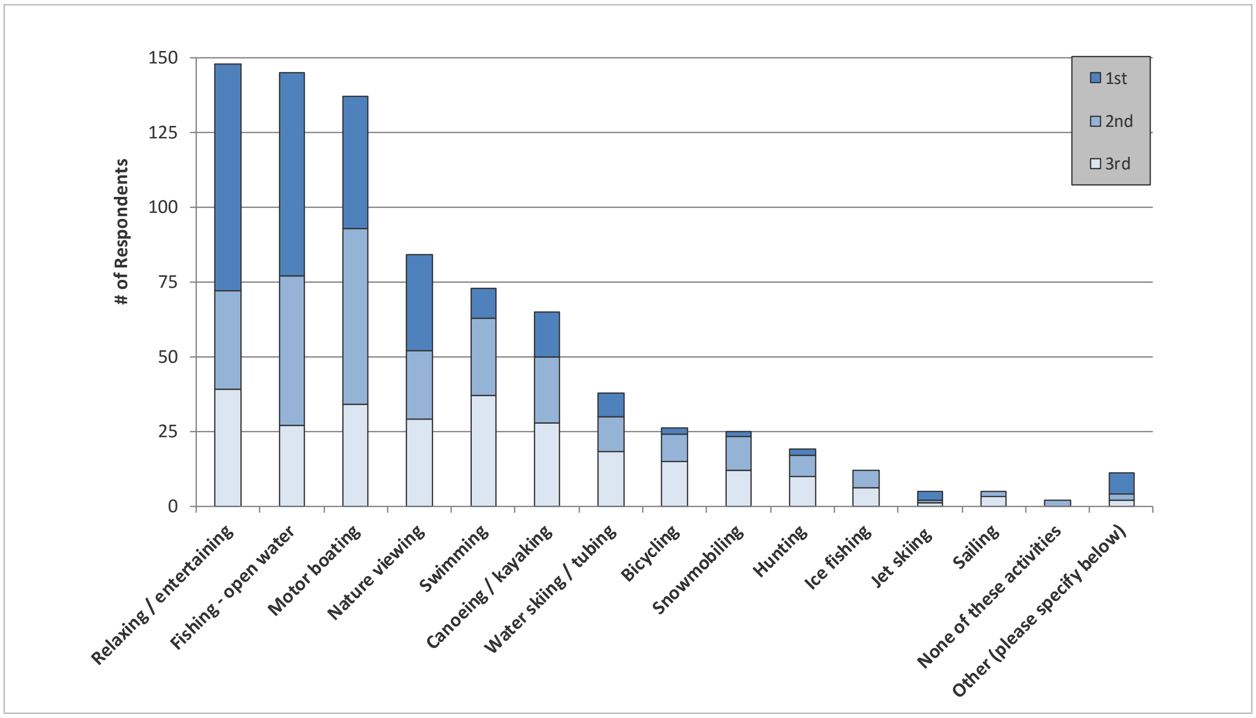
As a part of this project, a stakeholder survey was distributed to MWLA members and non-member riparian property owners. This survey was designed by Onterra staff and the MWLA / NLDC planning committee in winter of 2015-2016. The draft survey was sent to a WDNR social scientist for review during that 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 types of watercraft do you currently use on the lake?



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

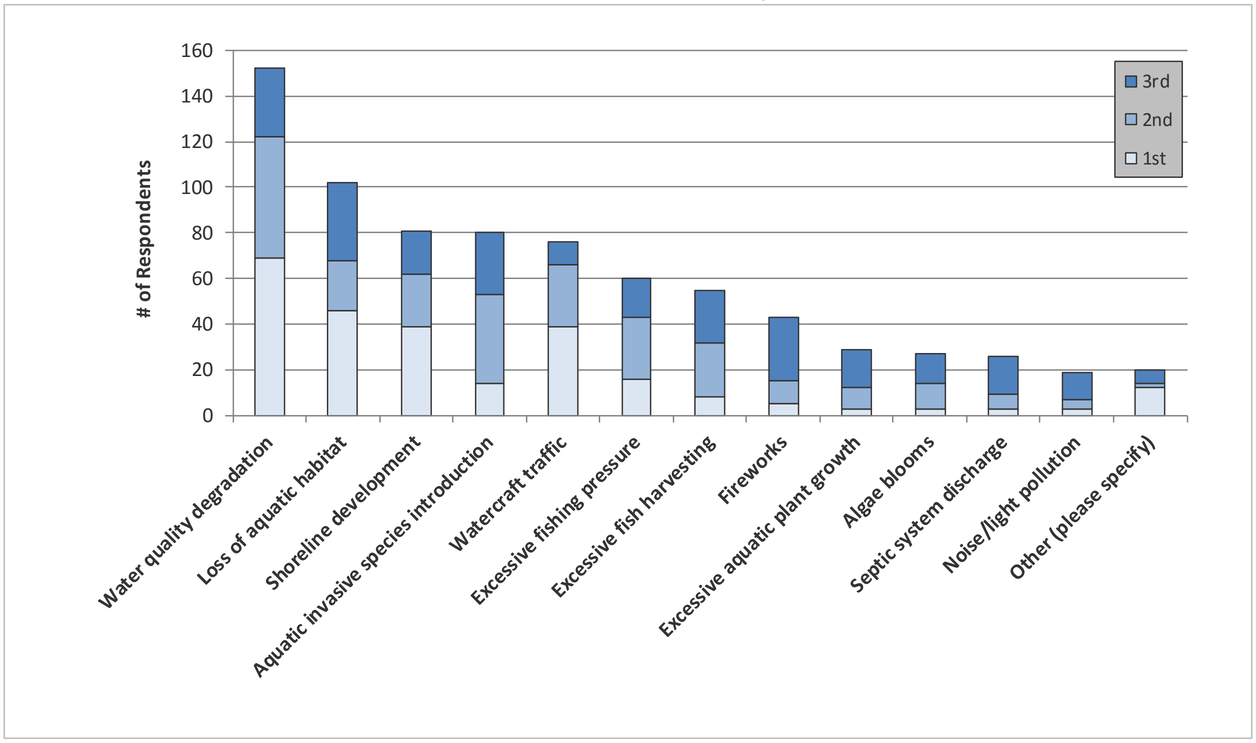


Figure 2.0-1. Select survey responses from the Manitowish Waters Chain of Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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 2.0-1 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 2.0-2 (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 2.0-2. 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), Purple loosestrife (2012)
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)

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

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

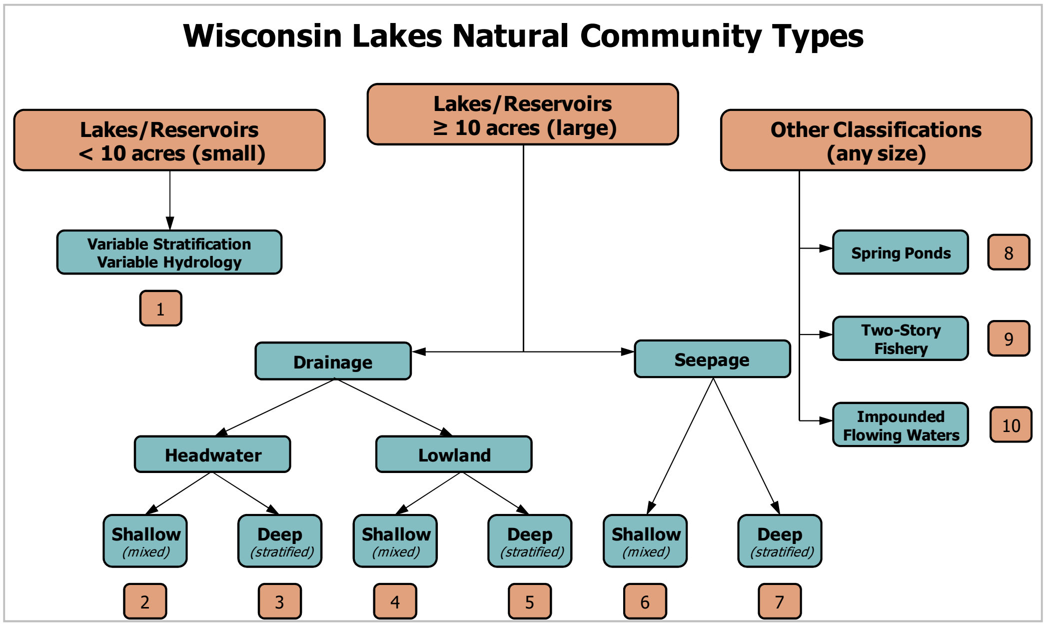


Figure 3.1-1. Wisconsin Lake Natural Community classifications. Adapted from WDNR 2013.

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.

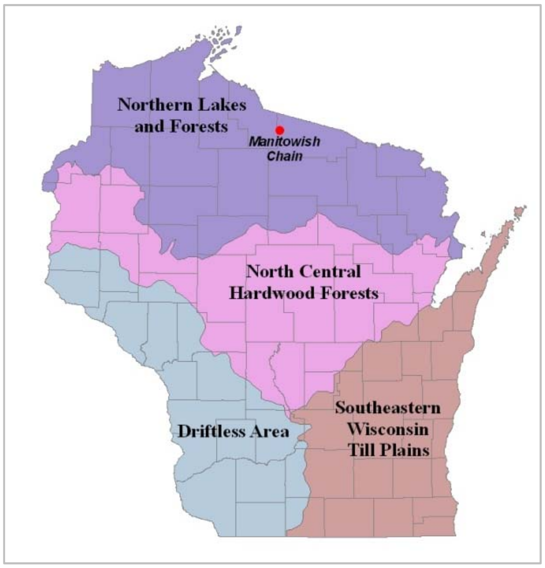


Figure 3.1-2. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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 (Map 1). 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. Finally, the lakes depicted on Figures 3.1-3 through 3.1-6 are color-coded based upon what natural lake community (Figure 3.1-1) they are classified as. It is appropriate to compare similar natural community lakes, as they are more alike than lakes of different natural community classifications.

As stated in the preceding text, three parameters are of greatest interest when considering the water quality of a lake; total phosphorus, chlorophyll-*a* and Secchi disk clarity. In the Phase I-III lakes, total phosphorus summer averages ranged between 11.7 and 19.2 µg/L (Figure 3.1-3). These values rank well when compared to the median value for similar lakes across the state and also when compared to the median of all lakes located in the Northern Lakes and Forests ecoregion.

Average summer chlorophyll-*a* concentrations are displayed below in Figure 3.1-4. As with the total phosphorus parameter, chlorophyll-*a* values in the Phase I-III Manitowish Waters Chain of Lakes rank well when compared to the median value for similar lakes across the state and all lakes within the ecoregion. As discussed above, phosphorus has a special relationship with algae in that higher phosphorus concentrations are often correlated with higher algae concentrations. Though phosphorus is often a primary driver for algae production, other factors such as water clarity and abundance of other nutrients may impact the presence of algae as well. Overall, the phosphorus and chlorophyll-*a* concentrations presented in Figures 3.1-3 and 3.1-4 are characteristic of healthy lake systems.

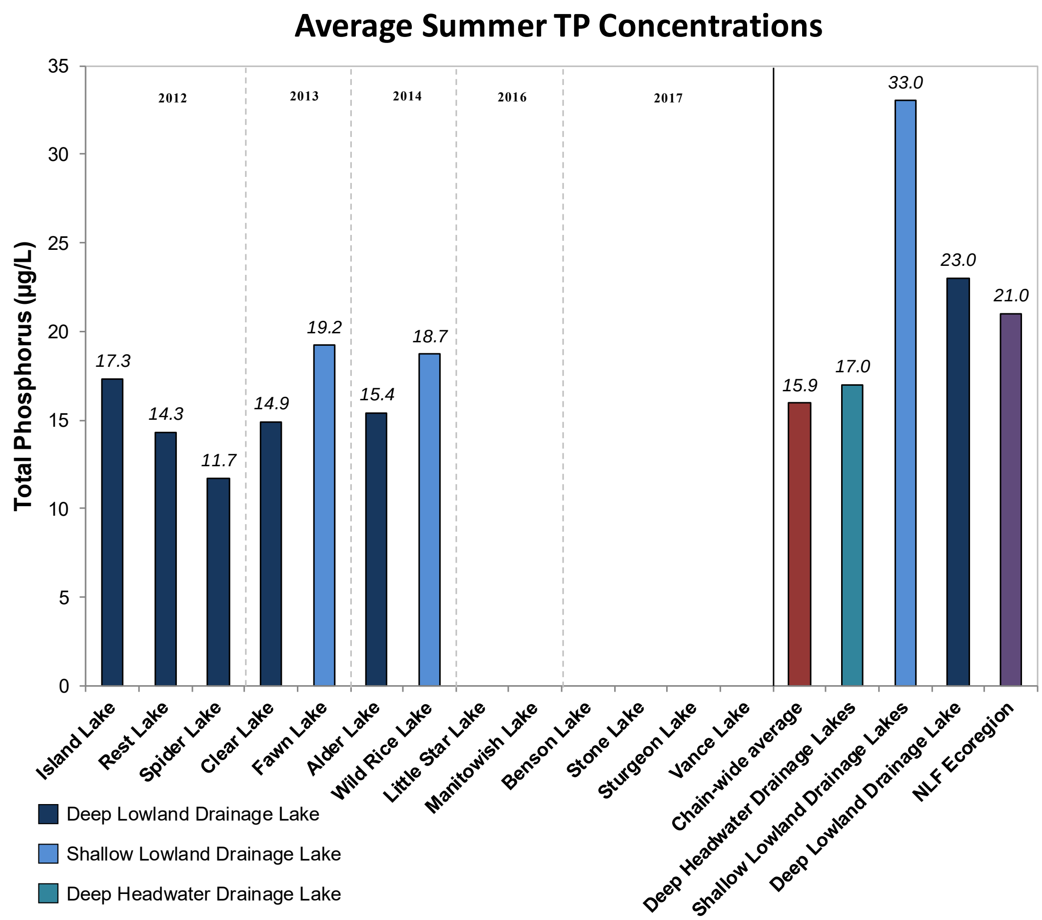


Figure 3.1-3. Manitowish Waters Chain of Lakes and comparable lakes total phosphorus concentrations. Mean values calculated with summer month surface sample data.

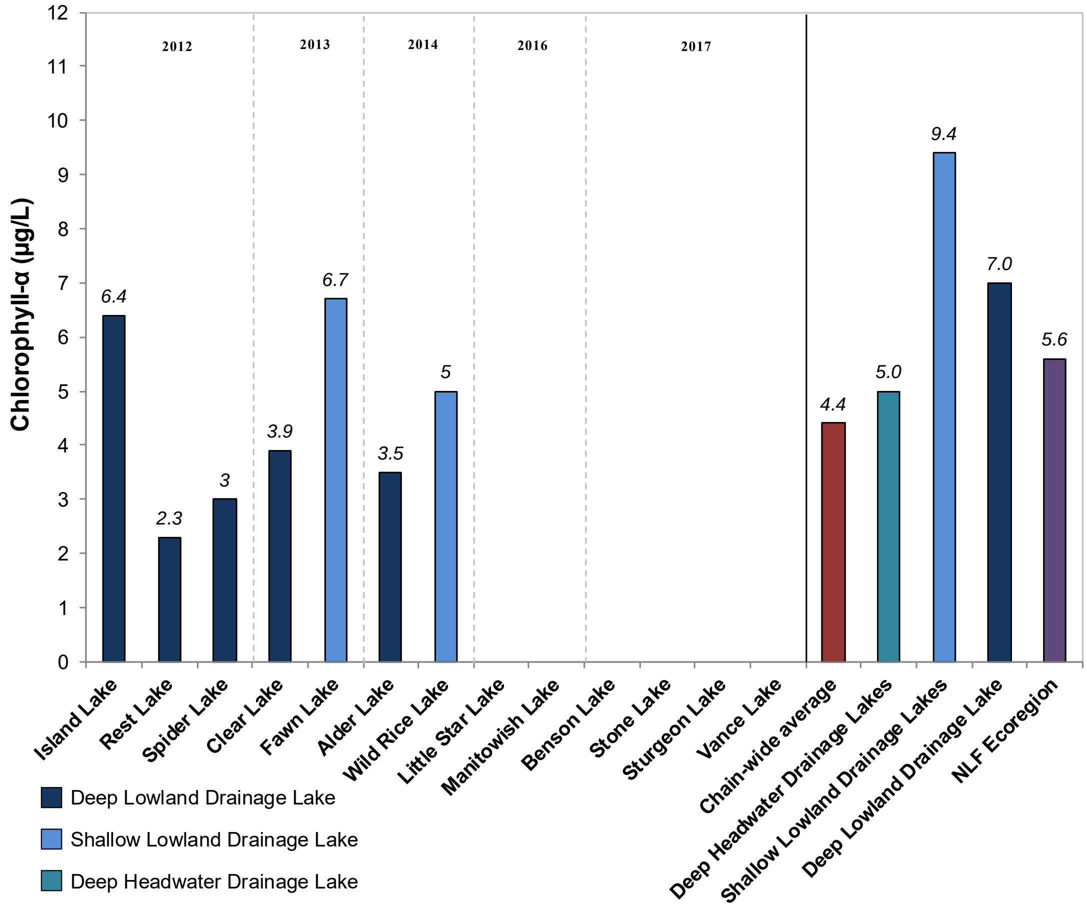


Figure 3.1-4. Manitowish Waters Chain of Lakes and comparable lakes chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data.

Average summer Secchi disk clarity ranged from 6.8 feet to 11.2 feet deep in the Manitowish Waters Chain of Lakes during the years of this project (Figure 3.1-5). Lakes in the Northern Lakes and Forests ecoregion are generally known to hold higher clarity than their southern counterparts, primarily due to the lack of development (urban areas, agriculture, etc.) which contributes to watershed runoff. Exceptions do apply however. Often, water clarity is determined by particulates in the water column, which include free-floating algae cells as well as any suspended sediments. Water clarity may be influenced by particulate substances but also by dissolved elements as well. Each individual lake report describes the influence of water color, a measurement of dissolved substances, on that lake's water clarity. The clarity of the water, in turn, affects other factors such as algae proliferation or the maximum depth at which aquatic plants grow in that lake.

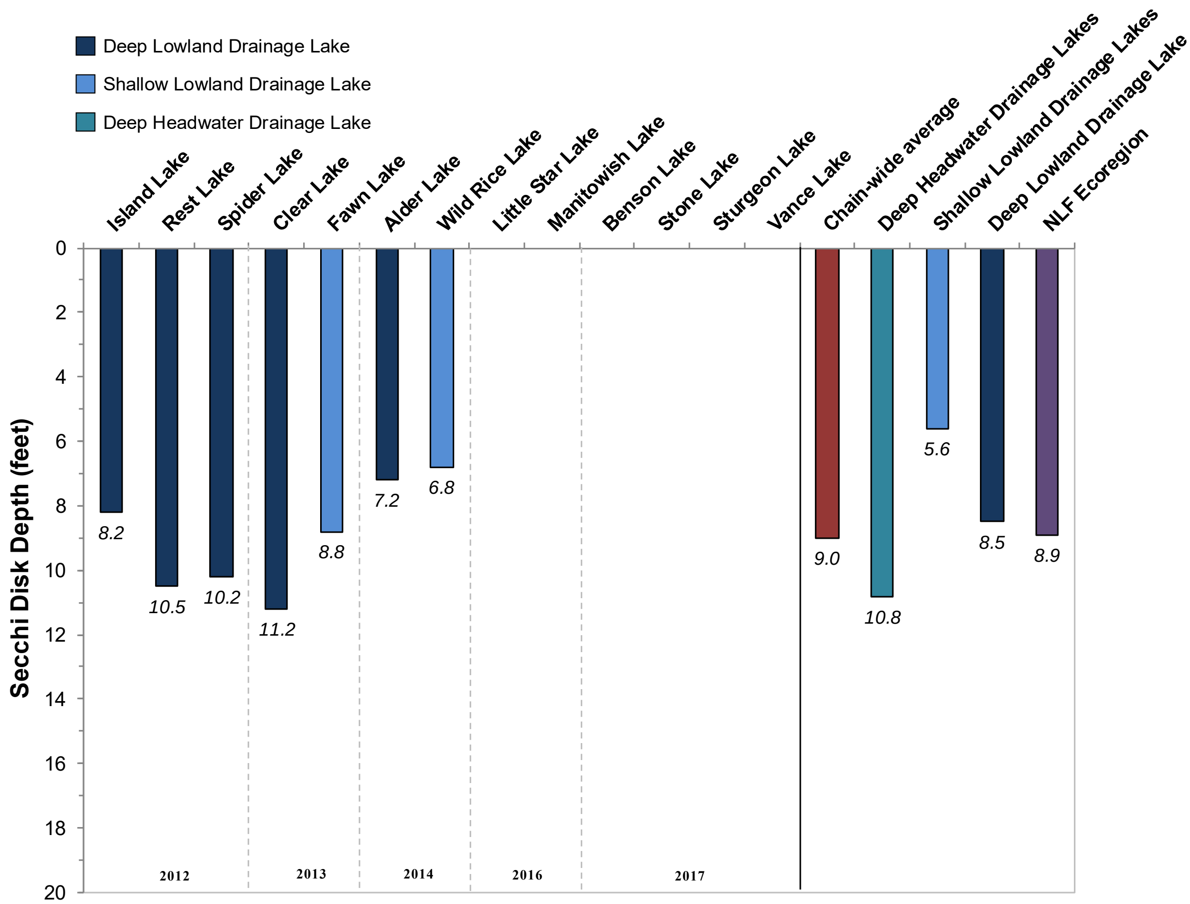


Figure 3.1-5. Manitowish Waters Chain of Lakes and comparable lakes Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Manitowish Waters Chain of Lakes

Using mid-summer nitrogen and phosphorus concentrations from all lakes included in the Manitowish Waters Chain of Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.2-1). In all lakes, the ratio weighed heavily in favor of nitrogen, rather than phosphorus. This finding suggests that all of the lakes of the Manitowish Waters Chain of Lakes are phosphorus limited, as are the vast majority of Wisconsin lakes. In general, this means that cutting phosphorus inputs may limit plant growth within the lakes.

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

Project Phase	Lake Name	Mid-summer Nitrogen (µg/L)	Mid-summer Phosphorus (µg/L)	N:P Ratio
Phase I - 2012	Island Lake	530	17.0	31:1
	Rest Lake	330	14.0	24:1
	Spider Lake	320	14.0	23:1
Phase II - 2013	Clear Lake	625	15.1	41:1
	Fawn Lake	636	20.0	32:1
Phase III – 2014	Alder Lake	368	14.3	26:1
	Wild Rice Lake	434	18.2	24:1
Phase IV – 2016	Little Star Lake			
	Manitowish Lake			
Phase V – 2017	Benson Lake			
	Stone Lake			
	Sturgeon Lake			
	Vance Lake			

Manitowish Waters Chain of Lakes Trophic State

Figure 3.1-6 contain the TSI values for Manitowish Waters Chain of Lakes. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to lower oligotrophic. In general, the best values to use in judging a lake's trophic state are the biological parameters. Many of the lakes within the chain fall within the range of mesotrophic – characterized by moderate to high water clarity and moderate to low phosphorus and chlorophyll-*a* content.

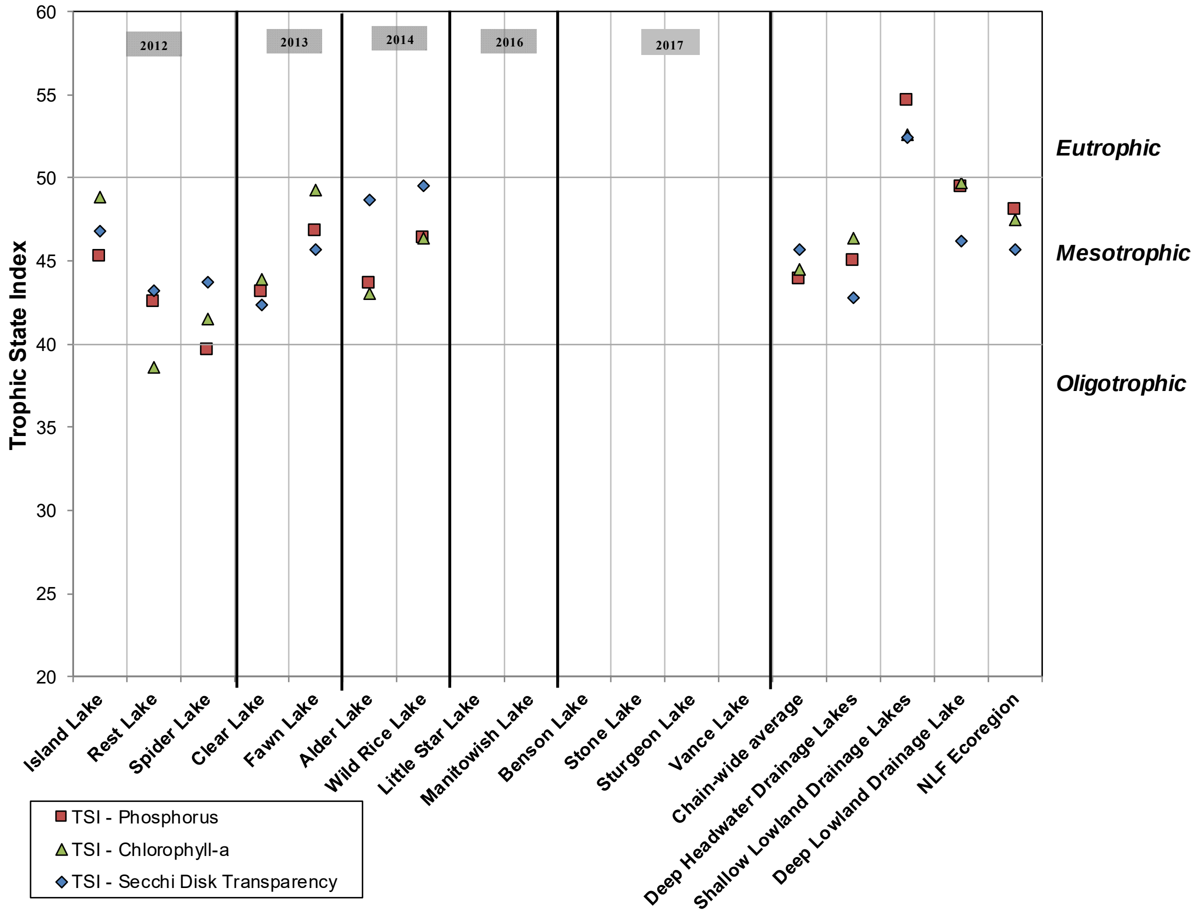


Figure 3.1-6. Manitowish Waters Chain of Lakes and comparable lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Additional Water Quality Data Collected on the Manitowish Waters Chain of Lakes

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

The pH scale ranges from 0 to 14 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. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius, 1985). The variability in pH between lakes is most likely attributable to a number of environmental factors, with the chief determiner being geology near the lake and within its surface and underground watersheds. On a smaller scale within a lake or between similar lakes, photosynthesis by plants can impact pH because the process uses dissolved carbon dioxide, which acts as a carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Within the Manitowish Waters Chain of Lakes, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Table 3.1-2). The values seen within the chain lakes are near neutral and are normal for Wisconsin lakes.

Table 3.1-2. Manitowish Waters Chain of Lakes pH, alkalinity, acid rain susceptibility, calcium, and zebra mussel susceptibility. Values are from sub-surface samples taken in mid-summer from each lake.

Project Phase	Lake Name	pH	Alkalinity (mg/L)	Acid Rain Susceptibility	Calcium (mg/L)	Zebra mussel Susceptibility
Phase I - 2012	Island Lake	7.1	45.1	Not sensitive	12.5	Low susceptibility
	Rest Lake	7.2	27	Not sensitive	12.7	Low susceptibility
	Spider Lake	7.7	44.5	Not sensitive	12.6	Low susceptibility
Phase II - 2013	Clear Lake	8.3	42.3	Not sensitive	11.7	Very low susceptibility
	Fawn Lake	9.1	39.2	Not sensitive	9.9	Very low susceptibility
Phase III – 2014	Alder Lake	7.6	40.2	Not sensitive	11	Very low susceptibility
	Wild Rice Lake	7.6	43.0	Not sensitive	11.5	Very low susceptibility
Phase IV – 2016	Little Star Lake					
	Manitowish Lake					
Phase V – 2017	Benson Lake					
	Stone Lake					
	Sturgeon Lake					
	Vance Lake					

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity it contains. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. Alkalinity is variable between the Manitowish Waters Chain of Lakes, but still within expected ranges for northern Wisconsin lakes (Table 3.1-2). Alkalinity determines the sensitivity of a lake to acid rain. Values between 2 and 10 mg/L as $CaCO_3$ are considered to be moderately sensitive to acid rain, while lakes with values of 10 to 25 mg/L as $CaCO_3$ are considered to have low sensitivity, and lakes above 25 mg/L as $CaCO_3$ are non-sensitive.

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

All of the Manitowish Waters Chain of Lakes are suitable for zebra mussel establishment based upon pH. As indicated on Table 3.1-2, the calcium concentrations within these lakes are at the low end for zebra mussel suitability, but still indicate fitting conditions. The Phase II and III lakes have slightly lower calcium concentrations, just outside but very near the low susceptibility range for zebra mussel suitability.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

In systems with high WS:LA ratios, like those 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.

Once completed near the end of this project, phosphorus modeling results will be discussed here. In addition, hydrologic data being collected by the USGS and WDNR on the Manitowish Waters Chain of Lakes will be used to calibrate the WiLMS models. Watershed modeling data will be produced in Appendix D.

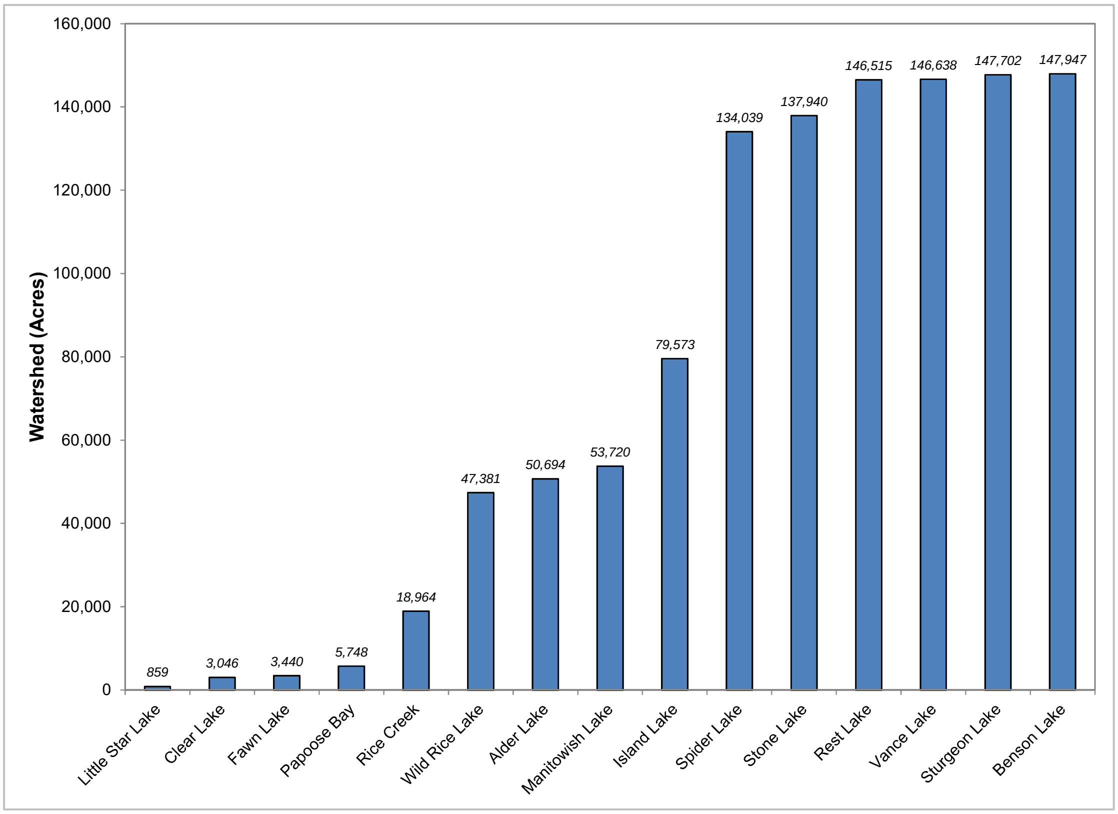


Figure 3.2-1. Manitowish Waters Chain of Lakes watershed sizes in acres.

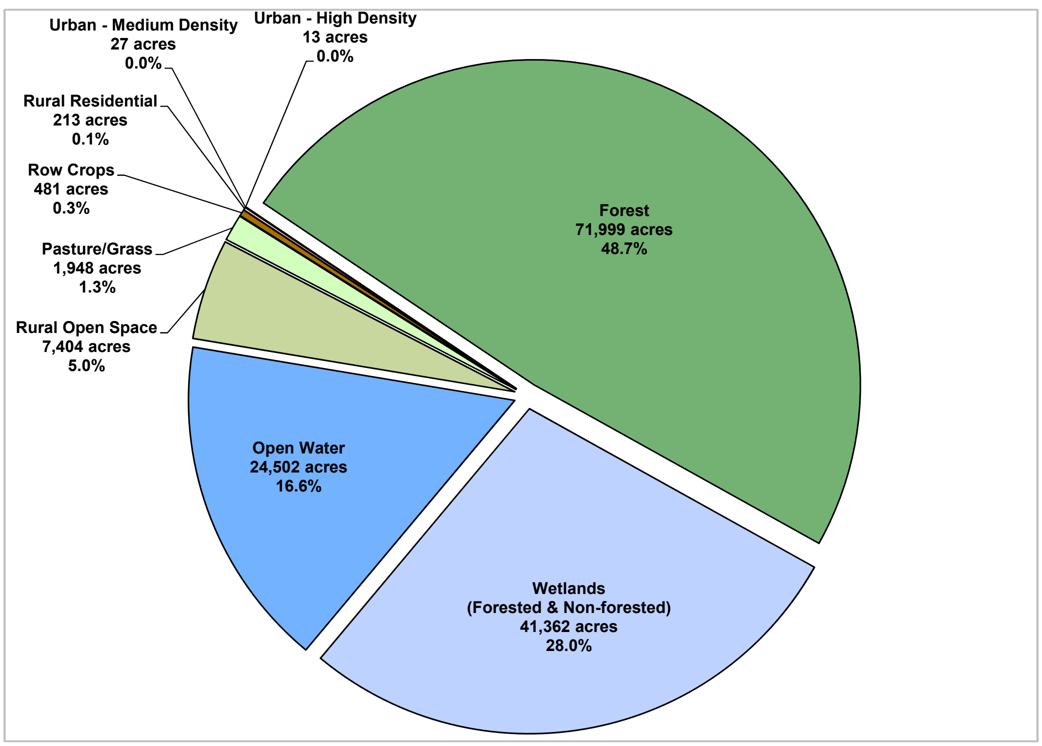


Figure 3.2-2. Manitowish Waters Chain of Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011)

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

One of the most vulnerable areas of a lake's watershed is the immediate shoreland zone (approximately from the water's edge to at least 35 feet shoreland). When a lake's shoreland is developed, the increased impervious surface, removal of natural vegetation, and other human practices can severely increase pollutant loads to the lake while degrading important habitat. Limiting these anthropogenic (man-made) 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 swimmers itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with 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 strict shoreland ordinances. Passed in February of 2010, the final NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below. Please note that at the time of this writing, changes to NR 115 were last made in October of 2015 (Lutze 2015).

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

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

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

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

Wisconsin Act 31

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

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 restrictive than the state's minimum standards contained in NR 115. Counties that had shoreland zoning ordinances that were more restrictive than state standards are no longer able to enforce those more restrictive standards. While county governments, countywide lake and river associations, individual lake associations, and lake districts across Wisconsin have moved to challenge Act 55, the Wisconsin Legislature 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.

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).

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.

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On each of 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-III Manitowish Waters Chain of Lakes contain approximately 28.6 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. A little over 9.2 miles (19%) of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each Phase I-III lake's shoreland condition, while each individual lake section discusses the shoreline condition further. Maps of each lake and the location of these categorized shorelands are included within each individual lake section as well.

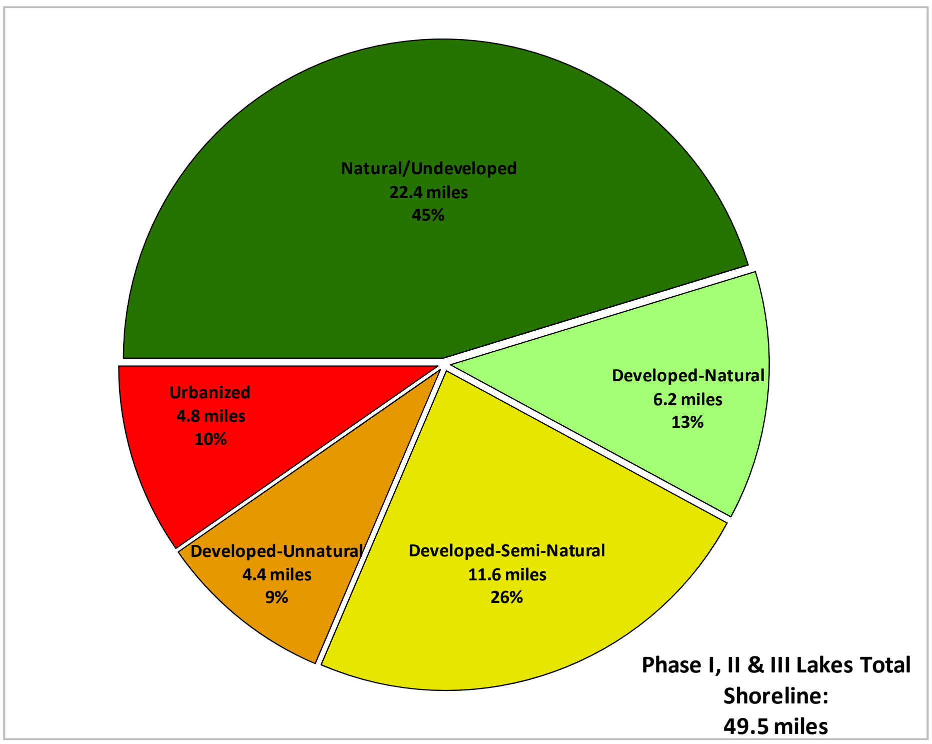


Figure 3.3-2. Phase I-III Manitowish Waters Chain of Lakes total shoreland category classification. Based upon field surveys conducted in late summer. Locations of these categorized shorelands can be found on maps within each individual lake section.

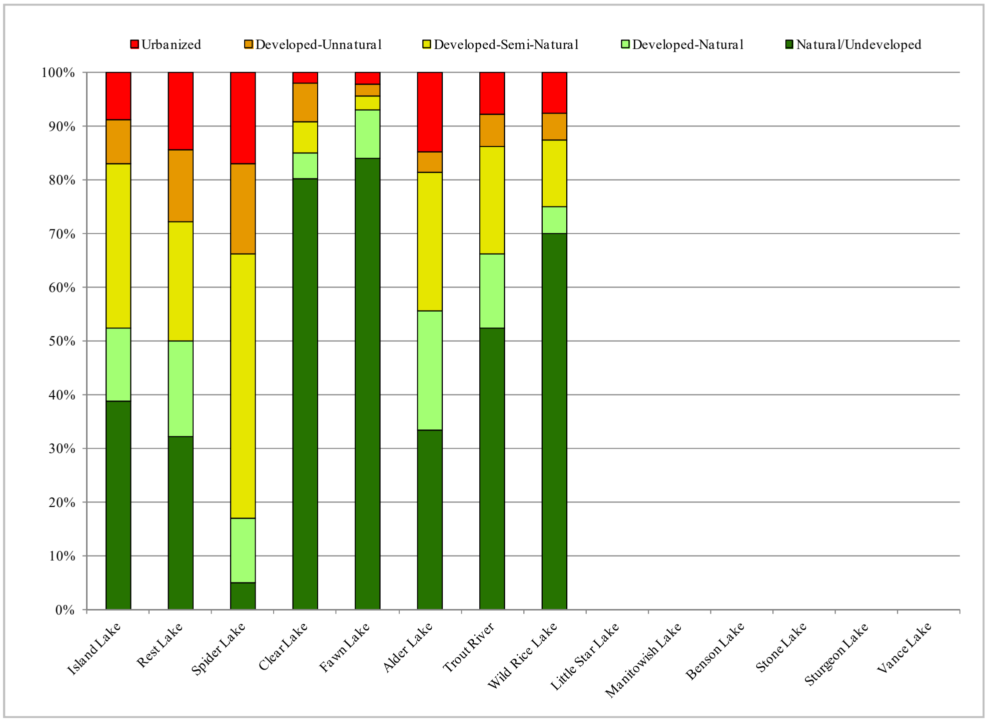


Figure 3.3-3. Phase I-III Manitowish Waters Chain of Lakes shoreline condition breakdown. Based upon late summer field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

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.

Each individual lake report examines the coarse woody habitat availability within the respective lake. Figure 3.3-4 displays results from the Phase I and II lakes combined. A total of 886 coarse woody habitat pieces were identified along 49.5 miles of shoreline. Although this may seem to be a considerable amount, WDNR studies have identified as much as 300-400 pieces *per mile* of shoreline (Christensen et al. 1996). In addition to structural related habitat projects, refraining from removing woody elements and other natural features from a shoreland area is the best way to increase availability of coarse woody habitat in a lake.

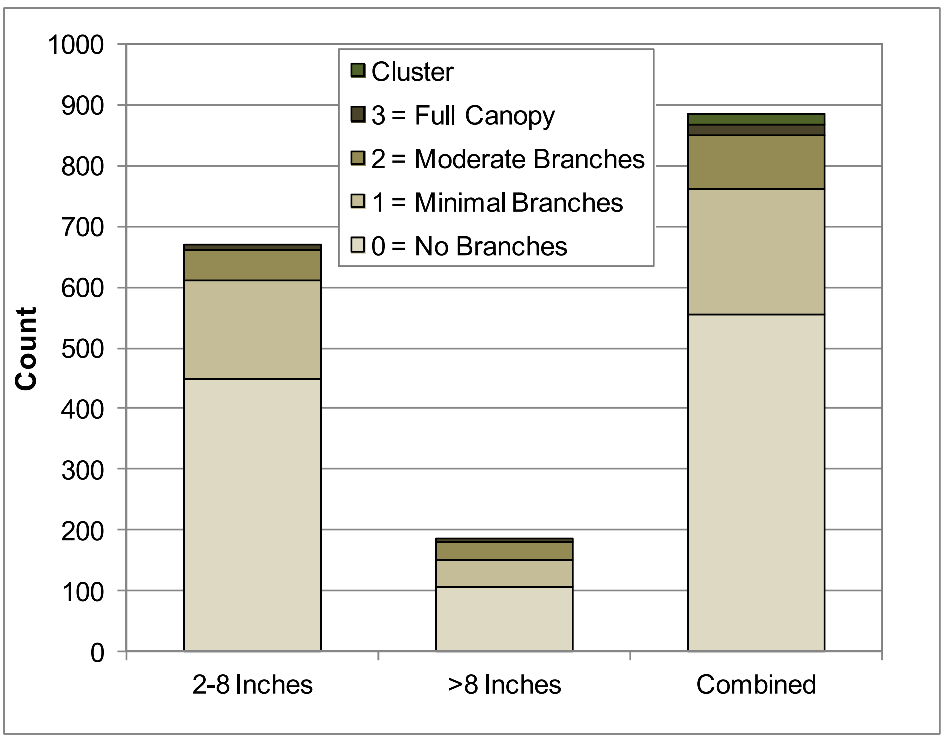


Figure 3.3-4. Phase I-III Manitowish Waters Chain of Lakes coarse woody habitat survey results. Based upon late summer surveys on each project lake.

3.4 Aquatic Plants

Introduction

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

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*). In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent 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.

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.

Mechanical Harvesting

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

Cost

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

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

Herbicide Treatment

The use of herbicides to control aquatic plants and algae is a technique that is widely used by lake managers. 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.

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

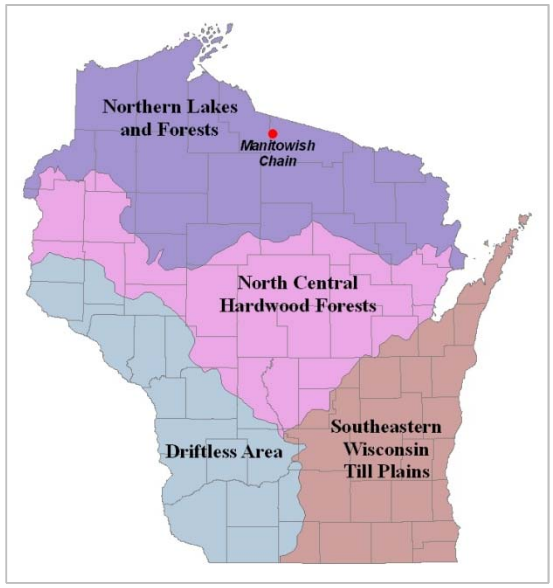


Figure 3.4-1. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Community Mapping

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

Exotic Plants

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

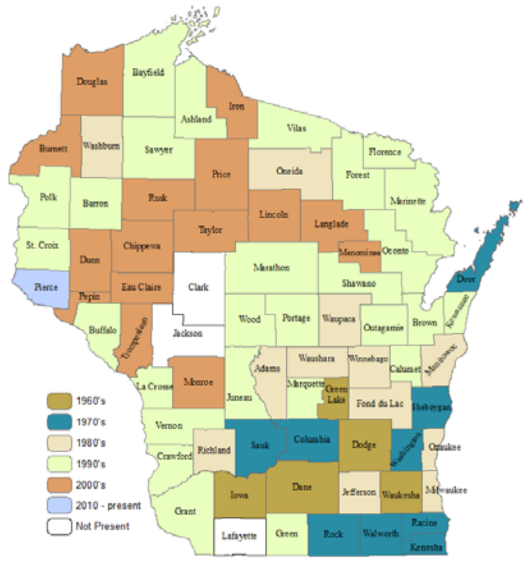


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 of 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. To gain an understanding of resident's perceptions of the aquatic plant community, several aquatic plant related questions were included in the project's stakeholder survey (Appendix B).

A total of 98 different aquatic plant species were identified from the project lakes (Figure 3.4-3 - 3.4-5). Of the 41 submersed aquatic plant species found, nine species were common to all eight PhaseI-III waterbodies. A single emergent plant was found on all eight waterbodies.

One submersed native aquatic plant species located in five of the eight Phase I-III lakes, Vasey's pondweed (*Potamogeton vaseyi* - Photo 3.4-1), is currently listed a species of special concern by Wisconsin's Natural Heritage Inventory due to uncertainty regarding its population and rarity in Wisconsin (WDNR 2011). One of the rarest water lily species in Wisconsin (Dr. Susan Knight person. comm.), yellow pond-lily (*Nuphar microphylla*), was found in several areas of the chain. Yellow pond-lily is a close relative of the common and widespread spatterdock (*N. variegata*), though is much smaller with flowers of only one to two centimeters wide and leaves of only up to ten centimeters long. These two species often hybridize, forming intermediate pond-lily (*N. x rubrodisca*), which was also observed growing in Rice Creek. While not listed by the NHI, yellow pond-lily is relatively rare and is restricted to northern Wisconsin.

Photo 3.4-1. Manitowish Waters Chain of Lakes rare plant species. Pictured is yellow pond-lily (*Nuphar microphylla,* left), the slightly larger intermediate pond-lily (*Nuphar x. rubrodisca, middle*) and state special concern species Vasey's pondweed (*Potamogeton vaseyi,* right*).*

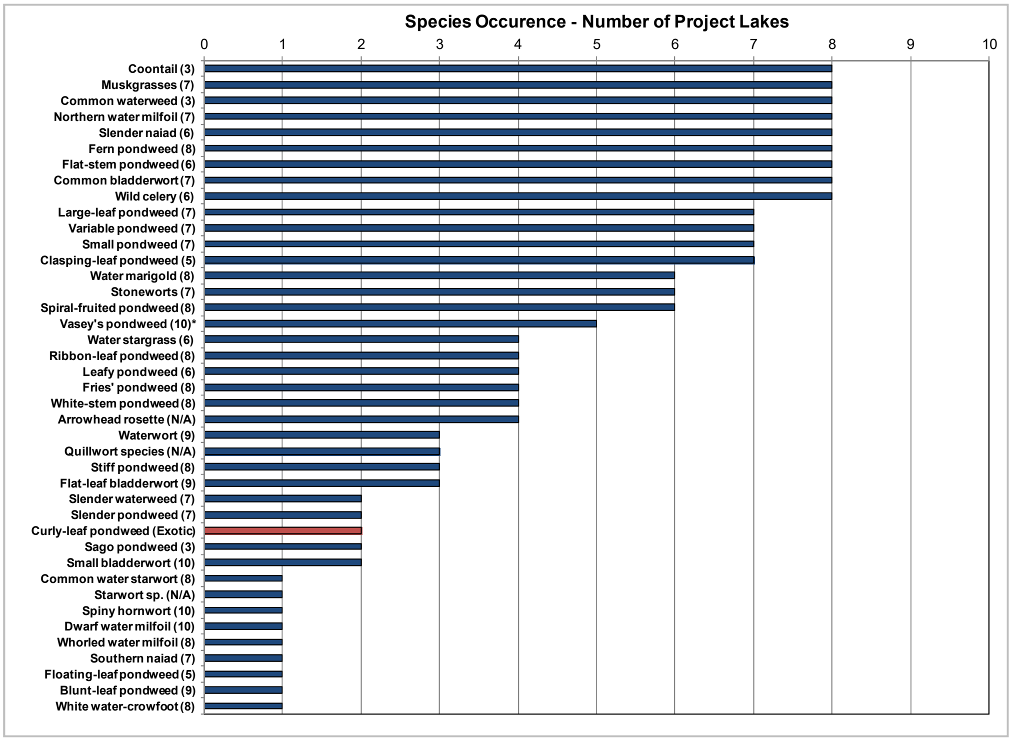


Figure 3.4-3 Manitowish Waters Chain of Lakes submergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.
* *State species of special concern*

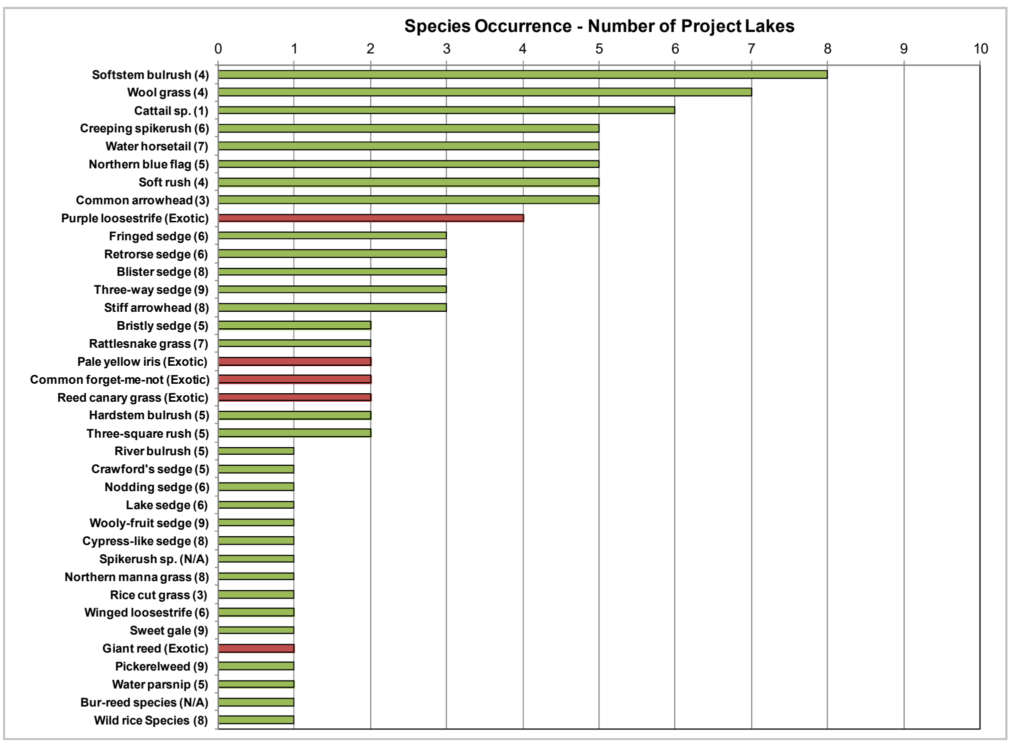


Figure 3.4-4 Manitowish Waters Chain of Lakes emergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism (C) are in parentheses.

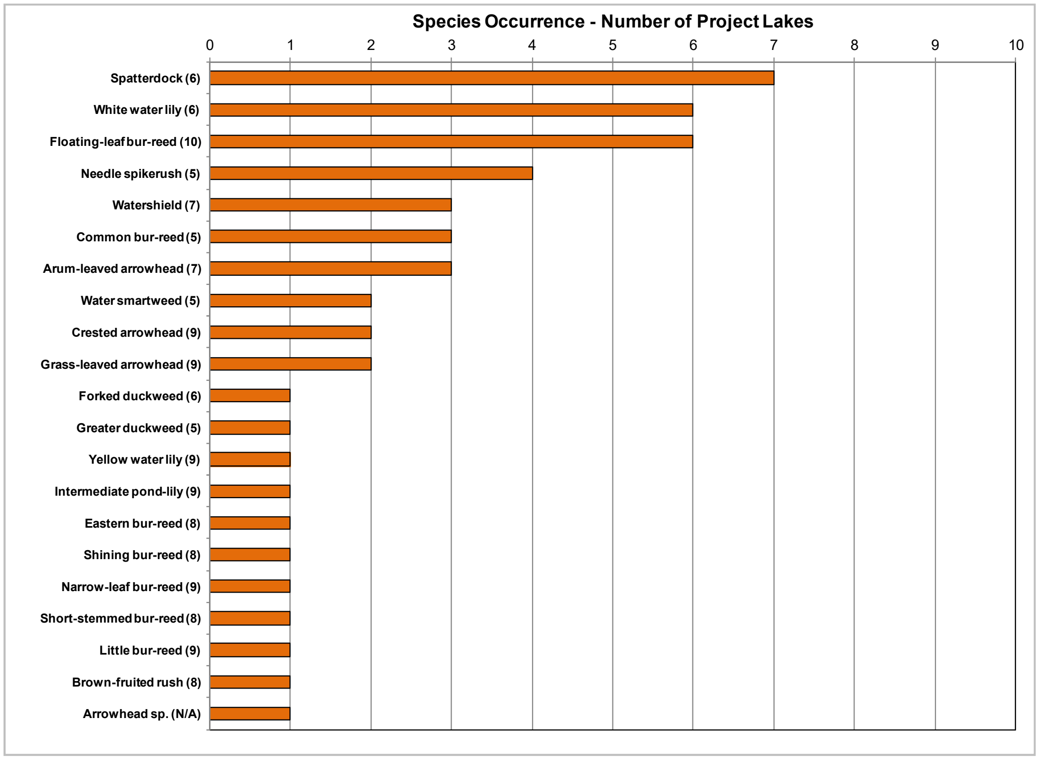


Figure 3.4-5. Manitowish Waters Chain of Lakes floating-leaf, free-floating, floating-leaf/emergent and submergent/emergent aquatic plant species occurrence. Created using data from point intercept and community mapping surveys. Exotic species indicated with red. Native species' coefficients of conservatism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

Of the 98 aquatic plant species located in the Phase I-III 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 eight Manitowish Waters Chain of Lakes that have been studied under Phase I-III, the number of native aquatic plant species (species richness) per lake ranged from 24 in Papoose Creek to 55 in Clear Lake, with an average of 40 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 55 native aquatic plant species were located in Clear Lake in 2013, 29 were sampled on the rake during the whole-lake point-intercept survey, while 26 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).

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

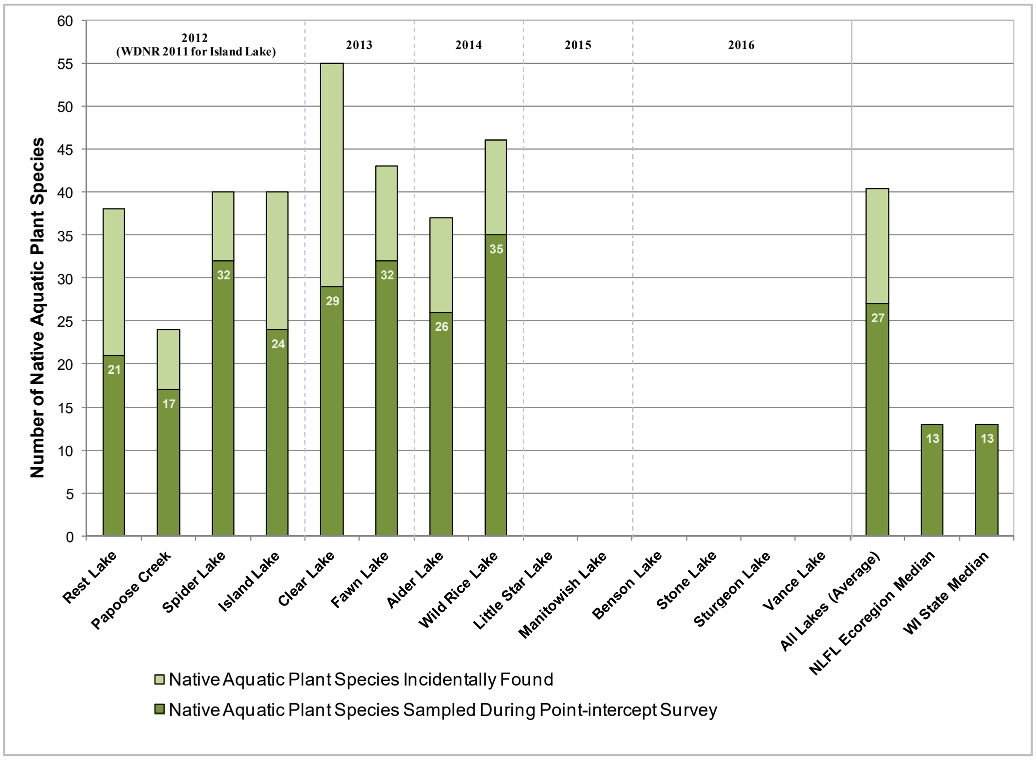


Figure 3.4-6. Manitowish Waters Chain of Lakes native aquatic plant species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

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 of Lakes lies near the Northern Lakes and Forests Lakes (NLFL) Ecoregional median with values ranging between 6.5 and 6.8. 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 41.1. 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.

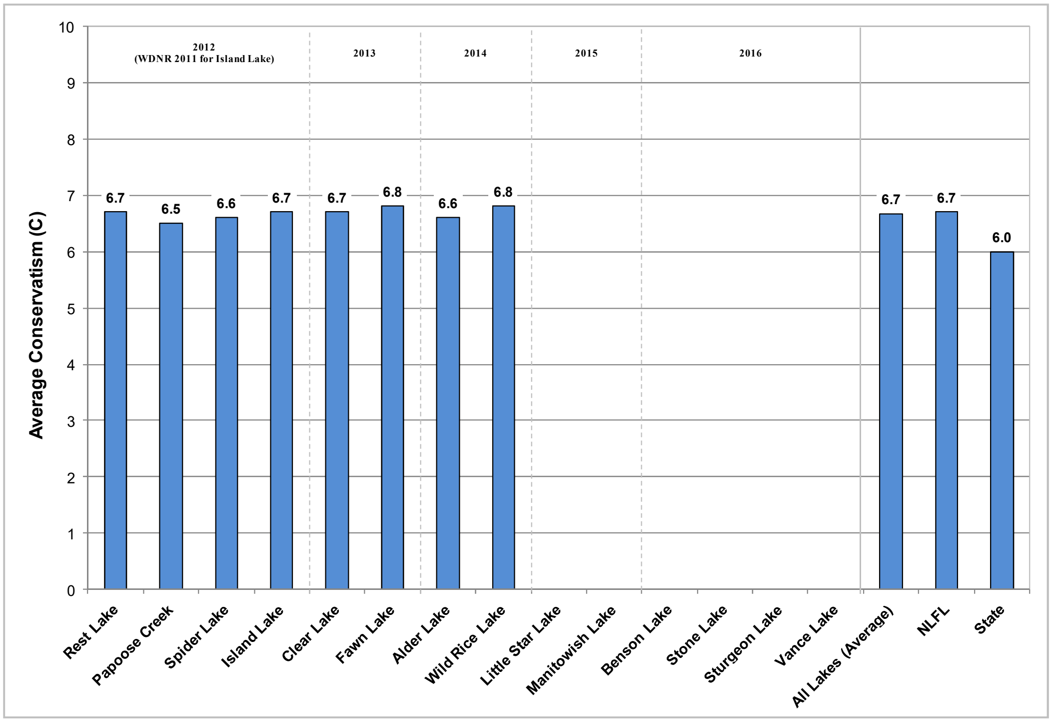


Figure 3.4-7. Manitowish Waters Chain of Lakes native species average conservatism values. Created using native aquatic plant species encountered on the rake during summer point-intercept surveys.

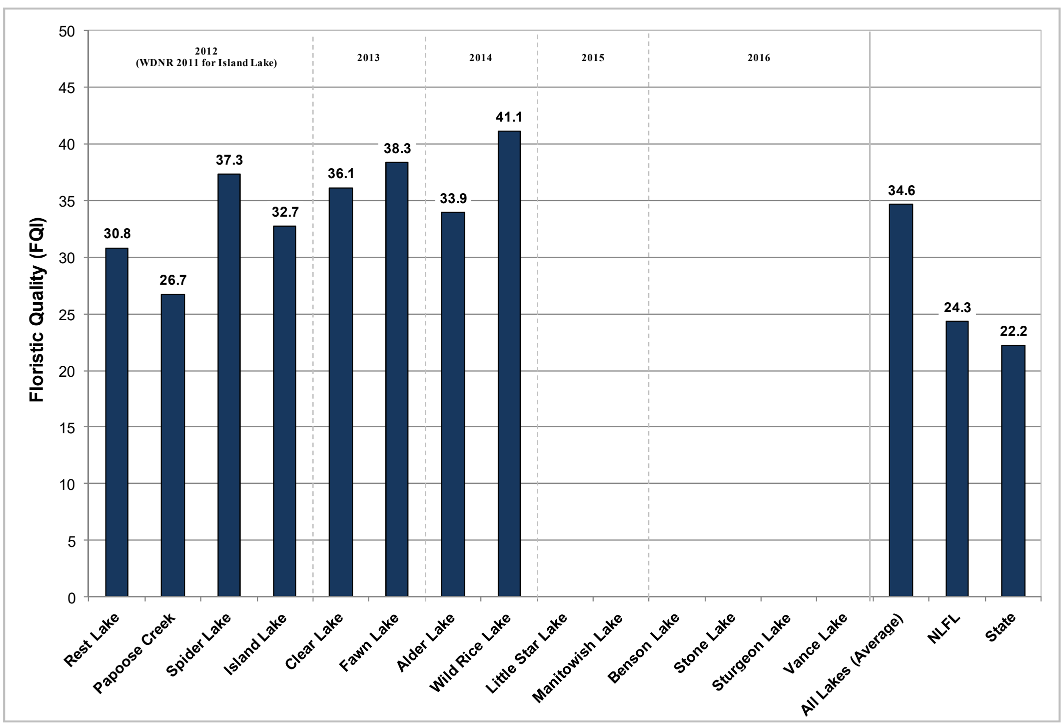


Figure 3.4-8. Manitowish Waters Chain of Lakes Floristic Quality Assessment. Created using data from native aquatic plant species encountered on the rake during summer point-intercept surveys. Analysis follows Nichols (1999).

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 109 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 project lakes, species diversity ranged from 0.86 to 0.93. As discussed within the Papoose Creek Aquatic Plant Section, the majority (66%) of its aquatic plant community is comprised of just four species: coontail, common waterweed, flat-stem pondweed, and northern wild rice. In comparison, the aquatic plant species in Spider Lake have a relatively more even distribution, with the four-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.

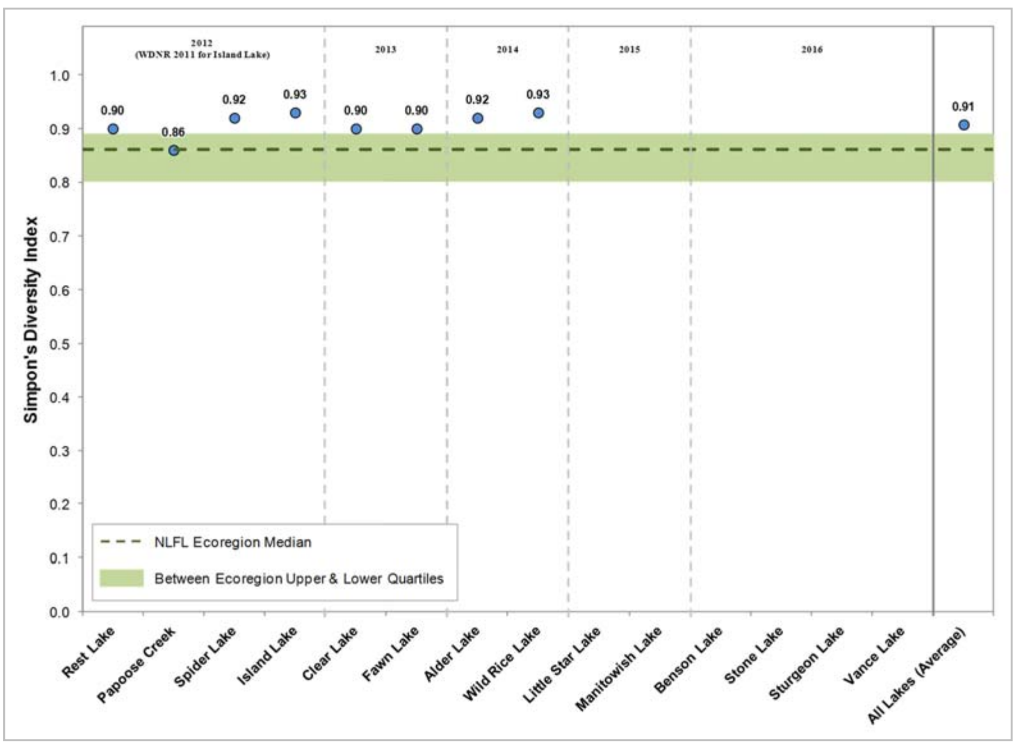


Figure 3.4-9. Manitowish Waters Chain of Lakes Simpson's Diversity Index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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). Spider Lake, a relatively deep lake, has only 2% of its lake acreage covered by these communities.

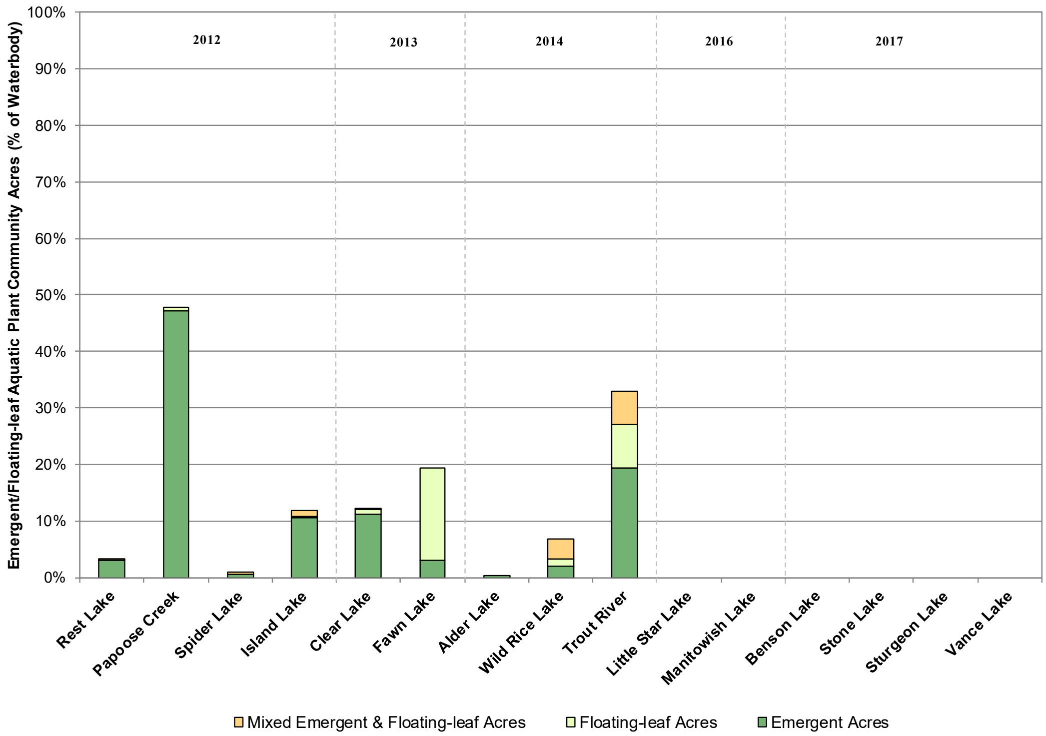


Figure 3.4-10. Manitowish Waters Chain of Lakes emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

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 2012-2017. 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.

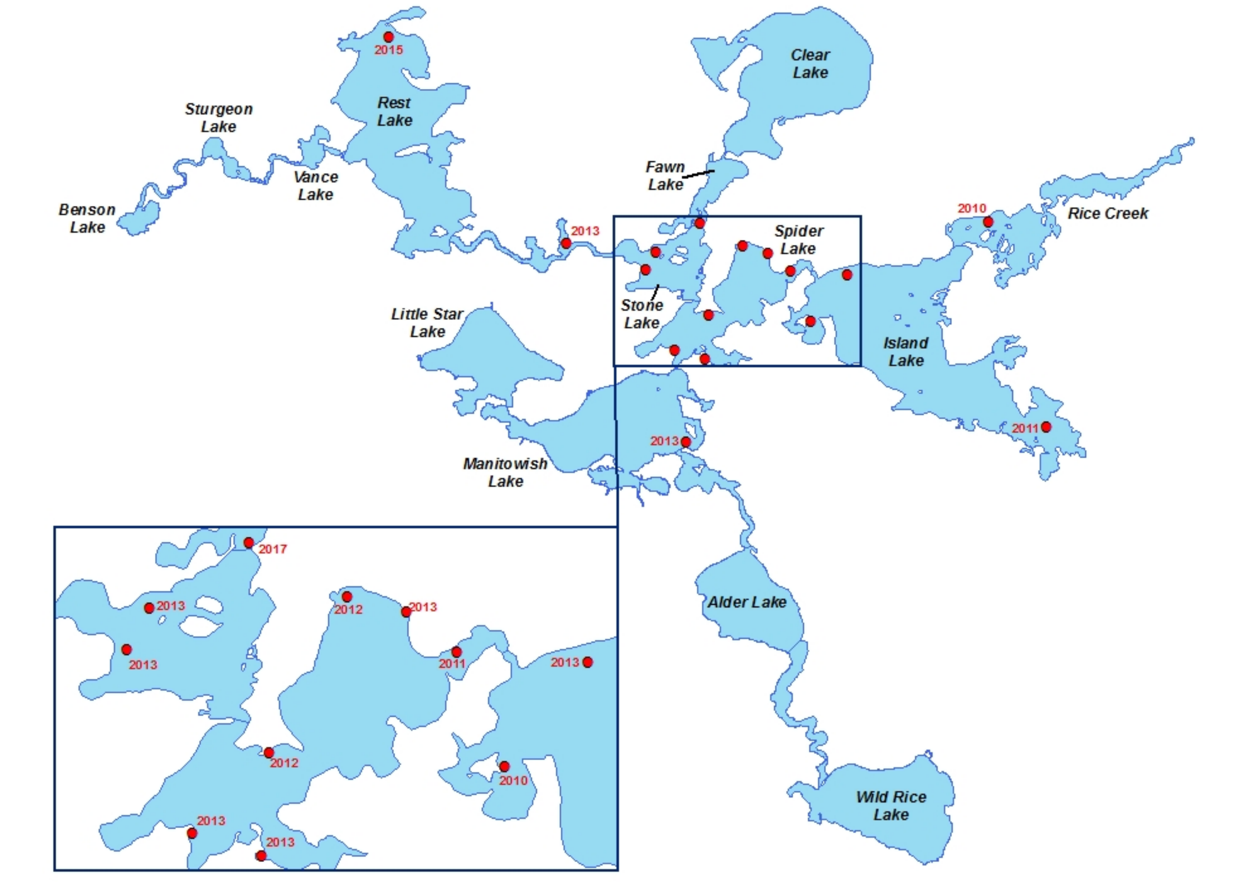


Figure 3.4-11. Curly-leaf pondweed discoveries in the Manitowish Waters Chain of Lakes. Initial discovery of curly-leaf pondweed throughout the chain, created using data from Onterra, MWLA volunteers and the NLDC.

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 2012-2017

Over the course of the six years between 2012 and 2017, 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. 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). 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, since 2014, the occurrence of curly-leaf pondweed has rebounded to including more and more *clumps of plants* and *small plant colonies* within the area.

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.

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. 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.

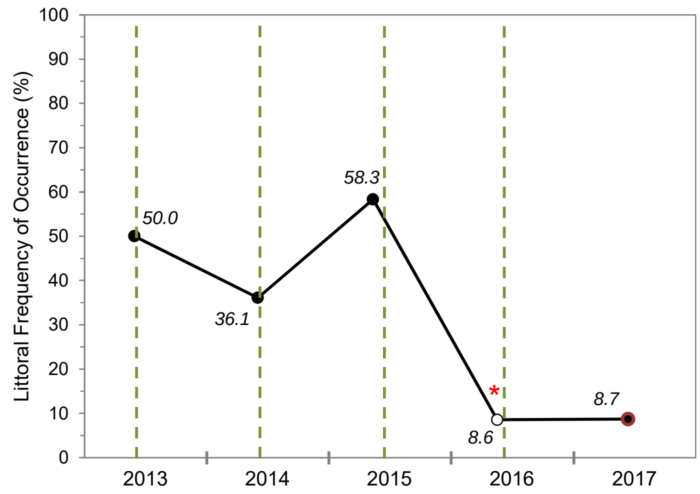


Figure 3.4-12. Curly-leaf pondweed littoral frequency of occurrence. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically valid change from 2013 to 2016; a red circle outline 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 plant 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.

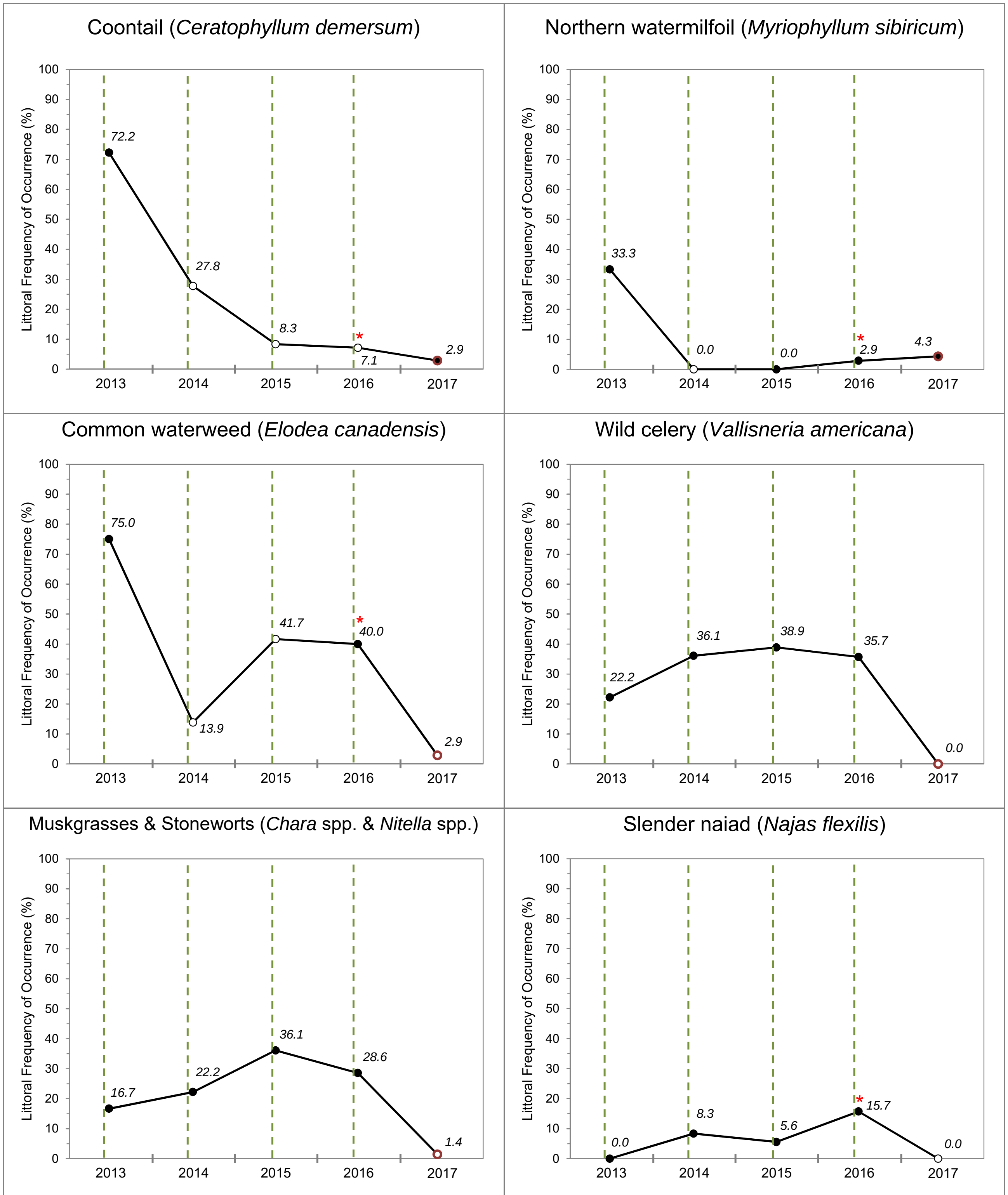


Figure 3.4-13. Spider/Island Channel littoral frequency of occurrence of aquatic plant species from 2013-2017. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically valid 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.

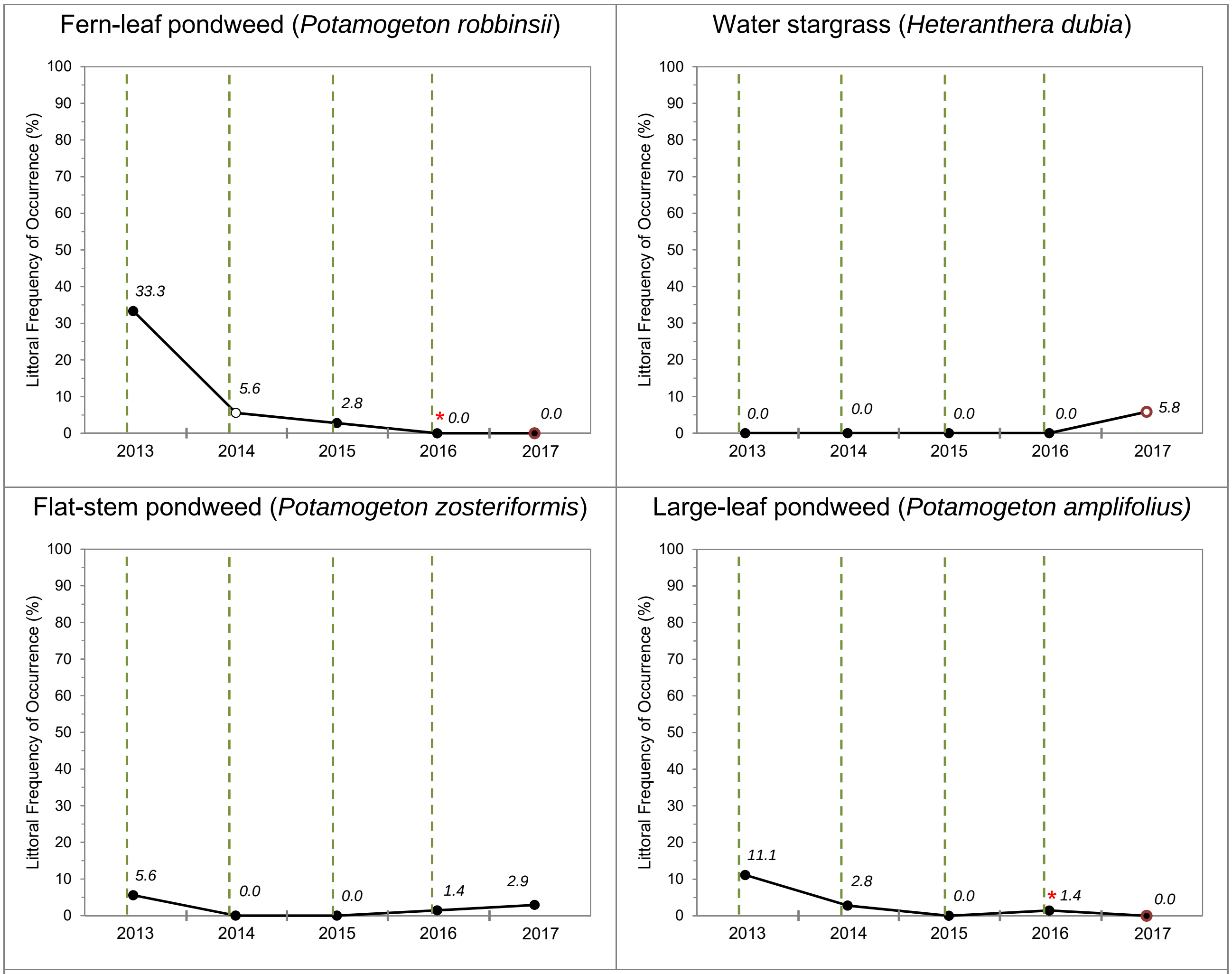


Figure 3.4-13 continued. Spider/Island Channel littoral frequency of occurrence of aquatic plant species from 2013 to 2017. Dotted lines indicate active curly-leaf pondweed management. Open circles indicate statistically valid change in occurrence from previous survey; red asterisk indicates a statistically 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.

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 Becker 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.

3.5 Fisheries Data Integration

Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of available data is included here as reference. The following section is not intended to be a comprehensive plan for the lake's fishery, as those aspects are currently being conducted by the numerous fisheries biologists overseeing Manitowish Waters Chain of Lakes. The goal of this section is to provide an overview, albeit likely incomplete, 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 fisheries information within this section 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). Further, because aquatic plants provide important fish habitat and aquatic plants have been actively managed in the Manitowish Waters Chain of Lakes in recent years, at the end of this section, information regarding herbicide use and fisheries impacts are presented.

Energy Flow of a Fishery

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

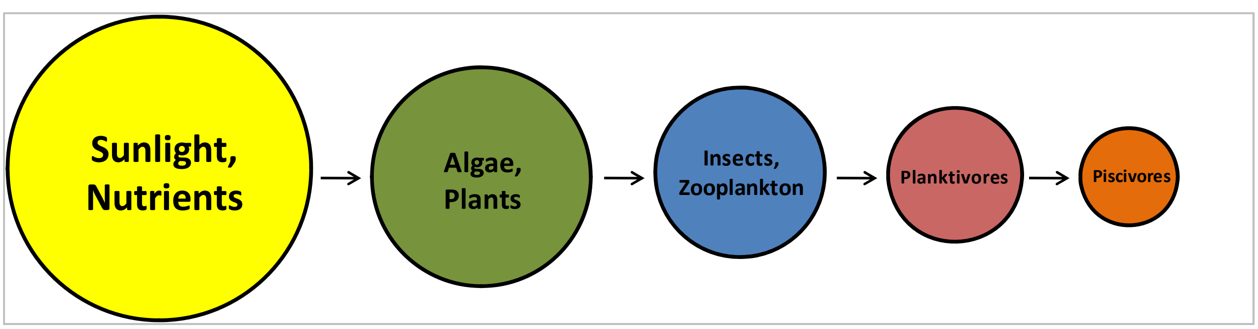


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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

Native American Spearfishing

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). The 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. This highly structured process 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 (Spangler, 2009). Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The state-wide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

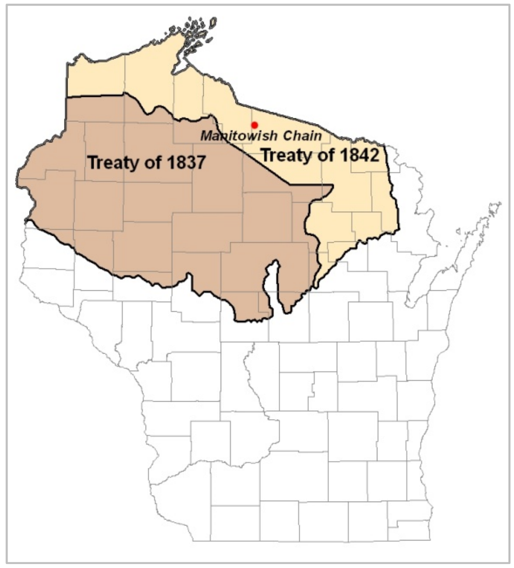


Figure 3.5-2. Location of Manitowish Waters Chain of Lakes within the Native American Ceded Territory (GLIFWC 2016). This map was digitized by Onterra; therefore it is a representation and not legally binding.

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 quota 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 quota is met.

While a safe harvest level and quota have been established on most lakes at some time between 1989 and present time, not all lakes within the chain have experienced a spearfishing harvest. Lakes with no recorded walleye harvest over this time period include Fawn, Benson, Stone, Sturgeon and Vance Lakes. Table 3.5-1 displays the walleye and muskellunge harvest frequency during the past 26 years in which data has been recorded. As seen on this table, the lakes that have historically seen a higher spear harvest include most of the larger bodied lakes in the chain – Island, Rest, Alder, Manitowish and Clear lakes.

Table 3.5-1. 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 & GLIFWC).

Lake	Years of walleye harvest, 1989-2014	Years of muskellunge harvest, 1989-2014
Clear Lake	26	24
Island Lake	26	12
Rest Lake	26	16
Manitowish	21	11
Alder	17	1
Spider Lake	16	8
Little Star	12	3
Wild Rice	10	5
Benson Lake	-	-
Fawn Lake	-	-
Stone Lake	-	-
Sturgeon Lake	-	-
Vance Lake	-	-

Individual lake Native American spearing statistics are displayed in Appendix F. 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). Once a safe harvest number is set for a given lake, tribal leaders may declare a quota of fish they may spear in the upcoming season. From 1989 to 2014, tribal spearers have claimed a walleye quota that is between 39.4% and 78.5% of the safe harvest, with the average safe harvest claim being 56.1%. Typically, Native American spear fishermen have harvested 77% of the declared quota on the Manitowish Waters Chain of Lakes with respect to walleye.

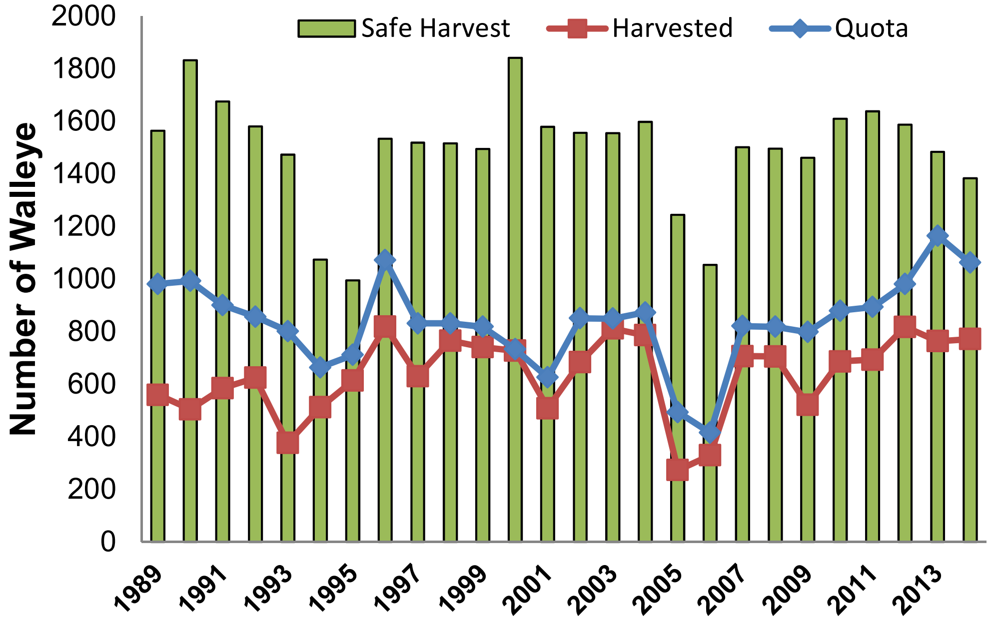


Figure 3.5-3. Total chain-wide walleye spear harvest statistics. Annual Native American walleye spear harvest statistics are summarized for 13 lakes in the Manitowish Waters Chain of Lakes. Data provided by WDNR & GLIFWC).

Figure 3.5-4 displays the Native American open water muskellunge spear harvest since 1989. From 1989 to 2013, 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 51.1%. Between 1989 and 2013, 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.

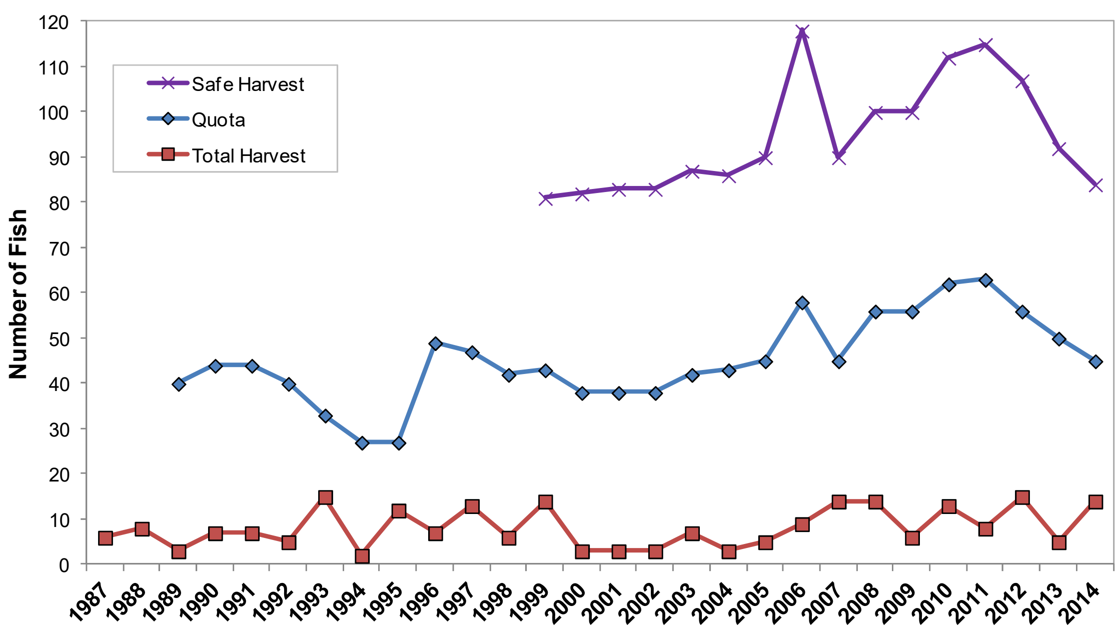


Figure 3.5-4. Total chain-wide muskellunge spear harvest statistics. Annual Native American muskellunge spear harvest statistics are summarized for 10 lakes in the Manitowish Waters Chain of Lakes. Data provided by WDNR & GLIFWC).

Overview of the Manitowish Waters Chain of Lakes Fishery

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).

Currently, 35 species of fish have been documented within the Manitowish Waters Chain of Lakes in WDNR or GLIFWC surveys. Three of these species, the greater redhorse (*Moxostoma valenciennesi*), pugnose shiner (*Notropis anogenus*), and the longear sunfish (*Lepomis megalotis*) are of special concern in Wisconsin. All three of these species have the listing of "threatened" within the state. The greater redhorse has been given a state rank of S3, which indicates it is rare or uncommon within the state (WDNR PUBL-ER-001 2011). 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 include the lake herring (*Cregonus artedii*) and the lake whitefish (*Coregonus clupeaformis*). Lake herring are found throughout the chain and are most commonly found in deeper water. Like herring, lake whitefish also prefer cooler, deeper water. Naturally sustaining inland populations of lake whitefish are rare within the United States, and also within Wisconsin. Two reports of whitefish are known; four fish found during WDNR surveys in 2011 and five fish found and reported anecdotally during a previous WDNR seining survey (WDNR 2012). Both occurrences were in Little Star Lake. Little Star, along with Manitowish Lake, top 60 feet of depth and are likely the only two lakes that could sustain whitefish within the Manitowish Waters Chain. Table 3.5-2 lists popular game fish that have been documented in the Manitowish Chain of Lakes during WDNR or GLIFWC surveys.

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. Once common in the Hudson Bay, Great Lakes-St Lawrence and Mississippi-Missouri drainage basins, this species has endured dramatic population declines due to habitat degredation and over-exploitation (Jackson et al., 2002). The sturgeon is a primitive looking, large fish that has a cultural significance to the states of Wisconsin and Michigan, who host 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.

Table 3.5-2. Common gamefish present in the Manitowish Chain of Lakes with 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.

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 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.

Manitowish Waters Chain of Lakes Substrate and Near Shore Habitat

Just as forest wildlife require proper trees and understory growth to flourish, fish prefer certain substrates and habitat types to nest, spawn, escape predators, and search for prey. Indeed, lakes with primarily a silty/soft substrate and much aquatic plants and coarse woody debris may produce a completely different fishery than lakes that are largely sandy 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, in other words, the eggs are left after spawning and not tended to by the parent fish. Muskellunge is one species that does not provide parental care to its eggs (Becker 1983). Muskellunge broadcast their eggs over woody debris and detritus, which can be found above sand or muck. This organic material suspends the eggs above the substrate, so the eggs are not buried in sediment and suffocate as a result. Walleye is another species that does not provide parental care to its eggs. Walleye preferentially spawn in areas with gravel or rock in places with moving water or wave action, which oxygenates the eggs and prevents them from getting buried in sediment. Fish that provide parental care are less selective of spawning substrates. Species such as bluegill tend to prefer a harder substrate such as rock, gravel or sandy areas if available, but have been found to spawn in muck as well.

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. Protecting valuable shoreland habitat and coarse woody debris is a way in which lake residents can enhance the fishery of the Manitowish Waters Chain of Lakes, in addition to working with WDNR fisheries biologists to create new habitat structure within the lake.

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 WDNR.

Project Phase	Lake	% Muck	% Sand	% Rock
Phase I - 2012	Island Lake*	62	26	12
	Rest Lake	35	60	5
	Papoose Bay	76	21	3
	Spider Lake	17	63	20
Phase II - 2013	Clear Lake	54	34	12
	Fawn Lake	87	13	0
Phase III – 2014	Alder Lake	31	61	8
	Wild Rice Lake	65	26	10
Phase IV – 2015	Little Star Lake			
	Manitowish Lake			
Phase V – 2016	Benson Lake			
	Stone Lake			
	Sturgeon Lake			
	Vance Lake			

**WDNR data, 2011*

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 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.

4.0 SUMMARY AND CONCLUSIONS (THIS WILL BE UPDATED IN FINAL PHASE)

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. While the plant has largely been kept under control through both herbicide applications and manual hand-removal efforts, it has been found in several of the lakes indicating it has a high potential to spread throughout the chain. Control of this plant is the center of discussion within the Rice Creek channel, where it currently can be found growing in the center of this channel, while a large, dense wild population of wild rice borders it on either shoreline. The colony is too large and too dense to target with hand-removal methods. Herbicide applications in this area have not been conducted due to the concern over damage to the wild rice plants, an edible and also highly culturally significant species to Native American tribes. Manitowish Waters Chain stakeholders, understanding of the issues surrounding control of this population, will remain diligent in seeking a solution to controlling curly-leaf pondweed in this area while not compromising native species.

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. Lakes with added attention or specific issues that were brought forth during this study will have their own Lake Specific Implementation Plan which is located at the end of each individual lake section.

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 hand 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,715.543.8400, mwchair@centurytel.net)	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	Aquatic Ecologist (Celeste Hockings, 715.588.4163)	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 (Steve Budnik, 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 AIS Coordinator	AIS Coordinator (Cathy Higley, 715.479.3738, cahigl@co.vilas.wi.us)	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.
Vilas County Land and Water Conservation Department	Lake Conservation Specialist (Mariquita (Quita) Sheehan, 715.479.3721, mashee@co.vilas.wi.us)	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 ,– 715.365.8937)	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 (Jane Malischke, 715.635.4062, Jane.Malischke@Wisconsin.gov)	Oversees financial aspects of grants.	As needed.	Information on grant financials and reimbursement, CBCW grant applications.
	Water Guard (John Preuss, 715.416.2482, john.preuss@wisconsin.gov)	Perform law enforcement duties to protect WI waters especially in regards to compliance with laws relating to AIS.	As needed.	Contact regarding violations in AIS/water laws. Inform of new AIS locations and seek assistance in AIS education as needed.
	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.
	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 Couty Sheriff Dept.	Manitowish Waters Chain of Lakes Water Safety Patrol Officer (Dan Cardinal, at 1.800.472.7290 non-emergency, 911 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	Citizens Lake Monitoring Network (Sandra Wickman, 715.365.8951) (Paul Skawinski, 715.346.4853, paul.skawinski@uwsp.edu)	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.
Wisconsin Lakes	Lakes 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.	

Management Action:	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 volunteers per lake to be involved in the Lake Captain and Deckhand Program and other volunteer opportunities that may arise. Lake Captains, Deckhands, and the volunteer coordinator should be friendly, outgoing persons who are able to engage people.
4.	MWLA Board of Directors, Lake Captains and Deckhands 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 9.2 miles (19%) of the Manitowish Waters Chain of Lakes shoreline (Phase I-III lakes) 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. 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

<u>Management Action:</u>	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 (28.6 miles or 58% of shoreline on Phase I-III 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 Action:	Investigate algal blooms on the Manitowish Waters Chain.
Timeframe:	Initiate 2014.
Facilitator:	NLDC; MWLA Board of Directors
Description:	The need for the management action below will revisited by the MWLA Board in 2018
Action Steps:	
1.	MWLA Board of Directors appoint volunteer as point-of-contact for algae issues.
2.	Volunteer establishes contact with NLDC should algae issues become present.

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. <u>Lake stewardship</u>: 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. <u>Recreation and safety</u>: 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. <u>Lake ecology</u>: 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. <u>Political events</u>: 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, 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 consider conducting 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)." 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 conducting 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.
Action Steps:	
	See description above as this is an ongoing program

Management Action:	Work with management partners to monitor curly-leaf pondweed and wild rice interactions within the Manitowish Waters Chain of Lakes while assessing future management options.
	This management action will be reviewed in 2018.
Timeframe:	Continuation of current effort.
Facilitator:	NLDC
Description:	Wild rice is an ecologically beneficial and culturally significant plant species that is found in areas of the Manitowish Waters Chain of Lakes. Though this species is good for the aquatic environment, aesthetics and recreational harvesting, it has been demonstrated to be sensitive to herbicide exposure, particularly in its early life stage. It is not currently believed that reproductive capacity would be impacted by herbicide treatments. Regardless, as discussed in the Aquatic Plant Section, this has posed a problem in Rice Creek and areas of Island Lake where curly-leaf pondweed and wild rice coexist. The Voigt Intertribal Task Force is a committee of representatives from each of the Ojibwe tribes that recommend policies relating to treaty rights within the ceded territories. Concerned with the potential collateral impacts to the wild rice in association with the early-season herbicide treatments targeting curly-leaf pondweed, the Voigt Task Force has objected to conducting this management strategy within Rice Creek and areas of Island Lake. Though cultural and ecological concerns exist with regards to treating curly-leaf pondweed in areas known to hold wild rice, the curly-leaf pondweed population in these areas also poses considerable concerns. Within Rice Creek, curly-leaf pondweed has reached great densities which could cause displacement of native plants (potentially including wild rice), cause recreational/navigational impairment, and act as a phosphorus and turion source that has implications for downstream waters. While the MWLA, NLDC, Voigt Intertribal Task Force, and

		WDNR are aware of both sides of these issues, a management solution has yet to be identified. The TAISP wishes to continue the conversation on this matter with other management entities, including the WDNR and Voigt Intertribal Task Force. Additionally, they would like to have a better understanding of the relationship that exists between wild rice and curly-leaf pondweed. It is not known currently which of these two species has the competitive advantage over the other; will curly-leaf pondweed displace wild rice, will wild rice populations hold curly-leaf pondweed from extending its population, or will the two intermingle and coexist? Finally, the TAISP would like to receive updates from the WDNR on discussions, developments and meetings that are occurring with regards to aquatic invasive species management in wild-rice waters. In an effort to explore possibilities in management and continue to learn about the dynamics between the two aforementioned species, the NLDC will: 1. Ask regional WDNR officials for an annual update on progress (meetings, discussions, research projects, etc.) that has occurred regarding the subject of aquatic invasive species management in wild-rice waters. 2. Communicate with the Lac du Flambeau Tribe on matters pertaining to general lake management, aquatic invasive species and wild rice on the Manitowish Waters Chain of Lakes as needed. 3. Continue wild rice and curly-leaf pondweed monitoring in Rice Creek and southeastern Island Lake on an annual basis to gather spatial data on population extents and densities. Monitoring may be completed by any entity capable of reproducing the methodology described in the Aquatic Plant Section. The curly-leaf pondweed infestation is believed to be fairly recent, so population dynamics of this species and its relationship with wild rice is unknown. Year-to-year monitoring of the populations may shed light on the interaction between these two species. Questions to be answered include, 1) Are curly-leaf pondweed and wild-rice occupying separate niches, with little or some overlap? 2) Is one plant species, curly-leaf pondweed or wild rice, out-competing the other for resources such as space?
Action Steps:		
	1.	NLDC acts as liaison between WDNR and MWLA/ Towns of Manitowish Waters and Boulder Junction
	2.	NLDC familiarizes self with matter at hand, corresponds with WDNR lakes coordinator Kevin Gauthier as necessary.

3.	TAISP retains qualified professional assistance to spatially map wild rice and curly-leaf pondweed within Rice Creek and Island Lake.
4.	Data collected on species interactions shared with management entities for use in discussion.

Management Action:	Reduce transport of curly-leaf pondweed from dense colony areas via watercraft.
Timeframe:	Begin summer of 2014.
Facilitator:	NLDC
Description:	With a large, dense colony of curly-leaf pondweed existing in the Rice Creek channel, the NLDC and MWLA have concerns about the invasive plant spreading through natural means to other regions of the chain. Additionally, there is concern about watercraft catching fragments on motor props, anchors, etc. and providing a secondary means of transport. This of course could happen without the knowledge of watercraft operators, who may be diligent about removing plant fragments between lakes at a public launch location but may not be aware of transport issues while on the same waterbody. The NLDC and MWLA are interested in placement of educational signage/buoys within the Rice Creek channel in order to make watercraft operators aware of this issue. A WDNR permit would be required, of which would largely be determined by the type of educational sign/buoy that was created. For example, waterway marker buoys are permitted through a different process (and different WDNR staff member) than a more permanent sign that is created and fixed on a post. Contact information for the WDNR staff member overseeing each sign type is included below: Waterway marker buoy permit staff: Jeffrey Dauterman, Recreational Safety Warden (715)-623-4190 Miscellaneous structure permit staff: Kyle McLaughlin, Water Management Specialist (715)-365-8991 More information on waterway signage may be viewed on the WDNR website (http://dnr.wi.gov/topic/boat/ordinances.html.). At a minimum, a seasonal education sign would be in place during high traffic times of the year (Memorial Day weekend through Labor Day weekend). The text of the sign would be drafted by NLDC and MWLA personnel, though insight and approval from Vilas County AIS Coordinator Cathy Higley and WDNR staff would be encouraged.
Action Steps:	

1.	NLDC and MWLA members confer on signage text and structure type.
2.	Appropriate WDNR staff member contacted for permit procedures.
3.	Signage is installed within Rice Creek according to WDNR permit specifications and WDNR waterway markers guidelines (available via the aforementioned weblink - PUB-LE-317-2008). Maintenance and removal (applicable for seasonal buoys or signs) overseen by NLDC staff according to the permit and posted guidelines.
4.	Costs may be included within management planning grant or within a separate small scale WDNR grant.

Management Action:	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 Freckman 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.
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:	Continue locally-based efforts including aquatic invasive species monitoring through the Lake Captain and Deckhand Program and watercraft inspections.
Timeframe:	Continuation of current effort.
Facilitator:	MWLA and NLDC
Description:	Across Wisconsin, many lake groups are both working to control and prevent introduction of aquatic invasive species in their lakes. In many cases, volunteer efforts have been primary in keeping a lake free of invasive species. Volunteer efforts have also resulted in the early find of an aquatic invasive species' introduction. Finally, many volunteer hours have been logged in hand-harvesting invasive aquatic plants, or removing invasive animals from a lake such as carp or rusty crayfish. Moving forward, the influence of volunteer-based monitoring and action will be essential in preserving Wisconsin's lakes. The Manitowish Waters Chain of Lakes is fortunate to host a healthy partnership with the Towns of Manitowish Waters and Boulder Junction, the NLDC and MWLA. Through this partnership, a coalition called the Town Aquatic Invasive Species Partnership (TAISP) was formed. The TAISP has worked to address threats posed by aquatic invasive species through education, prevention and control. The Manitowish Waters Chain of Lakes has benefited from this partnership

		through a thorough lake monitoring program as well as inclusion in the Clean Boats Clean Waters program. Additional actions include a project to control purple loosestrife through raising and application of *Galerucella* spp. beetles and hand removal, aquatic invasive species workshops and partnering with local schools to introduce a hands-on aquatic invasive species experience. This pioneering effort has kept many invasives out of the highly used chain of lakes and assisted in finding early infestations. The TAISP will need to maintain its diligence in educating Manitowish Waters Chain of Lakes visitors as well as continue monitoring the chain lakes for invasive species. Though other programs than those previously mentioned may be initiated in the future, the TAISP will continue two programs – Clean Boats Clean Waters and the chain-wide aquatic invasive species education and monitoring programs – as these have been highly successful as well as visible within the Town of Manitowish Waters.
Action Steps:		
1.	NLDC staff and volunteers from the MWLA continue to update skills through trainings by Vilas County Aquatic Invasive Species Coordinator Cathy Higley.	
2.	Conduct aquatic invasive species monitoring during peak growth times for species of interest.	
3.	Continue Clean Boats Clean Waters inspections during weekends or other high use times.	
4.	Continue to report results of programs to WDNR and TAISP.	
5.	Promote enlistment of volunteers in coordination with Management Goal 1.	

<u>Management Action:</u>	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. Eventually, the MWLA hopes to add at least three cribs to each lake in the chain.

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: Continue the development of comprehensive management plans for the Manitowish Waters Chain of Lakes waterbodies.

Timeframe: In progress.

Facilitator: NLDC and MWLA

Grant: Lake Management Protection Grant in Diagnostic/Feasibility Studies category.

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 develop comprehensive management plans for each lake in the chain. This phased project will proceed in the manner outlined within Map 1. These studies may be completed with the assistance of state funds through the WDNR's Lake Management Protection Grant program.

Action Steps:

1. Apply for WDNR grants annually to continue state financial assistance in management planning projects.
2. Retain qualified consultant to conduct science-based studies and facilitate management planning.

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

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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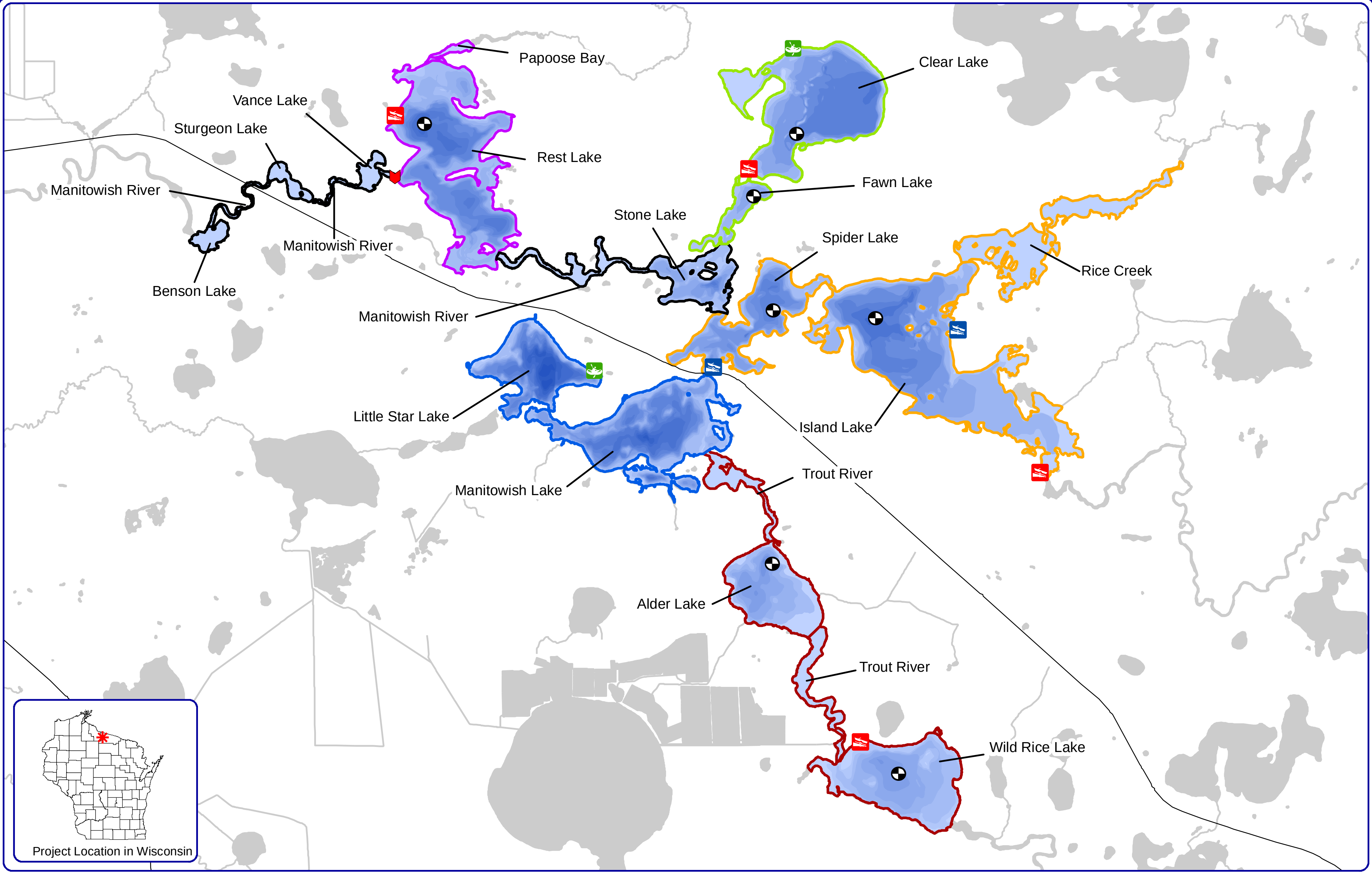


5,750
Feet

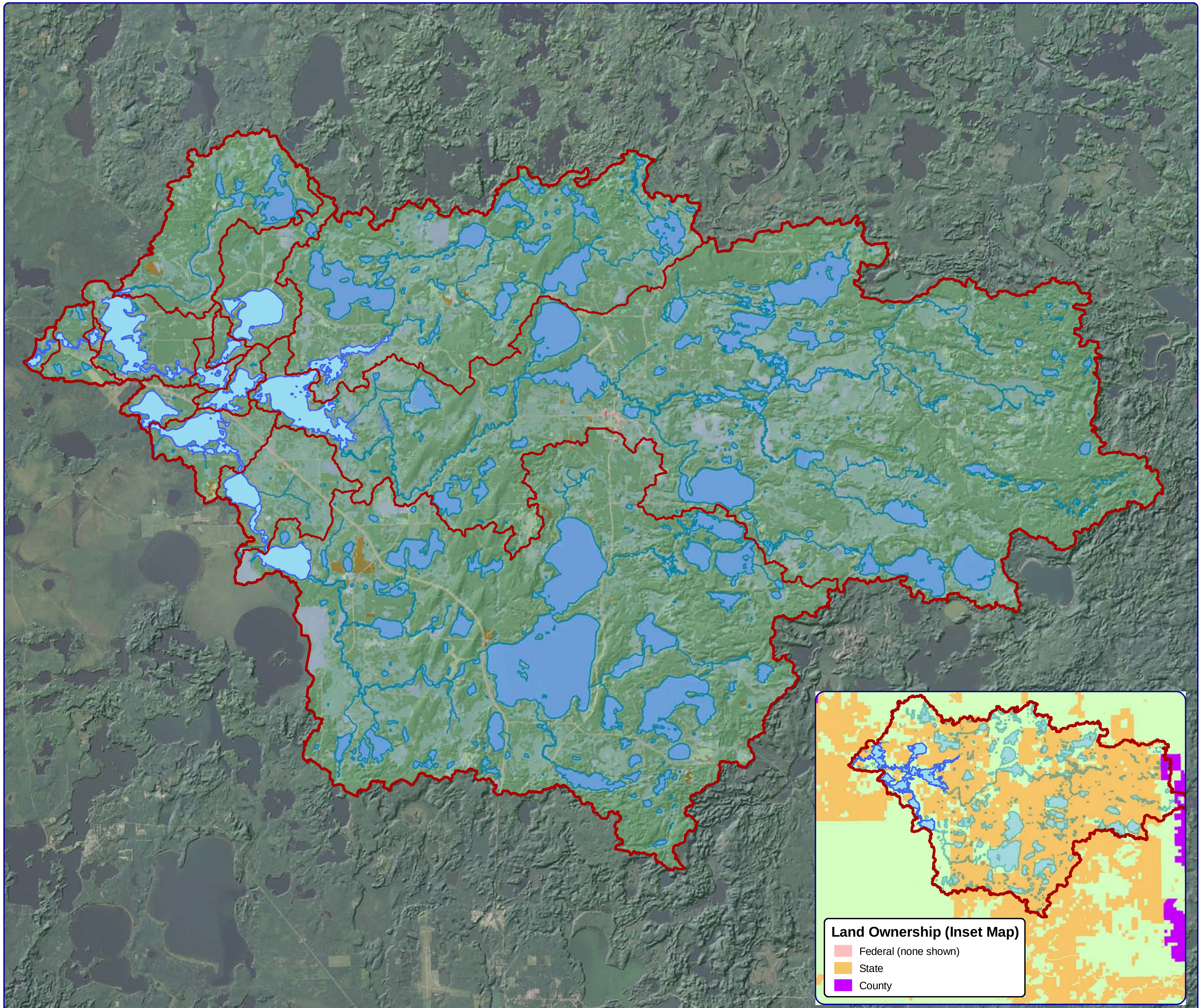
Onterra LLC
Lake Management Planning
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: WDNR - digitized by Onterra
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

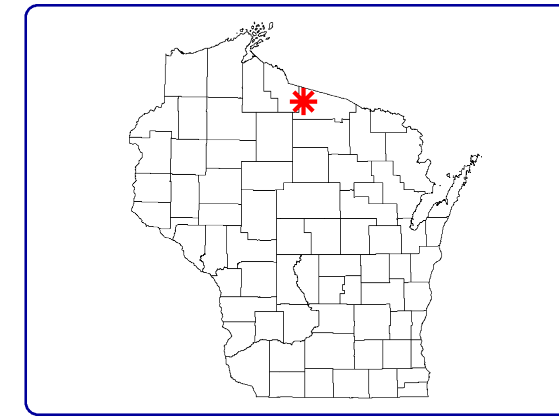


Map 2

Manitowish Waters Chain of Lakes

Vilas County, Wisconsin

Watershed Boundaries & Land Cover Types



Project Location in Wisconsin

Legend

Watershed Boundary

Land Cover Types

- Forest
- Forested Wetlands
- Wetlands
- Manitowish Chain of Lakes
- Open Water
- River/Stream
- Pasture/Grass
- Rural Open Space
- Row Crops
- Rural Residential
- Urban - Medium Density
- Urban - High Density

N W E S

2.25 Miles

Sources:
Watershed: WDNR and Onterra
Landcover: NCLD, 2006
Hydro: WDNR
Orthophotography: NAIP, 2010
Map Date: September 24, 2013
Filename: Map2_Manitowish_WS.mxd

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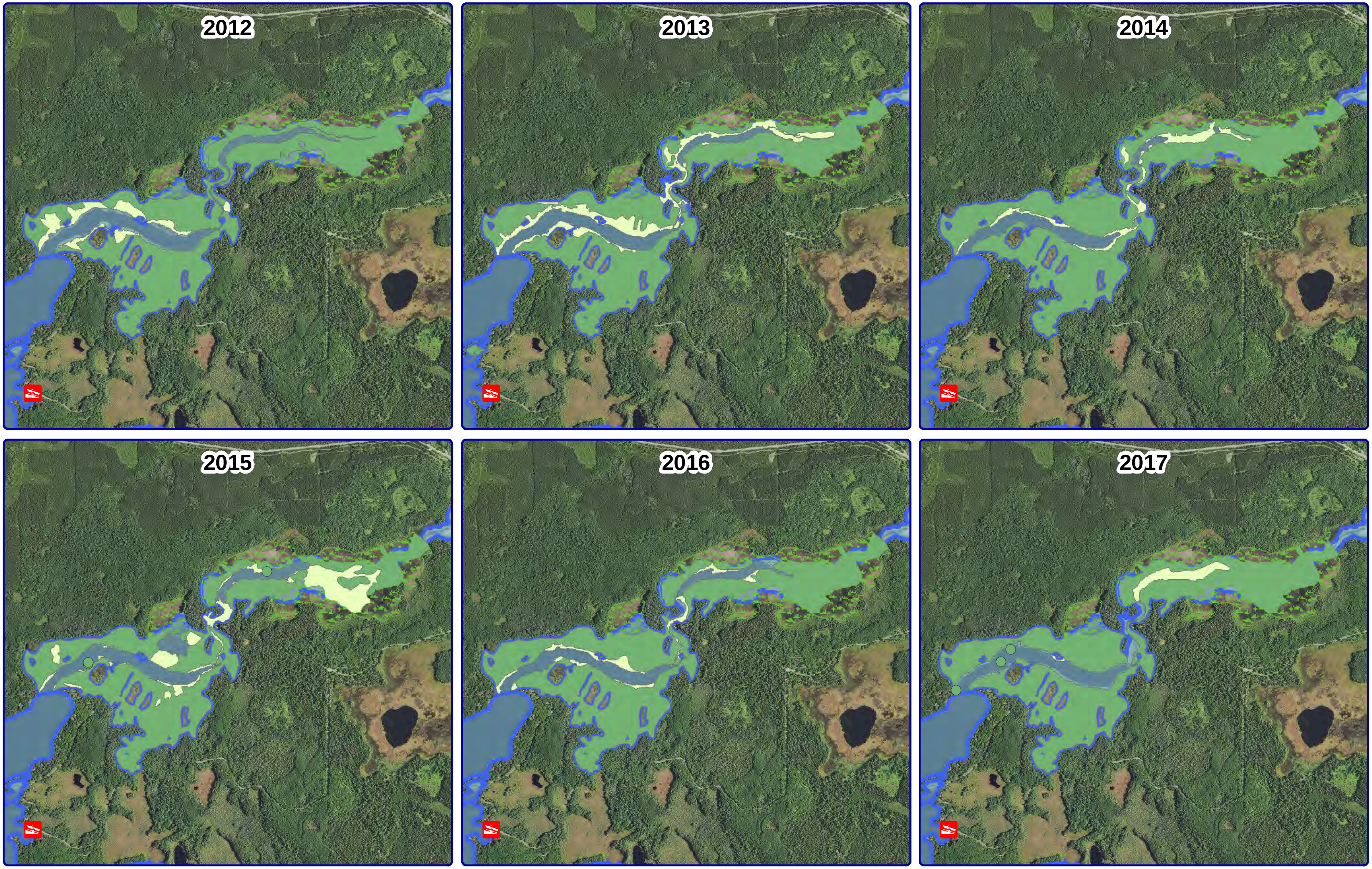

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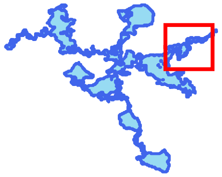
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_RiceCreek_WildRice_2012-2017.mxd



Inset Map Location in red

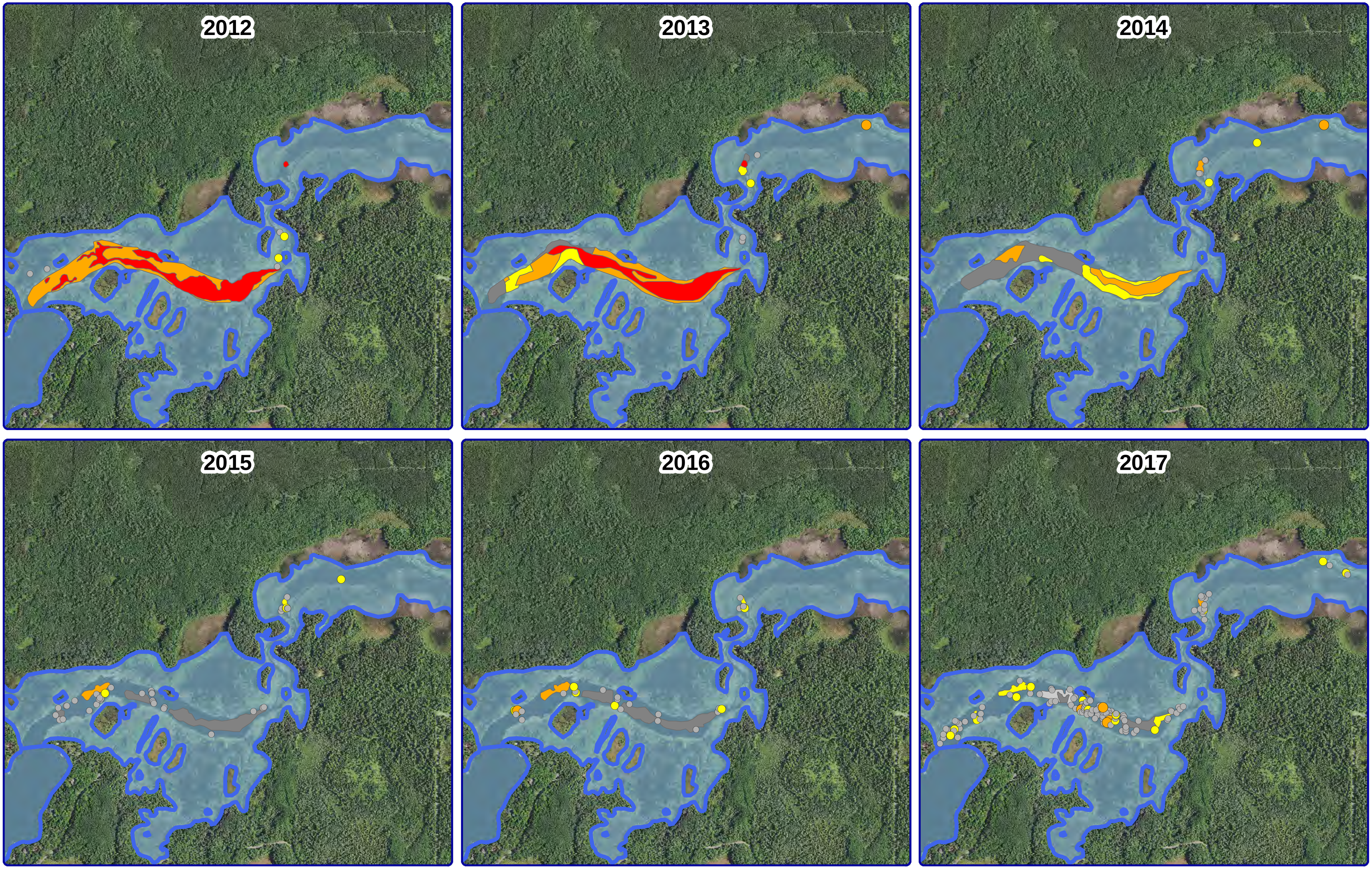
Legend

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

Map 3

Rice Creek
Vilas County, Wisconsin

Rice Creek Wild Rice Communities



N
W E
S

1,900

Feet

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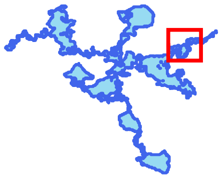
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_RiceCreek_CLP_2012-2017.mxd



Inset Map Location in red

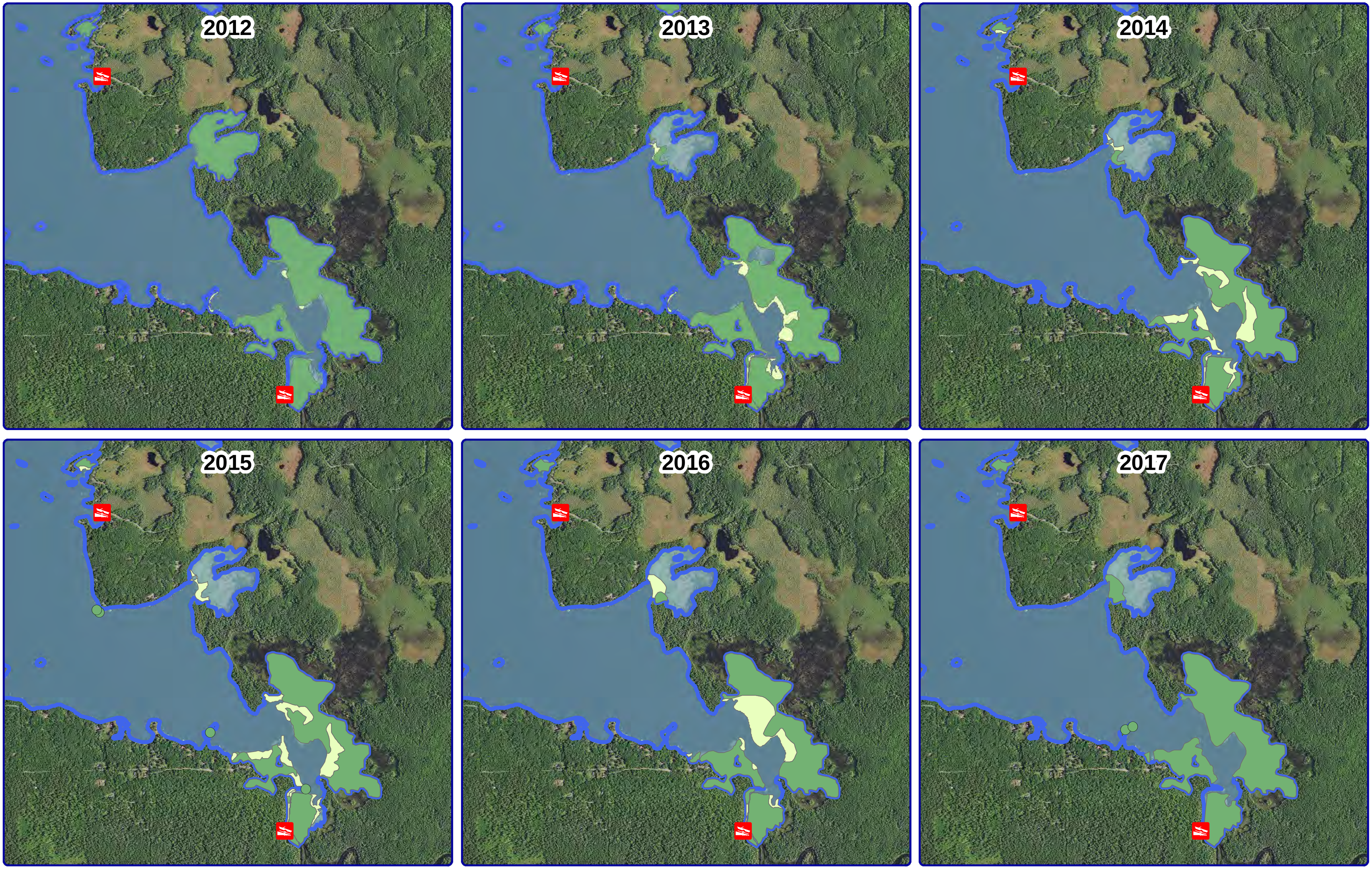
Legend

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

Map 4

Rice Creek
Vilas County, Wisconsin

Rice Creek CLP
Peak-Growth Mapping



N
W E
S

2,500
Feet

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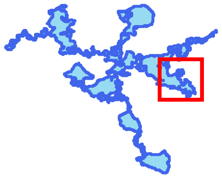
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_Island_WildRice_2012-2017.mxd

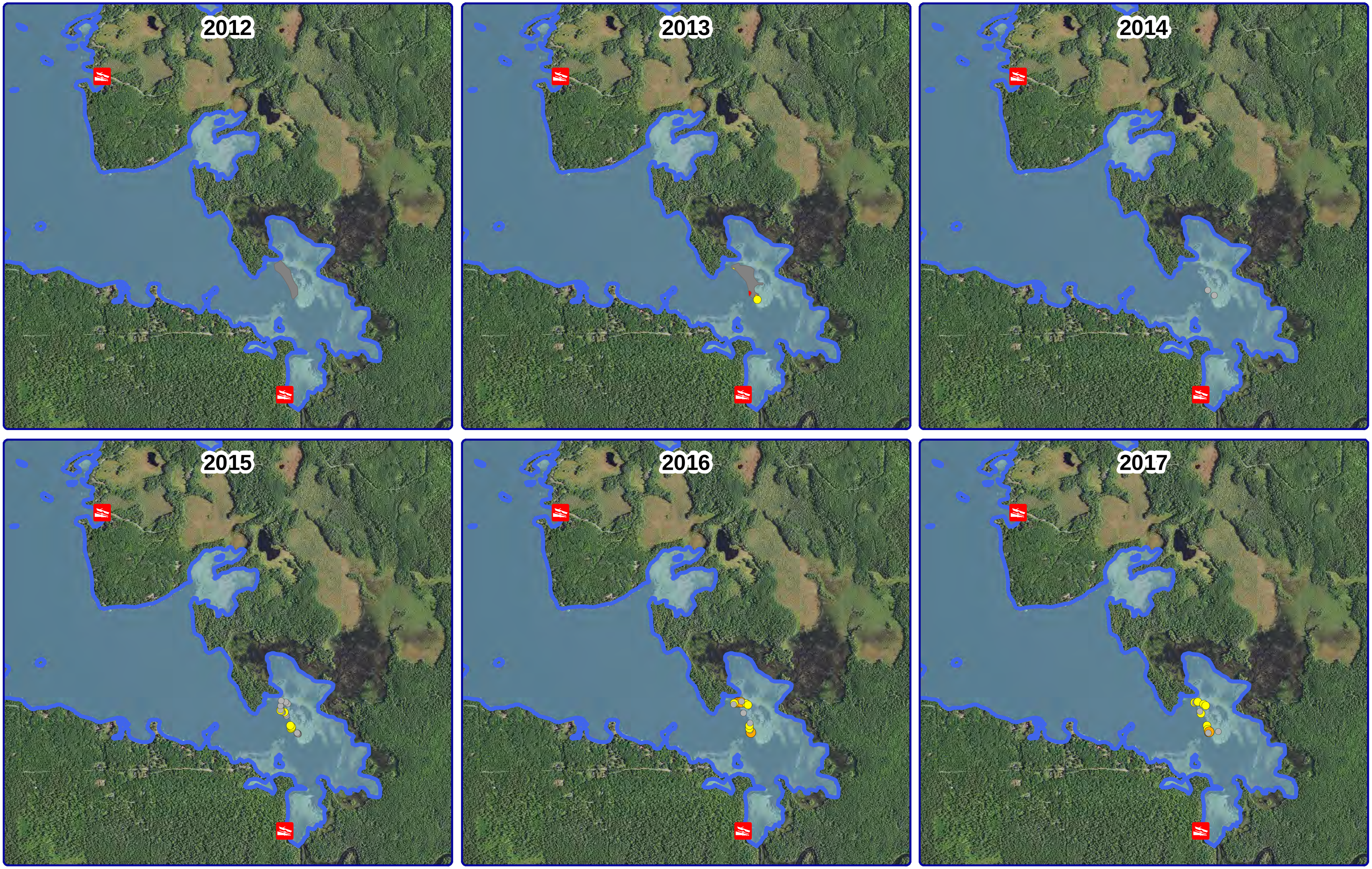

Inset Map Location in red

Legend

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

Map 5
Island Lake
Vilas County, Wisconsin

Island Lake Wild Rice Communities



N
W E
S

2,500
Feet

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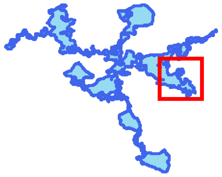
Sources:
Hydro: WDNR
Orthophotography: NAIP, 2015
Aquatic Plants: Onterra, 2012-2017
Map Date: January 2, 2018
Filename: Manitowish_Island_CLP_2012-2017.mxd


Inset Map Location in red

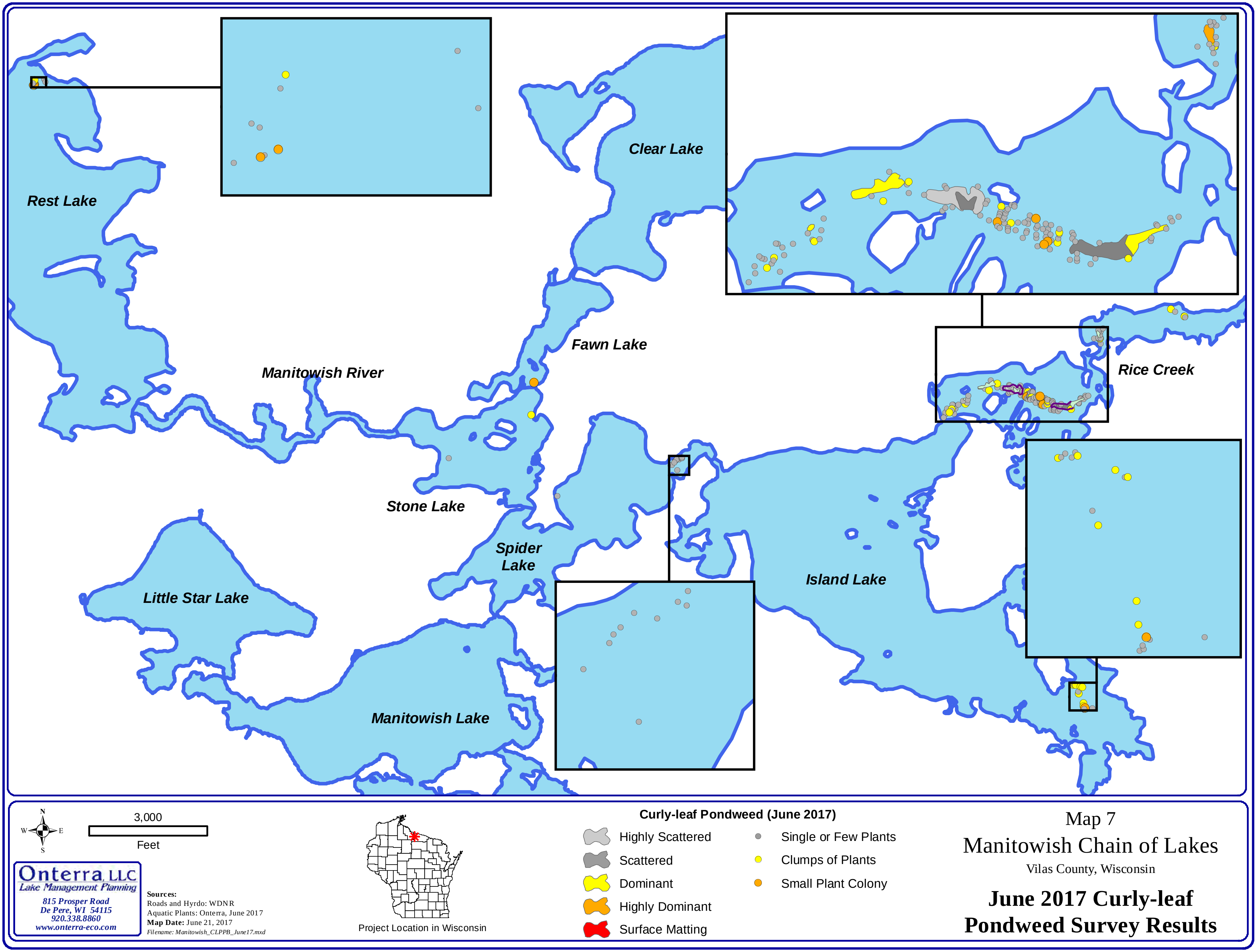
Legend

- 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



Map 7
Manitowish Chain of Lakes
Vilas County, Wisconsin

June 2017 Curly-leaf Pondweed Survey Results