Manitowish Waters Chain

Vilas County, Wisconsin

Comprehensive Management Plan Phase I

January 2016

Sponsored by:

North Lakeland Discovery Center

Wisconsin Department of Natural Resources
Grant Program

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

Onterra, LLC
Lake Management Planning

Manitowish Waters Chain of Lakes Comprehensive Management Plan Phase I

Vilas County, Wisconsin

January 2016

Created by: Dan Cibulka, Brenton Butterfield and Tim Hoyman
Onterra, LLC
De Pere, WI

Funded by: North Lakeland Discovery Center
Manitowish Waters Lake Association
Wisconsin Dept. of Natural Resources Lakes Grant Program

Acknowledgements

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:

Anne Kretschmann	Azael Meza
Tom Joseph	Karen Dixon

Organization

Town of Manitowish Waters	Town of Boulder Junction
Manitowish Waters Lake Association	Lac du Flambeau Tribe

Management Plan Collaborators and Reviewers

Kevin Gauthier (WDNR)	Lisa David (GLIFWC)	Michele Woodford (WDNR)
Jim Kreitlow (WDNR)	Tim Plude (WDNR)	Zach Lawson (WDNR)

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

Note: Individual lake maps are included within each individual lake section

APPENDICES

1.0 INTRODUCTION

The Manitowish Waters Chain of Lakes consists of 10 lakes totaling over 4,200 acres located in and just east of the Town of Manitowish Waters in Vilas County, and three additional lakes located below the Rest Lake Dam (Map 1). The chain is fed by a series of streams, including Papoose Creek, Rice Creek, Island Creek, the Manitowish River and Trout River. Downstream of the Rest Lake Dam, the Manitowish River runs into Iron County where it becomes one of two main tributaries to the 13,500+ acre Turtle Flambeau Flowage. The Rest Lake Dam was first constructed in 1887 by the Chippewa Lumber and Boom Company. Its construction was implemented then to store water for the purpose of floating logs downstream. Eventually, other purposes were recognized (flood control, recreation, hydropower, etc.). In 1939, the Public Service Commission of Wisconsin approved an operating order that allowed for a winter (November 1 to spring thaw) drawdown to a minimum of 5’0” (Public Service Commission, 1939). Summer water levels were raised to between 7’3”-8’6”, while downstream flows were to be maintained at 40 cfs (cubic feet per second). At the time of this writing, the Wisconsin Department of Natural Resources (WDNR) is considering alterations of this order to a more natural flow regime.

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 promote stewardship of the region’s natural and cultural resources. 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 transversing 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’s 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 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 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. 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.

Table 1.0-1. Manitowish Waters Chain Lakes phased management timeline. Table outlines the approximate schedule and major tasks to be completed during the multi-phased project.

Phase / Year	Lakes Studied	Other Components
Phase I (2012)	Rest Lake / Papoose Bay Island Lake Rice Creek Spider Lake	NLDC AIS Education and Training
Phase II (2013)	Clear Lake Fawn Lake	NLDC AIS Education and Training
Phase III (2014)	Wild Rice Lake Alder Lake Trout River	NLDC AIS Education and Training Chain-wide Stakeholder Survey
2015	*Project not funded*	n/a
Phase IV (2016)	Manitowish Lake Little Star Lake	NLDC AIS Education and Training
Phase V (2017)	Stone Lake Vance Lake Sturgeon Lake Benson Lake Manitowish River	NLDC AIS Education and Training Chain-wide Watershed Modeling

Note: This chain-wide management plan and individual lake plans will serve as the deliverable for Phase I 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

Kick-off Meeting

On July 28, 2012, Onterra ecologist Tim Hoyman delivered the project Kick-off presentation at the MWLA's annual meeting at the NLDC's facility in Manitowish Waters. Mr. Hoyman described the chain-wide management planning project, including how it would be conducted and what exactly would be studied. Following the presentation, Mr. Hoyman answered many questions on general lake ecology as well as curly-leaf pondweed management and water quality concerns.

Project Update Meeting

On July 27, 2013, Onterra Ecologist Dan Cibulka attended the MWLA's annual meeting to provide an update on the Manitowish Waters Chain of Lakes Management Planning Project. Mr. Cibulka's presentation highlighted the grants the NLDC had been awarded, and what grants would be pursued next. Discussion of the water quality, aquatic plant, shoreland habitat and other studies were had as well. The presentation concluded with detailed maps depicting the results of curly-leaf pondweed mapping and treatments.

Planning Meeting I

Planning meetings were conducted periodically through the chain-wide study, and focused upon the lakes involved with each current phase. On October 21, 2013, Dan Cibulka and Eddie Heath met with NLDC staff, MWLA Board of Directors and WDNR Lakes Coordinator Kevin Gauthier to discuss the results of studies that had taken place on the Phase I lakes as well as chain-wide curly-leaf pondweed monitoring. During this five hour meeting, all project components were discussed extensively. Many questions were answered by Mr. Cibulka and Mr. Heath pertaining to issues such as aquatic invasive species, nutrient concentrations within the lakes, and navigation and safety. The discussions held at this meeting were recorded for integration within the Planning Project's Implementation Plan.

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. On October 14, 2015, the WDNR supplied comments from several staff reviewers on the Phase I management plan. These comments were integrated within this document in December of 2015, and a final Phase I management plan was produced in January of 2016.

With the draft plan already meeting the approval of the project's planning committee, the final Phase I management plan would be introduced to the TAISP partners (NLDC, MWLA, Town Boards of Boulder Junction and Manitowish Waters) for a formal adoption vote during meetings held in January 2016.

Stakeholder Survey

This space reserved for discussion of the Stakeholder Survey results, which will be completed during Phase III (2014) of this multi-phased project.

Survey results will be displayed 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 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 lakes.

While no reasonable and efficient control strategy exists for several of the species on Table 2.0-1 (banded and Chinese mystery snails and rusty crayfish), several effective methods have been utilized for control of curly-leaf pondweed and purple loosestrife. For the Manitowish Waters Chain of Lakes in which aquatic invasive plants are present, the history and management strategy for each is discussed further within that lake's Aquatic Plant Section and Implementation Plan.

Table 2.0-1. Aquatic Invasive Species located on the Manitowish Waters Chain 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)
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)
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 epiliminion 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 Phase I Manitowish Waters Chain lakes are all fairly deep (they stratify during the growing season). Furthermore, they are part of a lowland drainage system. Therefore, these lakes may be classified as Class 5 (deep, lowland drainage) lakes.

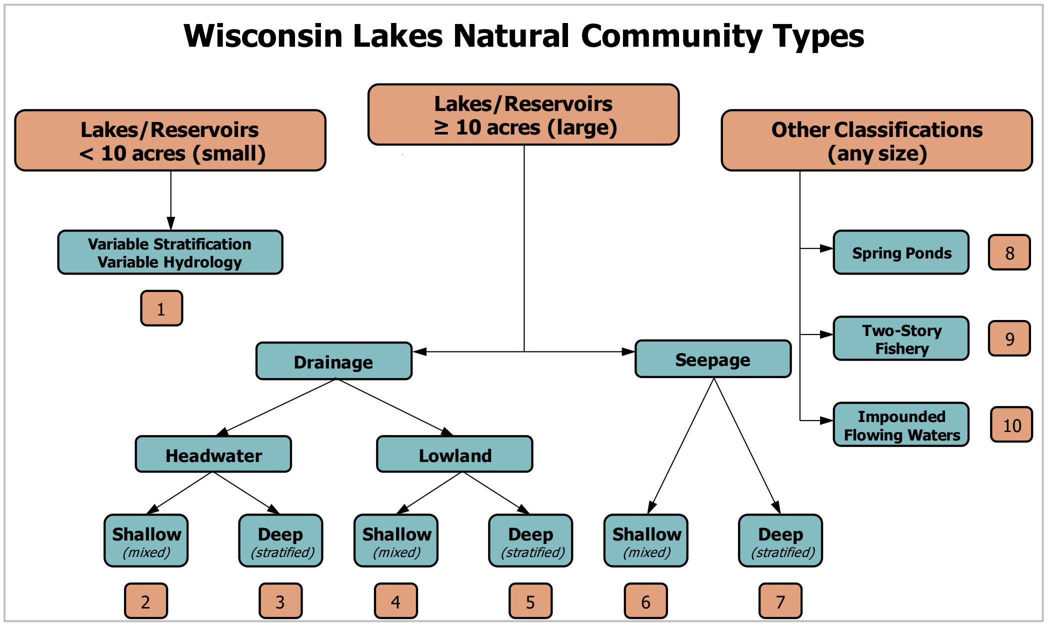


Figure 3.1-1. Wisconsin Lake Natural Community classifications. Adapted from WDNR 2013.

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 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.

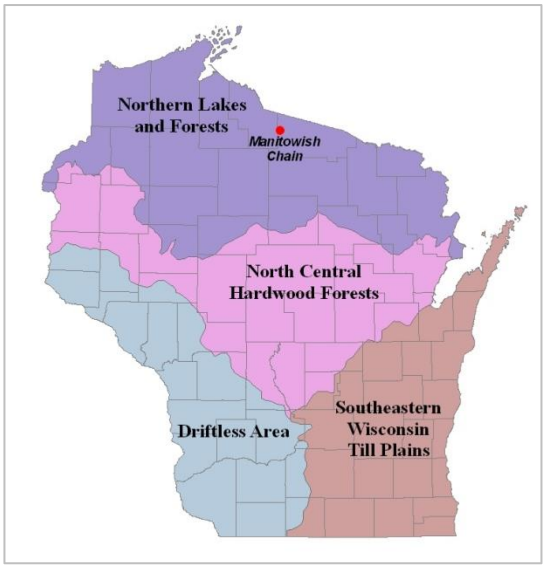


Figure 3.1-2. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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 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.

Onterra staff collected water quality samples and monitored Secchi disk clarity on each Manitowish Waters Chain 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.

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 lakes, total phosphorus summer averages ranged between 14.3 and 17.3 µg/L (Figure 3.1-3). These values rank well when compared to the median value for similar lakes (deep, lowland drainage 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 Manitowish Waters Chain 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 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 a healthy lake system.

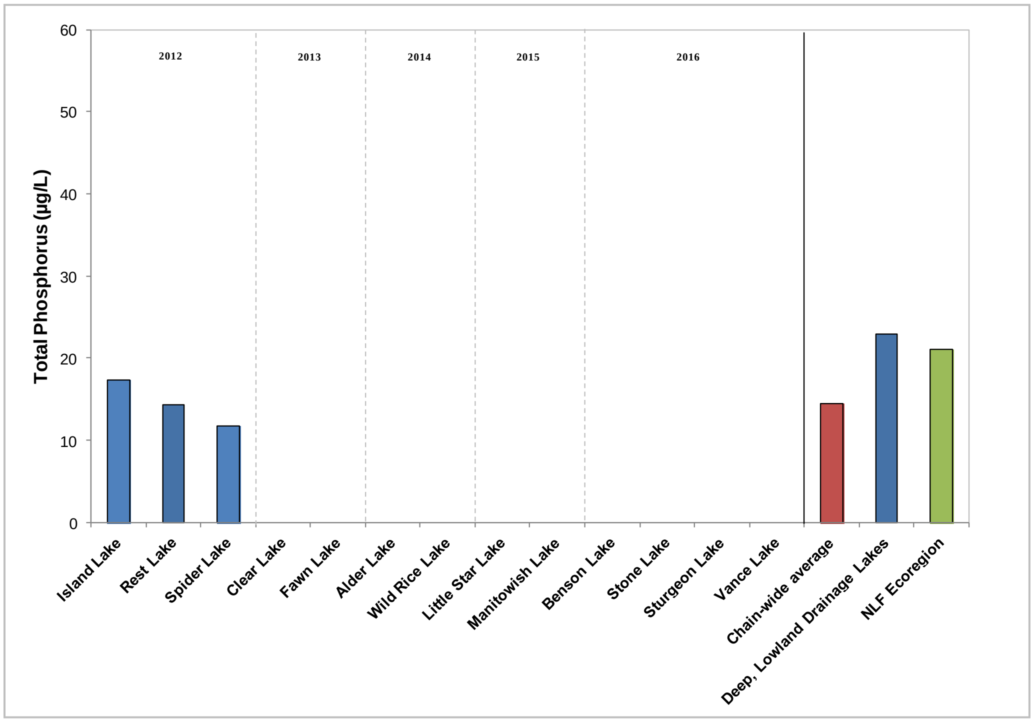


Figure 3.1-3. Manitowish Waters Chain of Lakes and comparable lakes total phosphorus concentrations. Mean values calculated with summer month surface sample data.

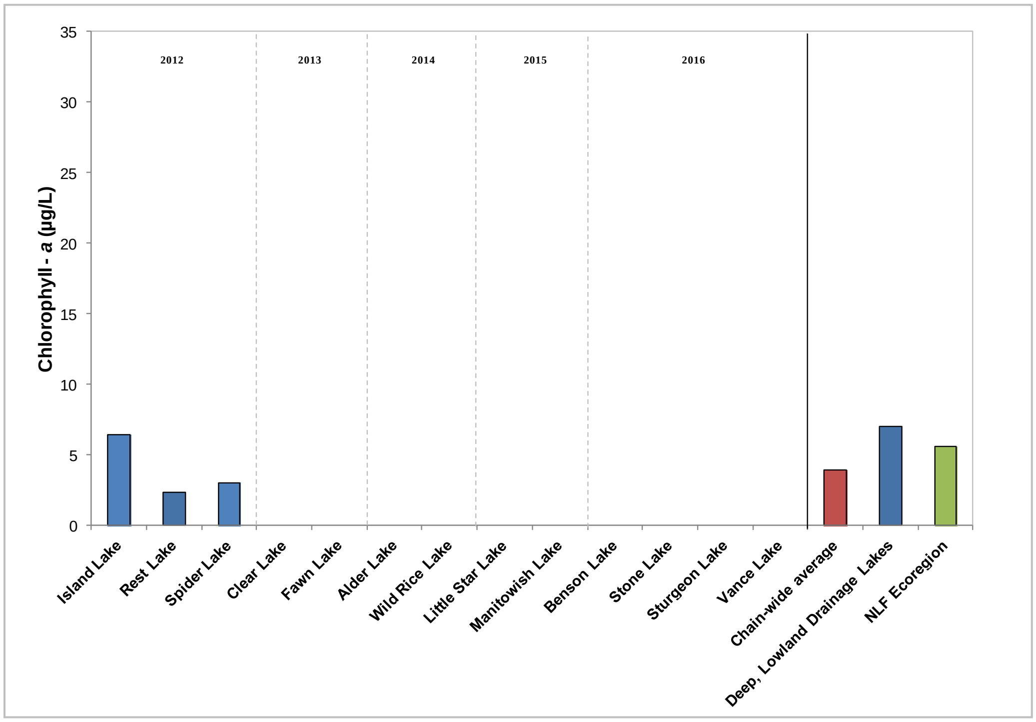


Figure 3.1-4. Manitowish Waters Chain of Lakes and comparable lakes chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data.

Average summer Secchi disk clarity ranged from 8.2 feet to 10.5 feet deep in the Manitowish Waters Chain lakes (Figure 3.1-5). The median value for Secchi disk clarity in deep, lowland drainage lakes across the state is 8.5 feet; Island Lake falls just under this value while Rest and Spider Lake exceed this value by two feet. Lakes in the Northern Lakes and Forests ecoregion are known for their clarity, so the median value for this region is 8.9 feet. While the Phase I lakes fall slightly short of this regional value, the WDNR's WisCALM characterizes any lake that has an average summer Secchi disk value of over 7.7 feet as being in an "excellent" category. Therefore, all the Phase I Manitowish Waters Chain lakes may be considered to have excellent water clarity.

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.

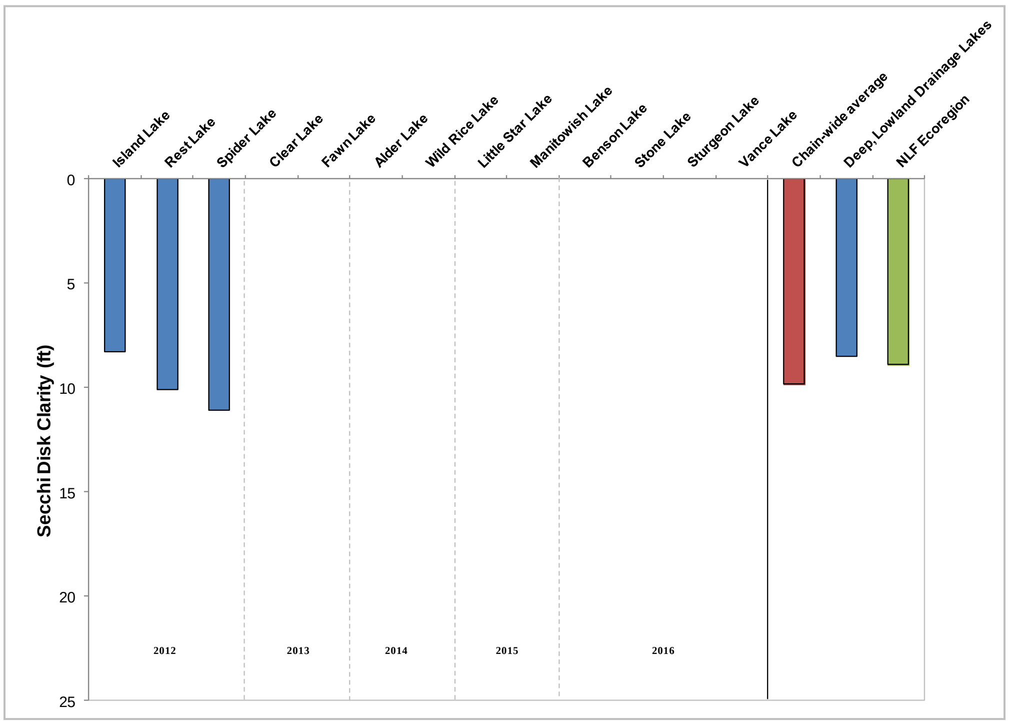


Figure 3.1-5. Manitowish Waters Chain of Lakes and comparable lakes Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Plant Nutrient of Manitowish Waters Chain of Lakes

Using average 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 indicates that all of the lakes of the Manitowish Waters Chain of Lakes are indeed 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			
	Fawn Lake			
Phase III – 2014	Alder Lake			
	Wild Rice Lake			
Phase IV – 2015	Little Star Lake			
	Manitowish Lake			
Phase V – 2016	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.

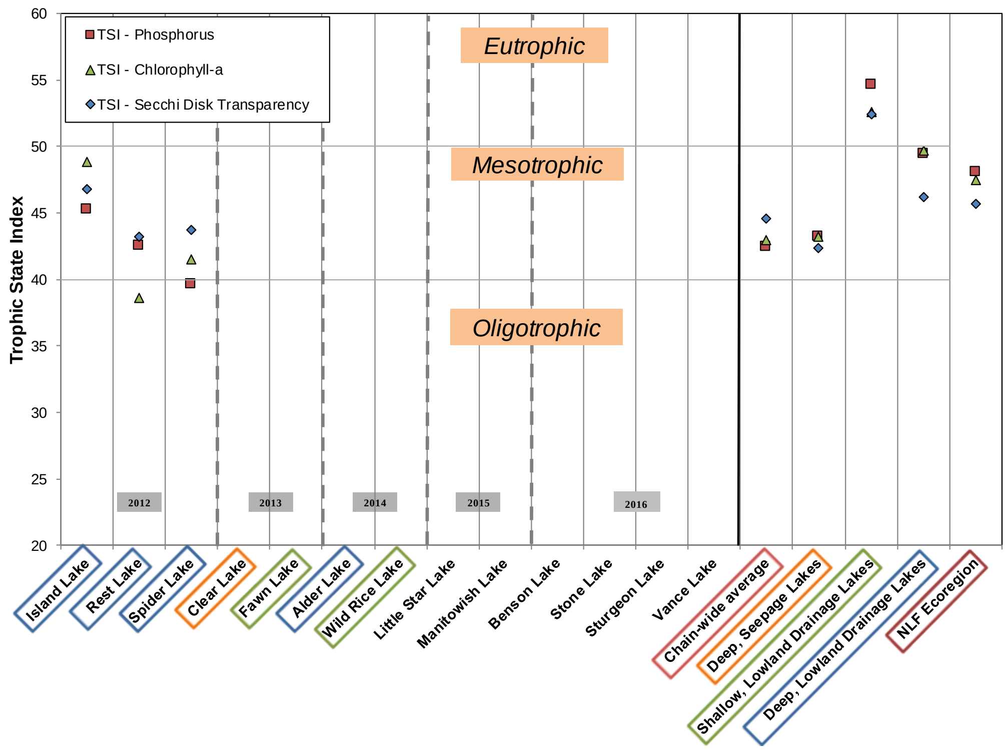


Figure 3.1-6. Manitowish Waters Chain of Lakes and comparable lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

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 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, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Figure 3.1-7). The values seen within the chain lakes are near neutral and are normal for Wisconsin lakes.

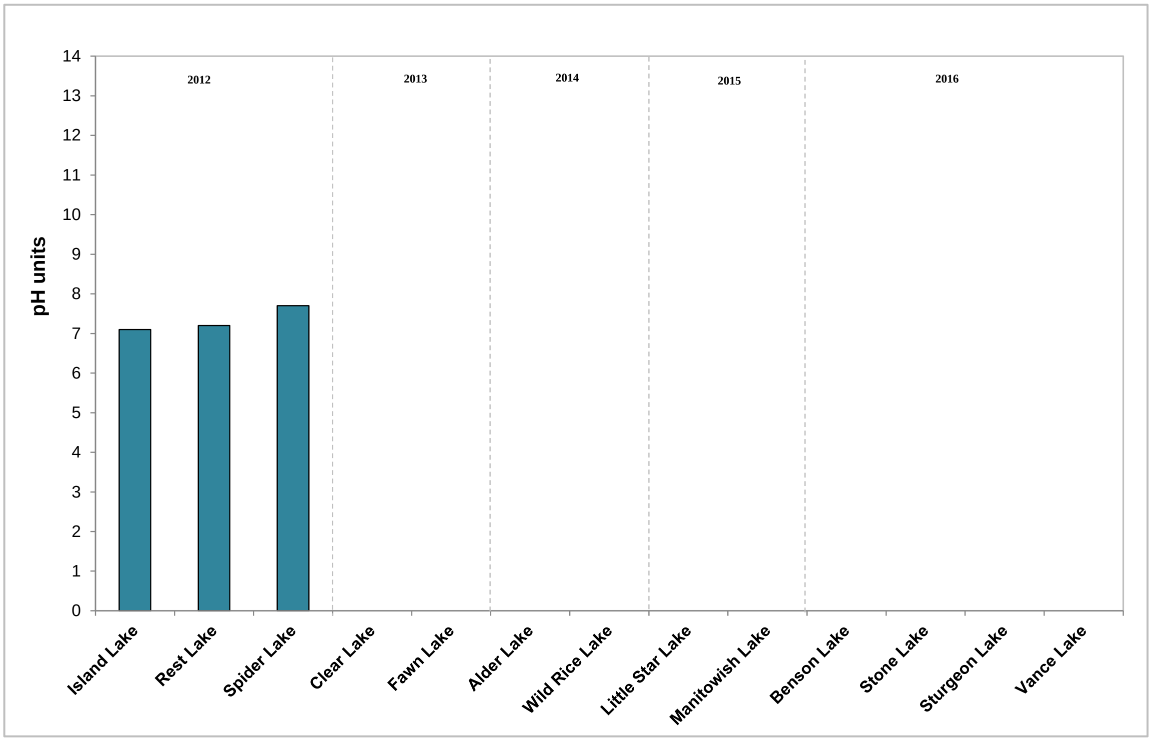


Figure 3.1-7. Manitowish Waters Chain of Lakes pH values. Data collected from mid-summer month surface samples.

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 lakes, but still within expected ranges for northern Wisconsin lakes (Figure 3.1-8). 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.

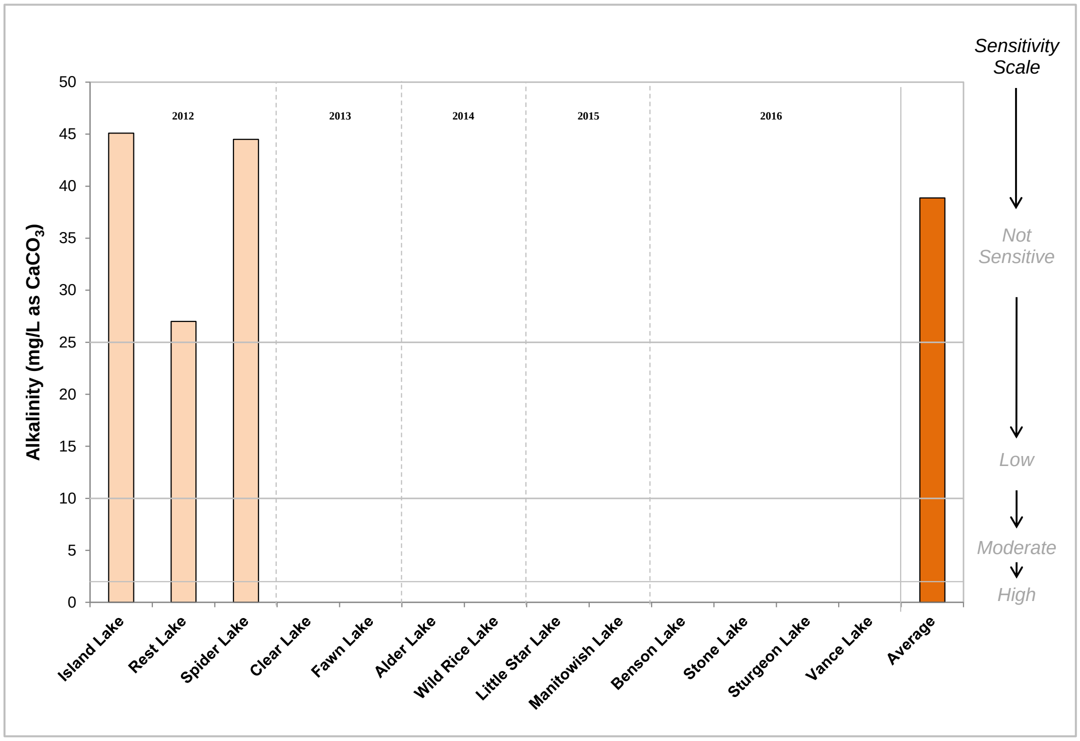


Figure 3.1-8. Manitowish Waters Chain of Lakes alkalinity values and acid rain sensitivity ranges. Data collected from mid-summer surface samples.

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 Phase I Manitowish Waters Chain lakes are suitable for zebra mussel establishment based upon pH. As indicated on Figure 3.1-9, the calcium concentrations within the chain lakes are at the low end for zebra mussel suitability, but still indicate fitting conditions.

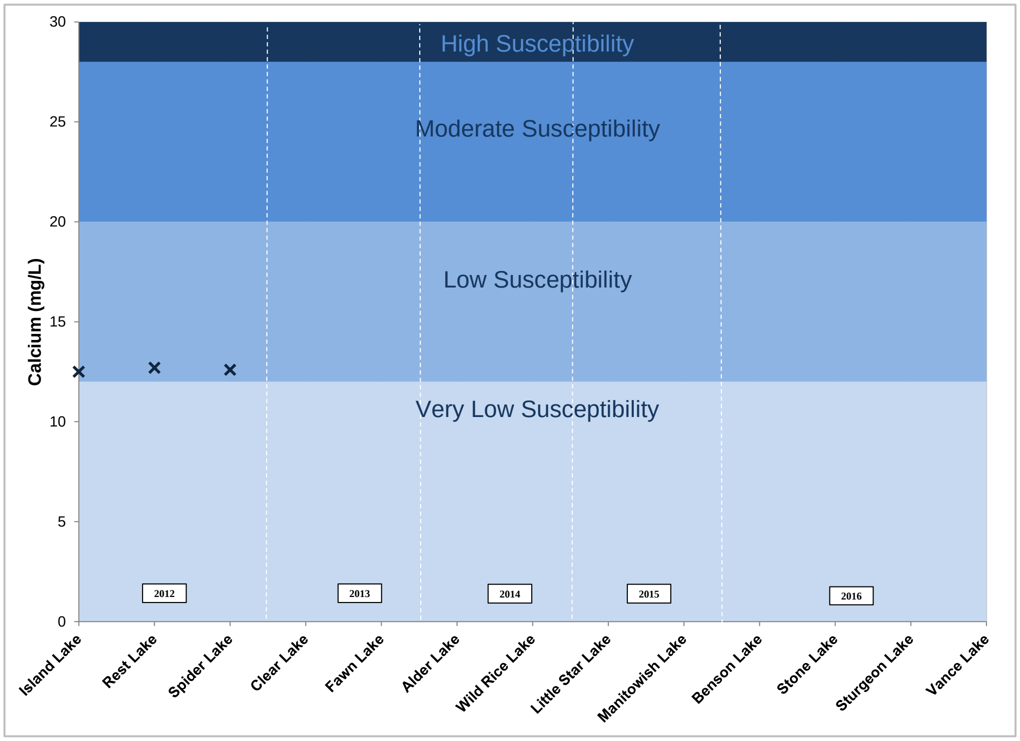


Figure 3.1-9. Manitowish Waters Chain of Lakes zebra mussel susceptibility. Susceptibility determined through surface calcium concentrations. Susceptibility range adapted from Whittier et al. 2008.

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 affect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS – Panuska, 2003). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface. WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the 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 lakes (Figure 3.2-1 and Map 2). The watershed to lake area ratios of the lakes in the Manitowish Waters Chain 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's 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 will be used to calibrate the WiLMS models. Watershed modeling data will be produced in Appendix D.

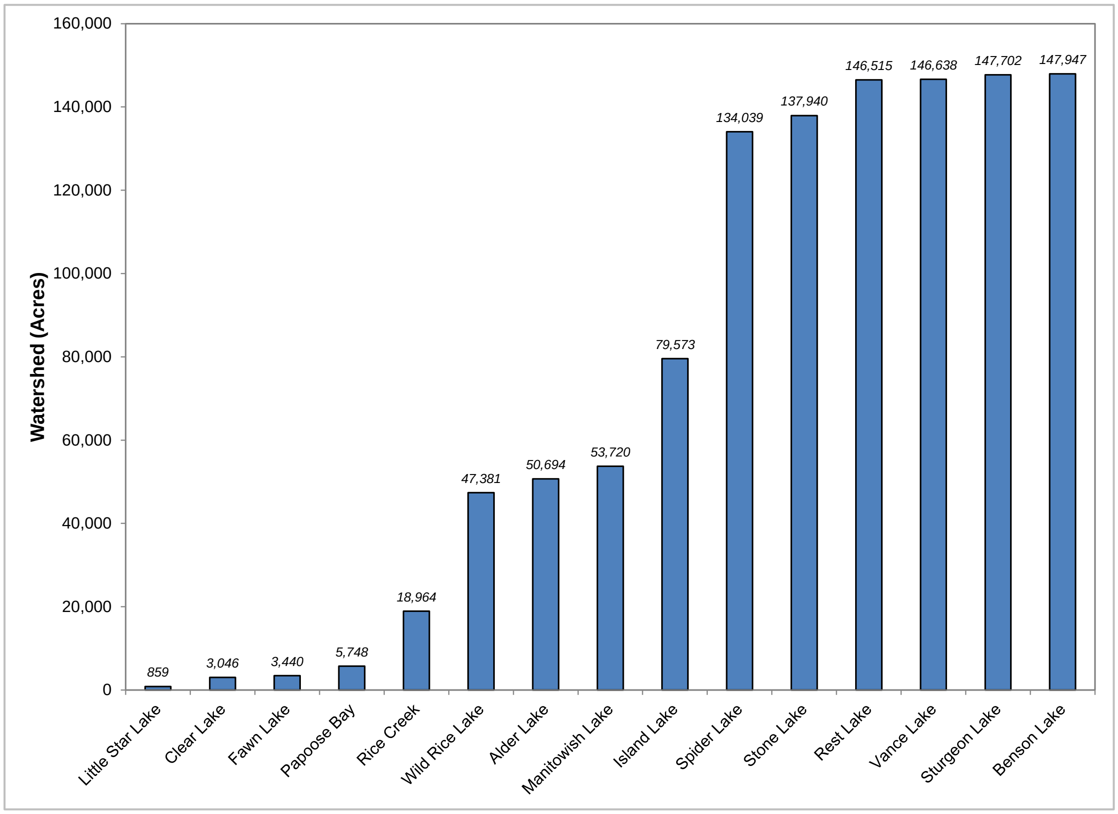


Figure 3.2-1. Manitowish Waters Chain of Lakes watershed sizes in acres.

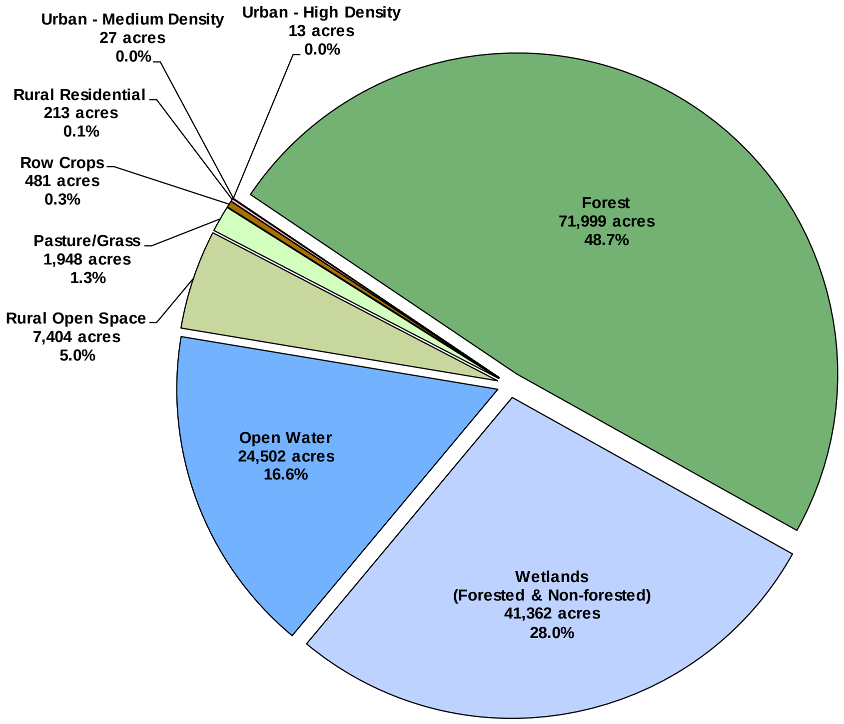


Figure 3.2-2. Manitowish Waters Chain of Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011)

Phosphorus loading chart will be included here once completed.

Figure 3.2-3. Manitowish Waters Chain of Lakes watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

- <u>Vegetation Removal</u>: 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. 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 entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- <u>Nonconforming structures</u>: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows 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 no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

- For county-specific requirements on this topic, it is recommended that lake property owners contact the county's regulations/zoning department.

Wisconsin Act 31

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

Shoreland Research

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

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

Shorelands provide much in terms of nutrient retention and mitigation, but also play an important role in wildlife habitat. Woodford and Meyer (2003) found that green frog density was negatively correlated with development density in Wisconsin lakes. As development increased, the habitat for green frogs decreased and thus populations became significantly lower. Common loons, a bird species notorious for its haunting call that echoes across Wisconsin lakes, are often associated more so with undeveloped lakes than developed lakes (Lindsay 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

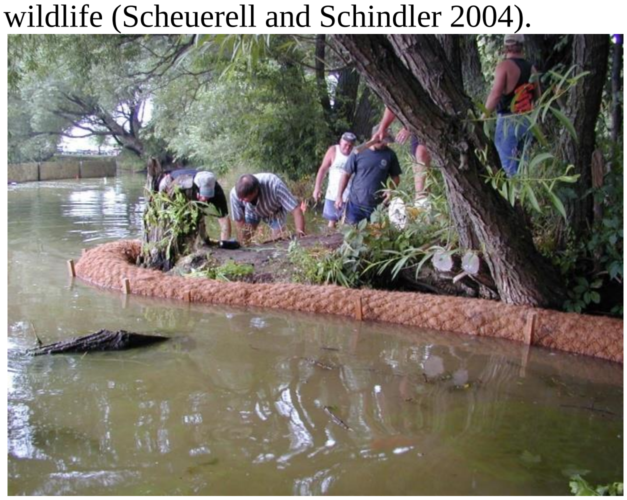
Unfortunately, along with Wisconsin's lakes, waterbodies within the entire United States have shown to have increasing amounts of developed shorelands. The National Lakes Assessment (NLA) is an Environmental Protection Agency sponsored assessment that has successfully pooled together resource managers 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 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 Manitowish Waters Chain lakes contain approximately about 12.0 miles of natural/undeveloped and developed-natural shoreline – 44% 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 6.6 miles (24%) of urbanized and developed–unnatural shoreline were recorded during field surveys. Figure 3.3-3 provides a breakdown of each Phase I 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.

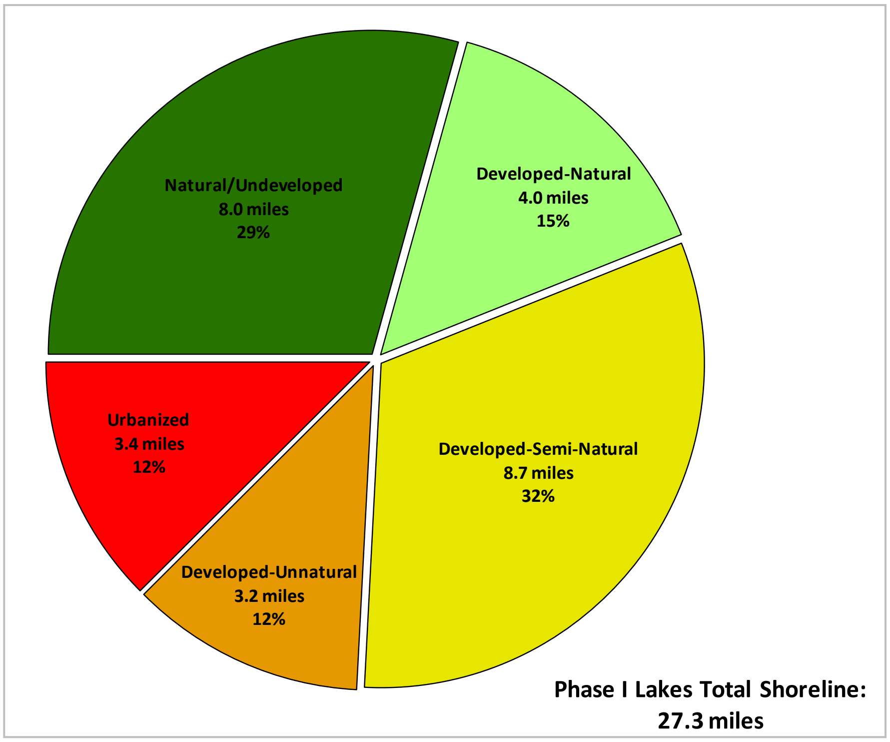


Figure 3.3-2. Phase I Manitowish Waters Chain of Lakes total shoreland classification. Based upon field surveys conducted in late summer 2012. Locations of these categorized shorelands can be found on maps within each individual lake section.

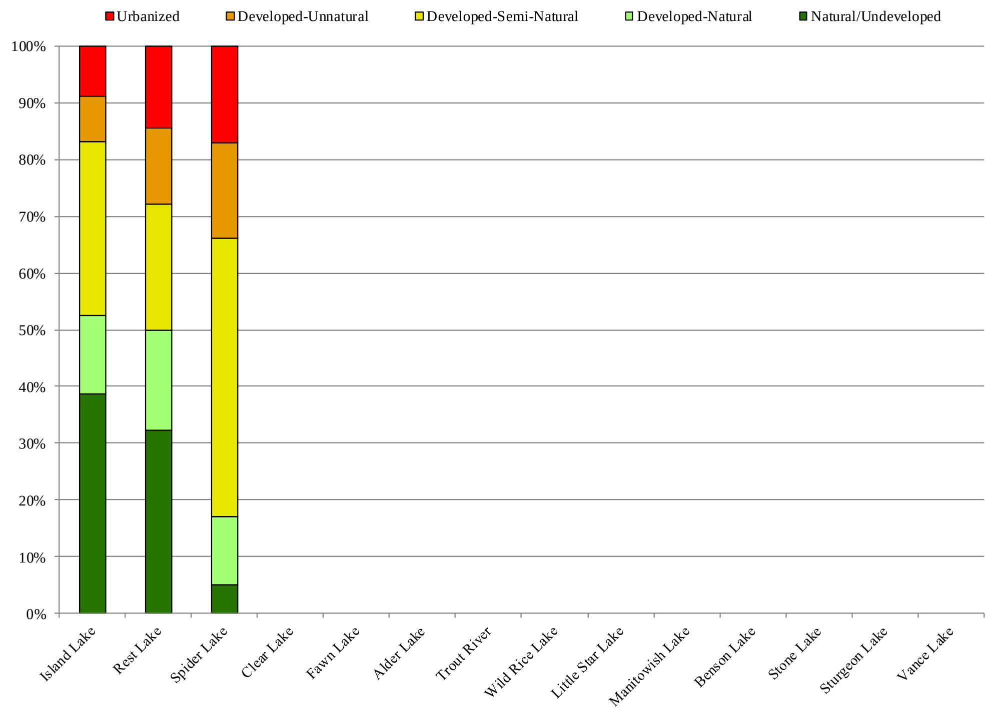


Figure 3.3-3. Phase I Manitowish Waters Chain of Lakes shoreline condition breakdown. Based upon late summer 2012 field surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

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 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 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 lakes combined. A total of 169 coarse woody habitat pieces were identified along 27.3 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.

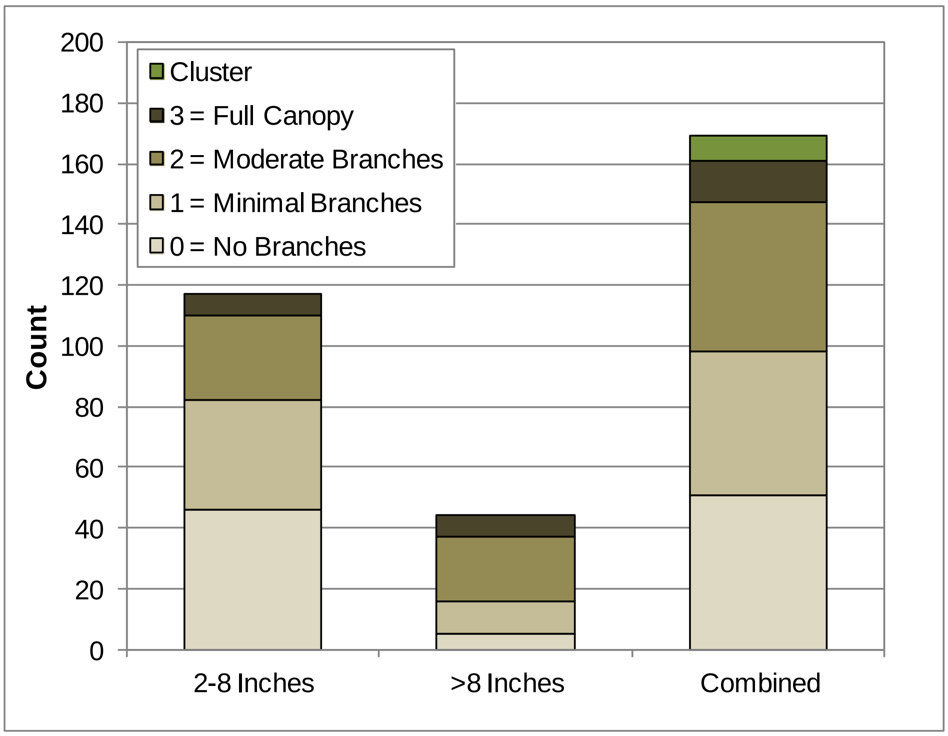


Figure 3.3-4. Phase I Manitowish Waters Chain coarse woody habitat survey results. Based upon a late summer 2012 survey.

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 water-milfoil (*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

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

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.

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

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

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

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

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

Cost

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

Advantages	*Disadvantages*
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil. • 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 water-milfoil 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 water-milfoil 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 water milfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian water milfoil.

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 water-milfoil 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.

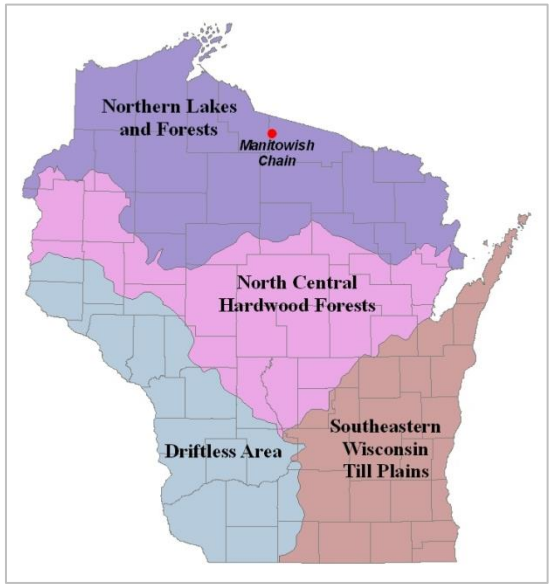


Figure 3.4-1. Location of Manitowish Waters Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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 water milfoil are the primary targets of this extra attention.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.4-2). Eurasian water-milfoil 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 water-milfoil 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 water-milfoil 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.

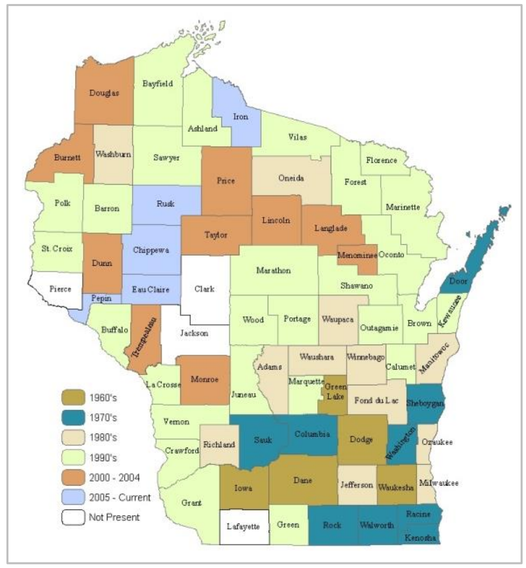


Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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 water-milfoil, 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 season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil 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 late summer.

Aquatic Plant Survey Results

Numerous aquatic plant surveys were completed as part of this project. In late-May 2012, meander-based early-season aquatic invasive species surveys were completed on Island Lake, Spider Lake, and Rest Lake/Rice Creek. 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. In June of 2012, curly-leaf pondweed was located in Rice Creek, Island Lake, and the channel between Island and Spider Lakes.

Herbicide treatments occurred over select areas of curly-leaf pondweed in Island and Spider Lakes in the spring of 2012 and 2013 in an effort to reduce the curly-leaf pondweed population. Early-season AIS surveys were again conducted in Rice Creek, Island Lake, Spider Lake, and Rest Lake in June of 2013, along with the Phase II lakes Clear Lake and Fawn Lake. In addition, early-season AIS surveys were also conducted on Stone Lake, Manitowish Lake, and the Manitowish River between Stone Lake and Rest Lake in June 2013 after members of the North Lakeland Discovery Center had located incidences of curly-leaf pondweed in these areas. Because of its ecological and sociological significance, the curly-leaf pondweed population in the Manitowish Waters Chain of Lakes will be discussed in the following section.

The whole-lake point-intercept surveys were conducted on the Phase I Lakes of Spider Lake, Rest Lake, and Papoose Bay in late July of 2012 by Onterra; 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 also completed by Onterra on all the Phase I Lakes at this time.

A total of 67 different aquatic plant species were identified from the four Phase I lakes in 2012 (Table 3.4-1). Of the 28 submersed aquatic plant species located in 2012, common bladderwort, common waterweed, coontail, fern pondweed, flat-stem pondweed, muskgrasses, northern water milfoil, slender naiad, stoneworts, and wild celery were found in all four waterbodies surveyed. Five of the 37 emergent and/or floating-leaf aquatic plant species were also found to be common to all four waterbodies surveyed in 2012. As this project continues on with Phases II, III, IV, and V, this analysis will be expanded to encompass lakes as their studies are completed.

Photo 3.4-1. Wisconsin special concern species Vasey's pondweed (*Potamogeton vaseyi*).

One submersed native aquatic plant located in Island and Spider Lake, 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 in Wisconsin (WDNR 2011). Its presence in these lakes is indicative of high-quality conditions.

Table 3.4-1. Aquatic plant species located in the Manitowish Waters Chain of Lakes. Created using data from point-intercept and community mapping surveys.

Growth Form	Scientific Name	Common Name	C-value	Phase I: Rest Lake	Phase I: Papoose Creek	Phase I: Island Lake	Phase I: Spider Lake	Phase II: Clear Lake	Phase II: Fawn Lake	Phase III: Alder Lake	Phase III: Wild Rice Lake	Phase IV: Little Star Lake	Phase IV: Manitowish Lake	Phase V: Benson Lake	Phase V: Stone Lake	Phase V: Sturgeon Lake	Phase V: Vance Lake
Emergent	*Carex crinita*	Fringed sedge	6	I		I	I										
	Carex lacustris	Lake sedge	6	I													
	Carex retrorsa	Retrorse sedge	6	I		I	I										
	Carex vesicaria	Blister sedge	8			I	I										
	Eleocharis palustris	Creeping spikerush	6			I	X										
	Equisetum fluviatile	Water horsetail	7	I	I		X										
	Glyceria canadensis	Rattlesnake grass	7	I													
	Iris pseudacorus	Pale yellow iris	Exotic	I		I											
	Iris versicolor	Northern blue flag	5	I		I											
	Juncus effusus	Soft rush	4	I		I	I										
	Leersia oryzoides	Rice cut grass	3			I											
	Lythrum alatum	Winged loosestrife	6	I													
	Lythrum salicaria	Purple loosestrife	Exotic	I		I	I										
	Myosotis scorpioides	Common forget-me-not	Exotic			I	I										
	Phalaris arundinacea	Reed canary grass	Exotic	I													
	Sagittaria latifolia	Common arrowhead	3	I		I											
	Sagittaria rigida	Stiff arrowhead	8				X										
	Schoenoplectus acutus	Hardstem bulrush	5				X										
	Schoenoplectus pungens	Three-square rush	5	I													
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I	I	I	X										
	Scirpus cyperinus	Wool grass	4	I	I	I	I										
	Sium suave	Water parsnip	5		I												
	Sparganium sp.	Bur-reed species	N/A			X											
	Typha sp.	Cattail sp.	1	I	I	I	I										
	Zizania palustris	Northern wild rice	8	X	X	X	I										
Submergent	*Bidens beckii*	Water marigold	8			X	X										
	Callitriche palustris	Common water starwort	8				X										
	Ceratophyllum demersum	Coontail	3	X	X	X	X										
	Ceratophyllum echinatum	Spiny hornwort	10			X											
	Chara sp.	Muskgrasses	7	X	X	X	X										
	Elatine minima	Waterwort	9				X										
	Elodea canadensis	Common waterweed	3	X	X	X	X										
	Heteranthera dubia	Water stargrass	6	X			X										
	Myriophyllum sibiricum	Northern water milfoil	7	X	X	X	X										
	Najas flexilis	Slender naiad	6	X	X	X	X										
	Najas guadalupensis	Southern naiad	7	X													
	Nitella sp.	Stoneworts	7	X	X	X	X										
	Potamogeton amplifolius	Large-leaf pondweed	7	X		X	X										
	Potamogeton crispus	Curly-leaf pondweed	Exotic			X	X										
	Potamogeton foliosus	Leafy pondweed	6	X		X											
	Potamogeton friesii	Fries' pondweed	8	X													
	Potamogeton gramineus	Variable pondweed	7		X	X	X										
	Potamogeton obtusifolius	Blunt-leaf pondweed	9		X												
	Potamogeton pusillus	Small pondweed	7	X		X	X										
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X	X	X										
	Potamogeton robbinsii	Fern pondweed	8	X	X	X	X										
	Potamogeton spirillus	Spiral-fruited pondweed	8	X			X										
	Potamogeton strictifolius	Stiff pondweed	8				X										
	*Potamogeton vaseyi**	Vasey's pondweed	10			X	X										
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X										
	Sagittaria cristata	Crested arrowhead	9				X										
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A			X											
	Utricularia vulgaris	Common bladderwort	7	X	X	X	X										
	Vallisneria americana	Wild celery	6	X	X	X	X										
FF	*Lemna trisulca*	Forked duckweed	6		X												
	Wolffia sp.	Watermeal species	N/A			X											
FL	*Nuphar microphylla***	Yellow pond-lily	9			I											
	Nuphar variegata	Spatterdock	6	X	I	X	X										
	*Nuphar x rubrodisca***	Intermediate pond-lily	9			I											
	Nymphaea odorata	White water lily	6	I		X	X										
FL/E	*Sparganium americanum*	Eastern bur-reed	8			I											
	Sparganium angustifolium	Narrow-leaf bur-reed	9			I											
	Sparganium eurycarpum	Common bur-reed	5			I	X										
	Sparganium fluctuans	Floating-leaf bur-reed	10	X	I	I	I										
S/E	*Eleocharis acicularis*	Needle spikerush	5				X										
	Sagittaria cuneata	Arum-leaved arrowhead	7		X		X										
	Sagittaria graminea	Grass-leaved arrowhead	9			I											

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

Photo 3.4-2. Rice Creek rare pond species. Pictured is yellow pond-lily (Nuphar microphylla) (left) and the slightly larger intermediate pond-lily (N. x rubrodisca) (right).

While whole-lake point-intercept and standard community mapping surveys were not completed on Rice Creek, one of the rarest water lily species in Wisconsin (Dr. Susan Knight person. comm.), yellow pond-lily (*Nuphar microphylla*) was located (Photo 3.4-2). 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* – Photo 3.4-2), which was also observed growing in Rice Creek. While not listed by the NHI, yellow pond-lily is relatively rare, and is restricted to waterbodies in northern Wisconsin.

Of the 67 aquatic plant species located in 2012, five are considered to be non-native, invasive species; one submersed species, the aforementioned curly-leaf pondweed, and four emergent plants which include purple loosestrife, common forget-me-not, pale yellow iris, 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 four Manitowish Waters Chain of Lakes Phase I lakes, the number of native aquatic plant species (species richness) ranged from 24 in Papoose Bay to 40 in both Spider and Island Lakes, with an average of 35 native species per lake (Figure 3.4-3). When comparing a lake's aquatic plant community to ecoregional and state medians, only those species that are physically encountered on the rake during the whole-lake point-intercept survey are used in the analysis. For example, while a total of 40 native aquatic plant species were located in Spider Lake in 2012, 32 were physically encountered on the rake during the whole-lake point-intercept survey. The species physically encountered on the rake and their conservatism values were used to calculate the Floristic Quality Index (FQI) for each lake's aquatic plant community (equation shown below).

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

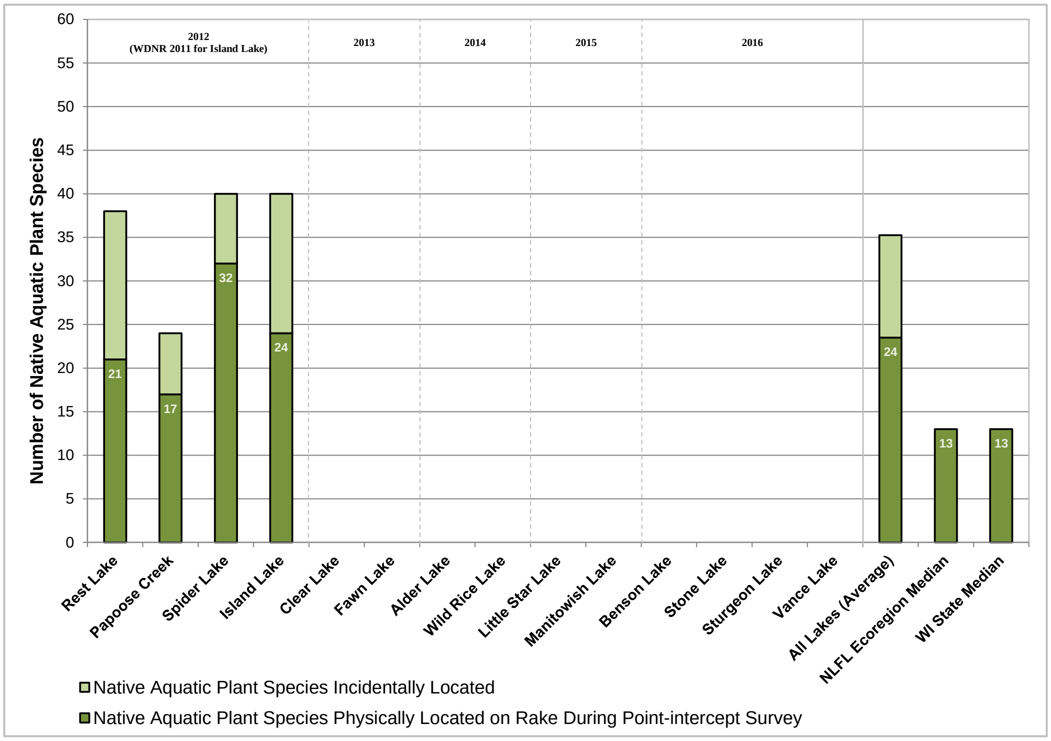


Figure 3.4-3. Manitowish Waters Chain of Lakes native aquatic plant species richness. Created using data from summer point-intercept and community mapping surveys. Chart includes incidental species (light colored bars). Note that NLFL is the Northern Lakes and Forests Lakes ecoregion after Nichols (1999).

Figure 3.4-4 compares the average conservatism values of the native aquatic plant species located in each lake of the Manitowish Waters Chain. The average conservatism values for Papoose Bay and Spider Lake fall slightly below the Northern Lakes and Forests Lakes (NLFL) Ecoregional median with values of 6.5 and 6.6, respectively, while the average conservatism values for Rest Lake and Island Lake are equal to the NLFL Ecoregional median, with a value of 6.7 (Figure 3.4-5). The Floristic Quality Index values were created for each lake using the lakes' average conservatism and native species richness values. Figure 3.4-5 illustrates that of the four Phase I lakes, Spider Lake had the highest Floristic Quality Index value of 37.3, while Papoose Bay had the lowest value of 26.7. The Floristic Quality Index values for all four 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.

As explained earlier, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because the lakes in the Manitowish Waters Chain contain a high number of native aquatic plant species, one may assume their aquatic plant communities also have high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

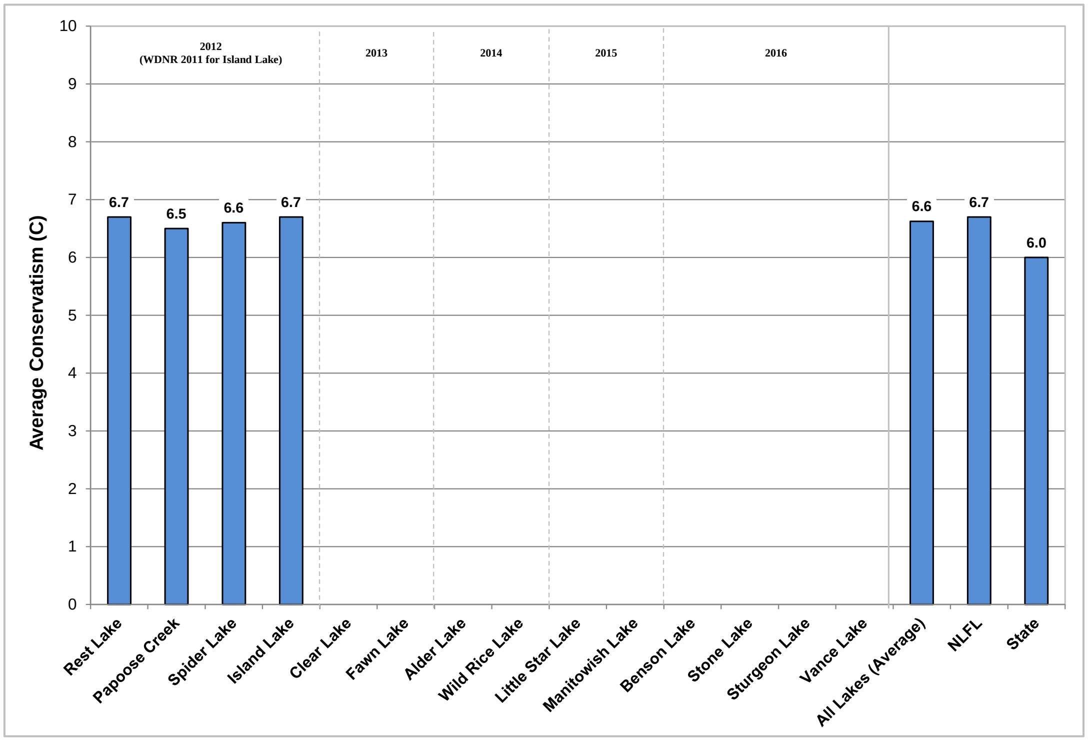


Figure 3.4-4. Manitowish Waters Chain of Lakes native species average conservatism values. Created using native aquatic plant species encountered on the rake during summer point-intercept surveys.

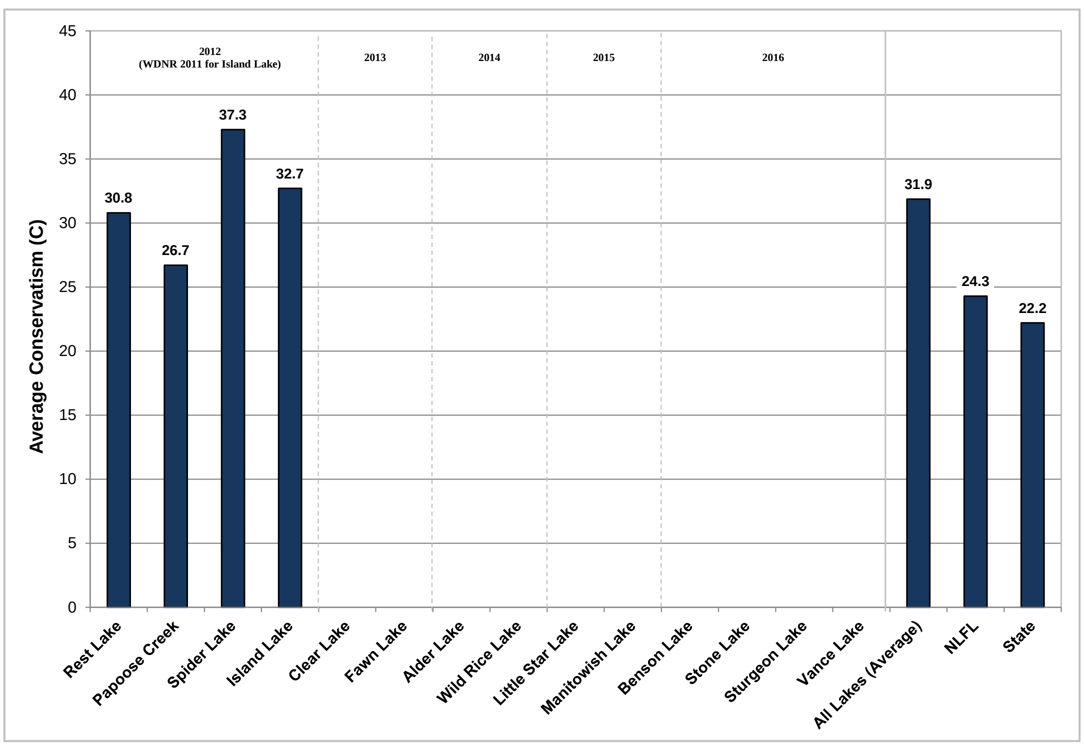


Figure 3.4-5. Manitowish Waters Chain of Lakes Floristic Quality Assessment. Created using data from native aquatic plant species encountered on the rake during summer point-intercept surveys. Analysis follows Nichols (1999).

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 3.4-6). Simpson's Diversity Index values were calculated for each lake using data collected during the summer point-intercept surveys. As Figure 3.4-6 illustrates that of the Phase I lakes, species diversity ranged from 0.86 in Papoose Bay to 0.93 in Island Lake. As discussed within the Papoose Bay Lake 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. Simpson's Diversity Index values for the Phase I lakes all fell at or above the median for lakes in the NLFL Ecoregion, indicating the plant communities of the Manitowish Waters Chain are highly diverse.

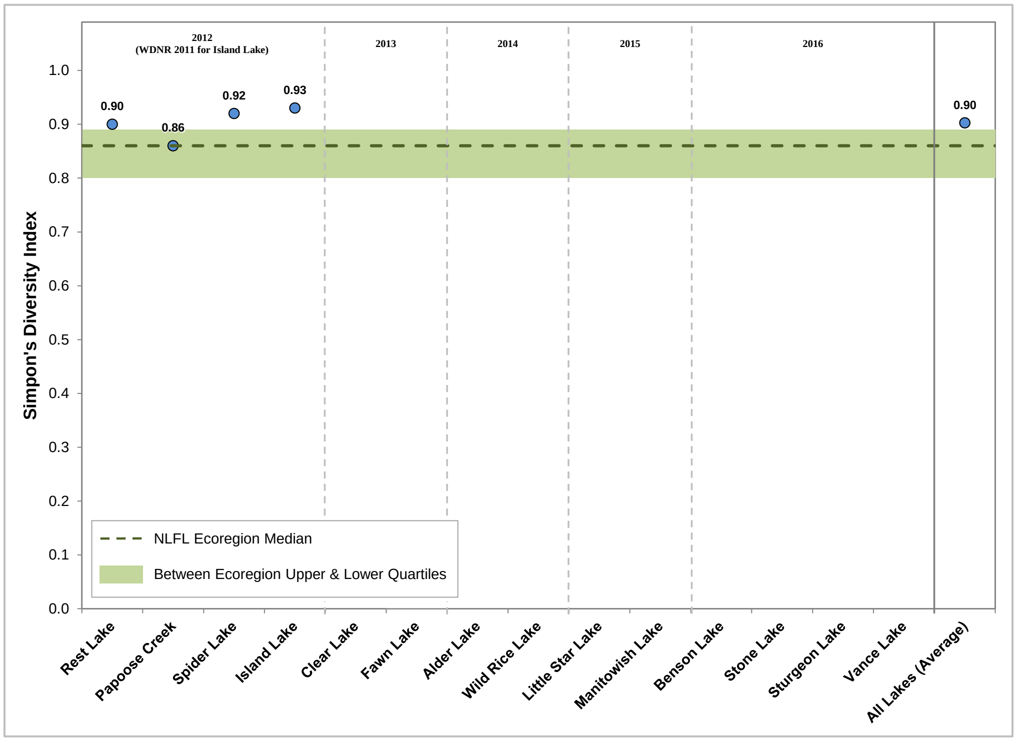


Figure 3.4-6. Manitowish Waters Chain of Lakes Simpson's Diversity Index. Created using data from summer point-intercept surveys. Ecoregion data provided by WDNR Science Services.

As illustrated in the previous analyses, the plant communities within the Manitowish Waters Chain 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 lakes contain large areas of these plant communities. Figure 3.4-7 displays the percent of lake acreage occupied by emergent, floating-leaf, or a combined emergent and floating-leaf plant communities. Papoose Bay, 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.

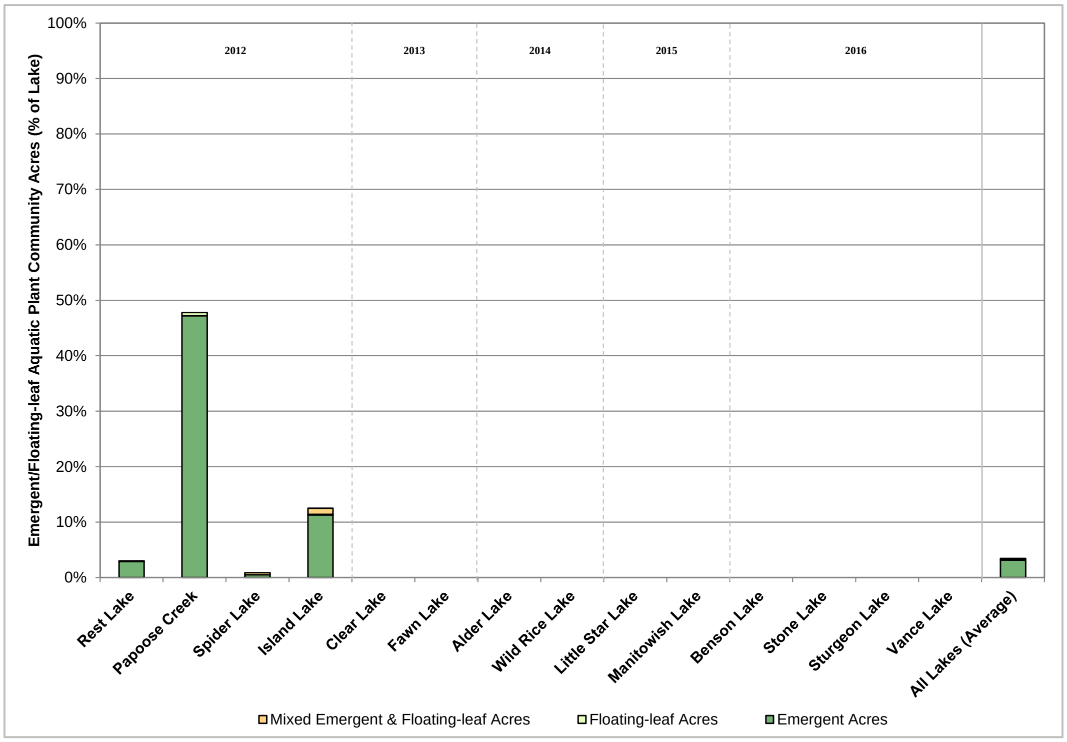


Figure 3.4-7. Manitowish Waters Chain of Lakes emergent and floating-leaf aquatic plant communities. Created using data from summer community mapping surveys.

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

Curly-leaf pondweed

The non-native, invasive aquatic plant curly-leaf pondweed (*Potamogeton crispus*) was first discovered in the Manitowish Waters Chain of Lakes in June 2010 in the northwestern area of Island Lake. These plants were discovered by trained volunteer monitor with the Lake Captain and Deckhand Aquatic Invasive Species (AIS) Program, which was started in 2010 by the North Lakeland Discovery Center (NLDC) to supplement the Clean Boats Clean Waters Program. In late June 2010, NLDC staff and volunteers confirmed the identification of the curly-leaf pondweed, and marked an area of approximately 15 feet by 6 feet in size via GPS. In early July 2010, the NLCD intensified their monitoring of Island Lake in an attempt to locate additional occurrences of curly-leaf pondweed. They located 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 realized.

On June 10, 2011, the NLCD held is annual Lake Captain Training including monitoring of the pre-identified curly-leaf pondweed populations in Island Lake. On June 18, NLDC staff (Anne Kretschmann) and Rest Lake Captain/Manitowish Waters Lake Association (MWLA) representative Tom Joseph visited Rice Creek in an attempt to quantify the curly-leaf pondweed population. During this survey, they found to the extent of the curly-leaf pondweed population to be much larger than they had expected, and estimated they had only traversed about half of the area of infestation.

On June 24, Ted Ritter (Vilas County AIS Coordinator) and Anne Kretschmann delineated the infestation via GPS while Karen Dixon (Stone Lake Captain/MWLA President) and Tom Joseph conducted meander surveys of Island Lake. Their mapping effort located greater than 22 acres of curly-leaf pondweed in Rice Creek, as well as additional small colonies on the southeastern side of Island Lake. Additionally, on their way back from Island Lake to Rest Lake, Anne and Joseph discovered curly-leaf pondweed on both sides of the channel between Spider and Island Lakes on the western (Spider Lake) side of the channel. They also observed curly-leaf pondweed fragments floating in Spider Lake. Volunteers continued monitoring throughout the rest of the 2011 growing season, and did not locate any additional occurrences of curly-leaf pondweed or any other non-native aquatic plants.

In February of 2012, the NLDC received a WDNR AIS Early Detection and Response Grant to initiate the first phase of curly-leaf pondweed control program on the newly identified locations of curly-leaf pondweed within Rice Creek, Island Lake, Spider Lake, and the Spider-Island Lake Channel. Traditionally, curly-leaf pondweed management consists of annual herbicide treatments conducted in May/June with the goal of killing the plants before they are able to produce their asexual reproductive structures called turions. After multiple (generally 3-5 years) of treatment, the turion bank in the sediment is exhausted and the curly-leaf pondweed population decreases. All of the spatial information gathered by the NLDC staff and volunteers in 2011 was provided to Onterra, and a preliminary treatment strategy targeting approximately 26.6 acres was proposed for treatment in the spring of 2012 (Map 3).

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 treatment of proposed treatment site A-12 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 herbicide treatments (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. The northern wild rice populations that inhabit Rice Creek and Island Lake and how they pertain to curly-leaf pondweed and its management will be discussed in detail in the following section.

On April 12, 2012, Onterra ecologists made their first visit to the Manitowish Waters Chain, making visits to Spider Lake, Island Lake, and Rice Creek to conduct a pre-treatment survey aimed at verifying the extents of the curly-leaf pondweed colonies and refining them where necessary. The curly-leaf pondweed was readily visible from the surface, but a submersible video camera was used to verify the colony extents in deeper water. This pre-treatment survey revealed that curly-leaf pondweed extended between and around the proposed treatment sites B-12 and C-12, and thus these proposed sites were merged into a single, expanded treatment site (Map 3). Proposed treatment site D-12 was also adjusted and expanded based upon data collected during the pre-treatment survey.

Herbicide treatments rely on a combination of herbicide concentration and exposure time to be effective (Netherland 2009). For control of curly-leaf pondweed, liquid endothall is typically applied at 1.5 ppm active ingredient (ai) with an understanding that exposure times are going to be relatively short (hours). Onterra's typical policy, which is supported by the WDNR, is to start with a conservative herbicide treatment strategy and get more aggressive if the preceding treatment did not satisfy expectations. This approach results in utilizing the minimal amount of herbicide required to effectively control the target plant. This approach also limits the unintended effects on the native plant community that can accompany overuse of herbicides. Because D-12 was quite small and studies have consistently shown that small treatment sites are extremely difficult to treat effectively, a slightly higher application dose (2.0 ppm ai) was recommended. Expecting a moderate level of water flow within the channel between Island and Spider Lakes, treatment site B-12 was also recommended to be treated at this slightly higher dose (Map 3). The 2012 final treatment areas were treated on May 2, 2012.

On May 29-30, 2012, Onterra ecologists completed post-treatment evaluation surveys of the 2012 treatment sites on Spider Lake and Island Lake. In addition, a full meander-based survey was completed on Rest Lake to locate any potential occurrences of curly-leaf pondweed and any other non-native species. Overall, it appeared that the 2012 herbicide treatments on Spider and Island Lakes were not effective at causing curly-leaf pondweed mortality. The Spider/Island Lake channel still contained large colonies of *dominant* and *highly dominant* curly-leaf pondweed, and *scattered* curly-leaf pondweed was located within treatment site D-12 in Island Lake (Map 4). This lack of success was likely due to an approximate 8-12 inch increase in water levels prior to the herbicide application, which likely slightly diluted the herbicide concentration. In addition, although the herbicide concentration was increased within the Spider/Island Lake channel to account for higher rates of water flow, it is suspected that this increased dose was not sufficient to overcome the dilution effects of flow.

No curly-leaf pondweed was located in Rest Lake in 2012, but it was located in a few areas in Spider Lake, Island Lake, and Rice Creek, some outside of 2012 treatment areas (Map 4). In total, approximately 39 acres of colonized curly-leaf pondweed were observed in 2012. Twenty-seven acres (69%) of the 39 acres of curly-leaf pondweed located in 2012 were located in Rice Creek. The curly-leaf pondweed in Rice Creek was also the densest that Onterra ecologists encountered during the 2012 surveys, much of which was non-navigable and matted at the surface (Map 4, Photo 3.4-3).

Photo 3.4-3. Onterra staff member with surface-matted curly-leaf pondweed in Rice Creek. Photo taken during late-May 2012 curly-leaf pondweed survey.

Because the 2012 curly-leaf pondweed treatments were largely ineffective, a more aggressive strategy was developed for 2013 (Map 5). Working with the NLDC and MWLA, it was decided that all colonized areas of curly-leaf pondweed within Island Lake and Spider Lake would be treated with a higher dose of liquid endothall in 2013. The endothall dosage was increased to 3.0 ppm ai for treatment sites C-13, E-13, and F-13. The smaller treatment area D-13 was treated with an endothall dose of 4.0 ppm ai to try and counteract the rapid dilution that current research indicates accompanies these small treatment sites. Areas of curly-leaf pondweed within Rice Creek were again proposed to be treated in 2013; however, these treatment areas again went untreated in 2013 due to concerns regarding their proximity to wild rice. In February 2013, the NLDC received another WDNR AIS Early Detection and Response Grant to aid in funding the 2013 treatments and associated monitoring.

On June 20 and 25-27, 2013, Onterra ecologists completed the post-treatment evaluation surveys of the 2013 curly-leaf pondweed treatments. Qualitatively, the 2013 treatments appeared to be successful as no curly-leaf pondweed could be seen from the surface within any of the herbicide application areas (Map 6). Quantitative monitoring was also completed in the form of a modified point-intercept survey over treatment site C-13 in Spider Lake. Sub-sampling locations were distributed across the treatment site at a 20-meter resolution, resulting in 36 sub-sample locations. Using a rake, the presence of curly-leaf pondweed and its relative abundance on the rake was documented on May 30, 2013 prior to the treatment, and again on June 25, 2013 following the treatment. For a more detailed description of the quantitative monitoring methodology used, please see the 2013 Manitowish Waters Chain of Lakes Treatment Report.

Photo 3.4-4. Newly sprouted curly-leaf pondweed plants observed in treatment site C-13.

While no curly-leaf pondweed was observed from the surface in treatment site C-13 following the treatment, small plants that appeared to have recently sprouted from turions were observed on the rake (Photo 3.4-4). Figure 3.4-8 illustrates that prior to treatment, 50% of the point-intercept sampling locations contained curly-leaf pondweed, and following the treatment, approximately 40% contained curly-leaf pondweed. While there was a slight reduction in curly-leaf pondweed occurrence, this reduction was not statistically valid (Chi-square $\alpha = 0.05$). However, it is believed that the curly-leaf pondweed observed in treatment site C-13 following the treatment represented new growth since the treatment from previously-deposited turions, and that the treatment was largely successful at controlling the three to four-foot tall plants observed prior to treatment. While the quantitative data did not indicate a statistically valid reduction in curly-leaf pondweed occurrence following the 2013 treatment, it is believed the treatment was still successful.

In addition to assessing the 2013 treatment areas, whole-lake early-season AIS surveys were completed on Island Lake, Rice Creek, Spider Lake, the project Phase II lakes Clear Lake and Fawn Lake, Manitowish Lake, and the Manitowish River between Stone Lake and Rest Lake. Early-season AIS surveys were not scheduled to occur on Manitowish Lake and Stone Lake until

2015 and 2016, respectively, but members of the NLDC discovered areas of curly-leaf pondweed in these lakes during their 2011 and 2012 monitoring.

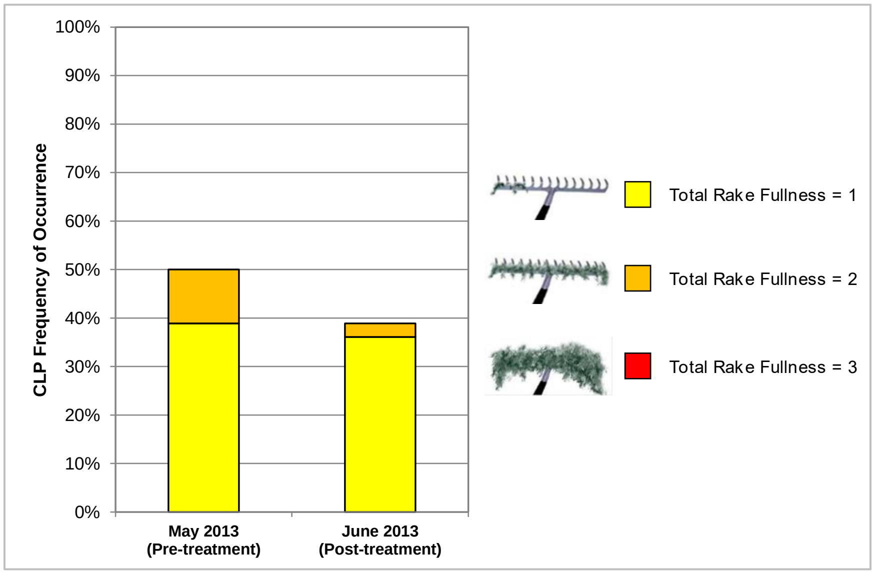


Figure 3.4-8. 2013 pre- and post-treatment CLP frequency of occurrence within C-13. Created using data from 36 sub-sample point-intercept locations sampled in May and June 2013.

No curly-leaf pondweed was located in Clear Lake or Fawn Lake in 2013 (Map 6). A small, *dominant* colony of curly-leaf pondweed was located in the Manitowish River, approximately midway between Stone Lake and Rest Lake, along with a number of single plants, clumps of plants, and small plant colonies. A few single plants/clumps of plants were located in Stone Lake and Spider Lake, while only one single curly-leaf pondweed plant could be located in Manitowish Lake. Colonized curly-leaf pondweed was located in the southeastern portion of Island Lake along with some single plants/clumps of plants. The large, colonized area of curly-leaf pondweed was still present in Rice Creek, though at somewhat lesser density on the westernmost end; the eastern portion was still dominated by *highly dominant* and *surface matting* curly-leaf pondweed. The upstream-most colonized area of curly-leaf pondweed observed in Rice Creek in 2012 was nearly three times larger in 2013 (Map 6). A small plant colony of curly-leaf pondweed was also discovered further upstream in Rice Creek than what had been located in 2012.

In total, 30.6 acres of colonized curly-leaf pondweed were located in the Manitowish Waters Chain in 2013, representing an eight-acre decrease in colonial acreage from 2012 (Figure 3.4-9). Most of the acreage lost was within treatment areas in Spider and Island Lakes. Like in 2012, the majority of the curly-leaf pondweed in 2013 was located in Rice Creek.

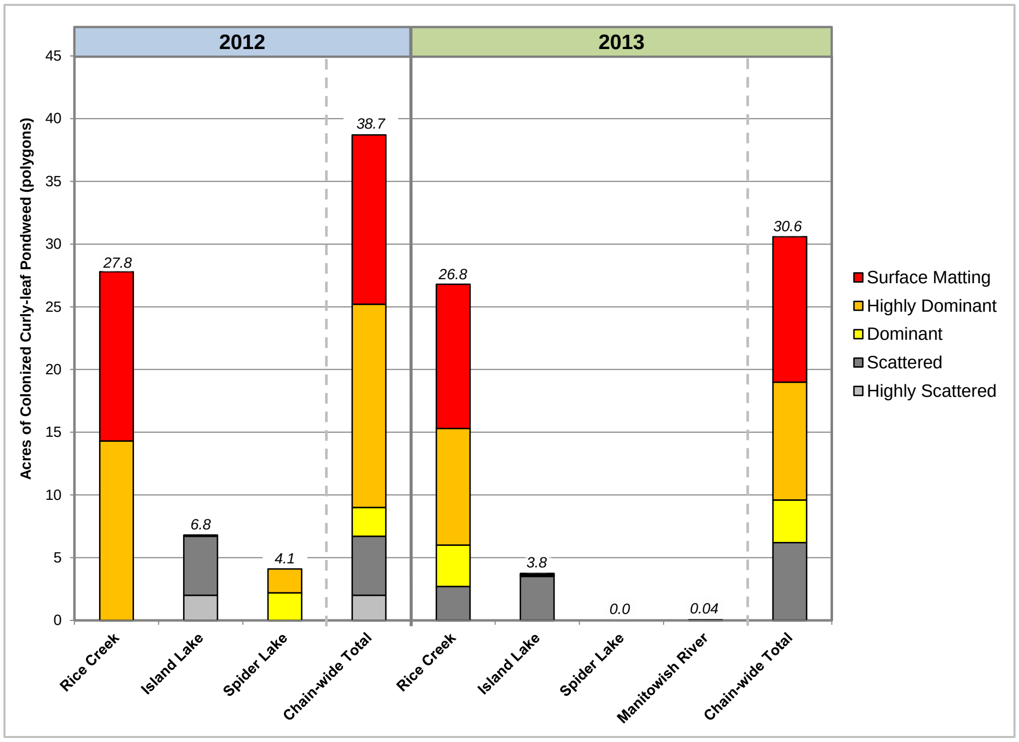


Figure 3.4-9. Manitowish Waters Chain of Lakes acreage of curly-leaf pondweed. Created using data from 2012 and 2013 early-season AIS surveys.

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 the shoreline in one location on the southeast portion of Island Lake (Island Lake – Map 4), and in one location on the west shore of Rest Lake (Rest Lake – Map 4). 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 the southern shores of Rest Lake (Rest Lake – Map 4), southern and northeastern shores of Spider Lake (Spider Lake – Map 4), and on the northwest and eastern shores of Island Lake (Island Lake – Map 4).

There are a number of effective control strategies for combating this aggressive plant, including herbicide application, biological control by native beetles, and manual hand removal. 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.

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 in one location along the southwest shore of Island Lake (Island Lake – Map 4), and in one location along the eastern shore of Spider Lake (Spider Lake – Map 4). At this time, the only means of controlling pale-yellow iris populations is 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 (Rest Lake – Map 4). Reed canary grass is difficult to eradicate; at the time of this writing there is no commonly accepted control method. This plant is quite resilient to herbicide applications. Small, discrete patches have been covered by black plastic to reduce growth for an entire season. However, the species must be monitored because rhizomes may spread out beyond the plastic.

Implementing AIS control strategies in wild rice waters

Northern wild rice (*Zizania palustris* – Photo 3.4-5) is an emergent aquatic grass that grows in shallow water of lakes and slow-moving rivers. Manoomin, as it is referred to by Ojibwe Tribal Communities, is of great cultural significance. Non-tribal rice harvesters, waterfowl hunters and birdwatchers praise wild rice for it being a quality food source and habitat. Wild rice is an important diet component for waterfowl, muskrats, deer, and many other species. Established wild rice communities can provide valuable nursery and brooding habitat for wetland bird and amphibian species as well as spawning habitat for various fish.

Photo 3.4-5. Northern wild rice (*Zizania palustris*), Island Lake, Manitowish Waters Chain of Lakes. Photo taken during August 2013 wild rice mapping survey.

One of the most overlooked benefits of having established wild rice communities is their ability to utilize excessive nutrients, stabilize sediments, and form wave-breaks to protect shorelines.

Approximately 22,400 square miles of northern Wisconsin, which includes the Manitowish Waters Chain of Lakes, was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842. The Great Lakes Indian and Wildlife Commission (GLIFWC) represents the 11 Chippewa Tribal Nations within the Upper Midwest to protect and enhance the natural resources of the ceded territory, particularly as they relate to the treaty rights of the member tribes.

As discussed above, northern wild rice is a valuable component of the Manitowish Waters Chain of Lakes ecosystem and is also of cultural significance to Native American communities in the area. For these reasons, GLIFWC focuses on the "preservation and enhancement of manoomin (wild rice) in ceded territory lakes". The State of Wisconsin works actively with GLIFWC to review all activities that have the potential to negatively impact wild rice populations. While the use of herbicides to control aquatic invasive species has broad intentions of benefiting the lake ecosystem, the herbicides may have the capacity to impact non-target plants such as wild rice.

<u>Timing:</u> Herbicide treatments targeting AIS in Wisconsin typically occur early in the season before water temperatures reach 60-65°F. Many of the native aquatic plant species have not begun growing at this time of year, increasing the selectivity of the control strategy towards the target AIS. At this time of year, Eurasian water milfoil and curly-leaf pondweed are more nubile and actively growing, which makes them more vulnerable to the control strategy. On the other hand, mature wild rice was shown to be resistant to aquatic herbicides (Nelson et al. 2003). It may be suggested that herbicide treatments targeting AIS within areas of wild rice be conducted late in the summer when the wild rice is mature and not vulnerable to the control strategy. While there may be some potential for late-season Eurasian water milfoil treatments, curly-leaf pondweed has senesced (died back) by this time of year and cannot be targeted in this manner.

The seedling growth stage of wild rice is likely the stage present (unless the rice has not yet germinated) when early-season herbicide treatments are conducted. Research indicates that four weeks after wild rice seedlings were exposed to various herbicides and doses, the plant height and number of seed heads and tillers were unaffected by the treatment (Nelson et al 2003). However, the biomass of the seedling wild rice was reduced and the magnitude of effect increased with dose. While conducting a targeted spot treatment when the wild rice is in the seedling stage may impact the biomass of wild rice, it is unclear if it would hold reproductive impacts on the population. It should be noted that while Nelson et al 2003 was a study that certainly shed light upon wild rice and herbicide interactions, the study was completed in an experimental setting so these same interactions may differ when in the natural environment

<u>Dose:</u> As discussed above, a greater dose of herbicide resulted in a greater reduction in the biomass of the seedling wild rice plants (Nelson et al. 2003). Within this study, two doses of endothall (1.0 & 2.0 ppm ai) were tested at exposure times of 72 hours. An ongoing cooperative research project between the WDNR, US Army Corps of Engineers Research and Development Center, and private consultants has shown that sustaining herbicide concentrations of 1.0-2.0 ppm ai for 72 hours in a spot treatment is unlikely. Measured herbicide concentration and exposure times in association with endothall treatments on the Manitowish Waters Chain would likely be significantly less than those used in this study, potentially suggesting that the dose-dependent effects on the wild rice biomass would also be significantly less.

The MWLA, NLDC and other stakeholders understand the ecological and cultural importance of wild rice within the Manitowish Waters Chain of Lakes. They are also concerned with the threat that curly-leaf pondweed poses to the native plants, including northern wild rice, within the chain. A detailed qualitative and quantitative herbicide treatment monitoring strategy was devised that would evaluate the efficacy of the 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. Northern wild rice colonies have been delineated and assigned a two-tiered density rating (dense or sparse), and 2012 and 2013 northern wild communities in Rice Creek and Island Lake can be found on Maps 7-10. While it is understood that wild rice populations naturally fluctuate from year to year, a multi-year dataset may provide insight to whether the herbicide application is directly affecting its population. If a reduction in the wild rice population is observed that has not been observed on non-treated areas, lake managers will be able to attribute the change to the control strategy.

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 strategy discussed above. Onterra was later invited by GLIFWC to attend a Voigt Intertribal Taskforce Workshop 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. 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. Thus, the curly-leaf pondweed in Rice Creek went untreated in 2013, and will likely not be treated in coming years.

The large, dense curly-leaf pondweed population in Rice Creek is of great concern to the Manitowish Waters Chain of Lakes stakeholders, as it is the furthest upstream curly-leaf pondweed colony and its potential expansion/spread threatens this ecologically valuable part of the chain. Specifically, in Rice Creek, the displacement of northern wild rice over time by an expanding curly-leaf pondweed population is of concern. The 2012 and 2013 mapping of northern wild rice in Rice Creek has not indicated this is yet occurring; in fact, wild rice acreage increased by nearly 10 acres in Rice Creek from 2012 to 2013 (Maps 7-10). During the mapping of northern wild rice in 2012 and 2013, the curly-leaf pondweed and northern wild rice populations were for the most part distinct, with curly-leaf pondweed inhabiting the deeper, channelized areas and northern wild rice inhabiting shallower water along the margins. However, where these two communities met, overlap or cohabitation/competition of curly-leaf pondweed and northern wild rice was observed (Photo 3.4-6).

Photo 3.4-6. Curly-leaf pondweed and northern wild rice (floating-leaf stage) in Rice Creek. Photo taken on July 1, 2013.

In spring (May 30, 2013), the northern wild rice was approximately one foot tall and not yet at the surface, while curly-leaf pondweed was approximately three to four feet tall. Where the boundaries of these two communities meet, it is possible that the curly-leaf pondweed may be competing with the northern wild rice for space and resources. The greater height of curly-leaf pondweed relative to the northern wild rice in the spring indicates that curly-leaf pondweed may shade out young rice plants or prevent seeds from germinating all together. The curly-leaf pondweed and northern wild rice in Rice Creek and Island Lake will continue to be monitored in the future, and hopefully the results of these ongoing surveys will shed some light on the dynamics between these two plant populations.

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 incomplete overview of some of the data that exists, particularly in regards to specific issues (e.g. spear fishery, fish stocking, angling regulations, etc) that were brought forth by the Manitowish Waters Chain stakeholders within the stakeholder survey and other planning activities. Although current fish data were not collected as a part of this project, the following information was compiled based upon some of the data available from the WDNR and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC) (WDNR 2014 & GLIFWC 2013A and 2013B).

Manitowish Waters Chain of Lakes Fishing Activity

Table 3.5-1 is a list of popular game fish that are present in many northern Wisconsin lakes. The Manitowish Waters Chain of Lakes is host to many of these species. On some northern Wisconsin lakes, management actions aimed at controlling exotic plant species or excessive native aquatic plant species are utilized and include either herbicide applications or mechanical harvesting. While the Implementation Plan will discuss these specific management actions as they relate to any of the Manitowish Waters Chain of Lakes, it should be noted that these measures are planned in a manner that reduces their potential impact on the system's fishery. Herbicide applications usually occur in May when the water temperatures are below 65°F, while mechanical harvesting occurs in mid-June and later. The goal is to reduce the impact upon the spawning environment which would be to remove the submergent plants that are actively growing at these low water temperatures. 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 vulnerable. 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.

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.

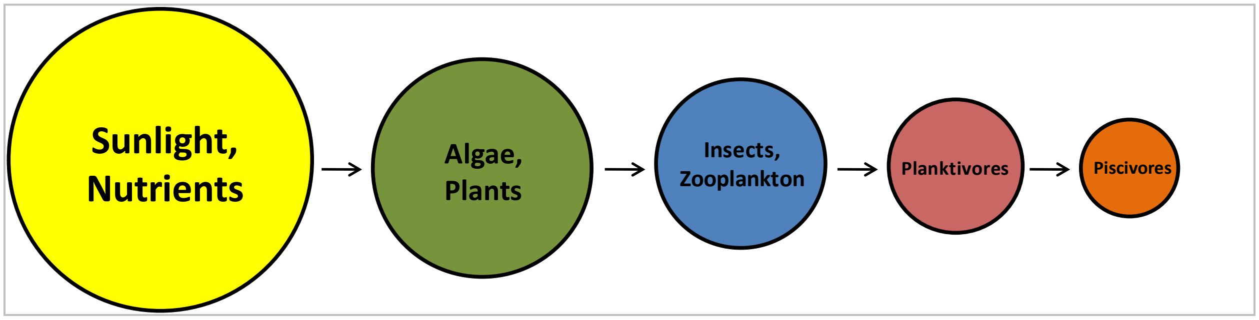


Figure 3.5-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

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.

Table 3.5-1. Gamefish documented in Manitowish Waters Chain WDNR surveys (WDNR 2012 with biological information from Becker, 1983)**.**

Common Name	Scientific Name	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie	*Pomoxis nigromaculatus*	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill	*Lepomis macrochirus*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass	*Micropterus salmoides*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge	*Esox masquinongy*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike	*Esox lucius*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Pumpkinseed	Lepomis gibbosus	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom	Crustaceans, rotifers, mollusks, flatworms, insect larvae (terrestrial and aquatic)
Rock Bass	Ambloplites rupestris	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep	Crustaceans, insect larvae, and other invertebrates
Smallmouth Bass	Micropterus dolomieu	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye	Sander vitreus	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch	Perca flavescens	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Native American Spearfishing

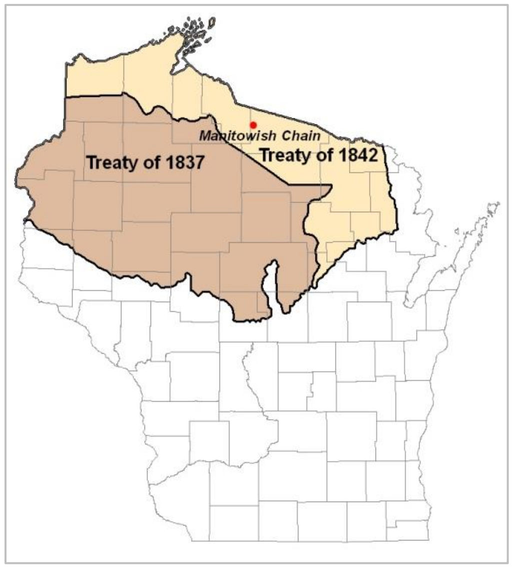


Figure 3.5-2. Location of Manitowish Waters Chain of Lakes within the Native American Ceded Territory (GLIFWC 2013A). This map was digitized by Onterra; therefore it is a representation and not legally binding.

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.5-2). The Manitowish Waters Chain falls within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on specified systems. This highly structured process begins with an annual meeting between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then an “allowable catch” is established, based upon estimates of a sustainable harvest of the fishing stock (age 3 to age 5 fish). This figure is usually about 35% of a lake's fishing stock, but may vary on an individual lake basis. In lakes where population estimates are out of date by 3 years, a standard percentage is used. The allowable catch number is then reduced by a percentage agreed upon by biologists that reflects the confidence they have in their population estimates for the particular lake. This number is called the “safe harvest level”. The safe harvest is a conservative estimate of the number of fish that can be harvested by a combination of tribal spearing and state-licensed anglers. The safe harvest is then multiplied by the Indian communities claim percent, or declaration. This result is called the quota, and represents the maximum number of fish that can be taken by tribal spearers (Spangler, 2009). Daily bag limits for walleye are then reduced for hook-and-line anglers to accommodate the tribal quota and prevent over-fishing. Bag limits reductions may be increased at the end of May on lakes that are lightly speared. The tribes have historically selected a percentage which allows for a 2-3 daily bag limit for hook-and-line anglers (USDI 2007). 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 2013B). This regulation limits the harvest of the larger, spawning female walleye.

Spearers are able to harvest muskellunge, walleye, northern pike, and bass during the open water season. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC 2013B). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed. An updated nightly 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 or the season ends. In 2011, a new reporting requirement went into effect on lakes with smaller quotas. Starting with the 2011 spear harvest season, on lakes with a harvestable quota of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

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 3.5-2 displays the walleye and muskellunge harvest frequency during the past 25 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 3.5-2. Native American spear harvest frequency on the Manitowish Waters Chain. The table summarizes the years in which each lake has experienced a walleye or muskellunge harvest. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Lake	Years of walleye harvest, 1989-2013	Years of muskellunge harvest, 1989-2013
Clear Lake	25	23
Island Lake	25	12
Rest Lake	25	15
Manitowish	20	10
Alder	16	1
Spider Lake	15	7
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 2013, 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 55.3%. On the average, Native American spear fishermen have harvested 77.2% of the declared quota on the Manitowish Waters Chain of Lakes with respect to walleye.

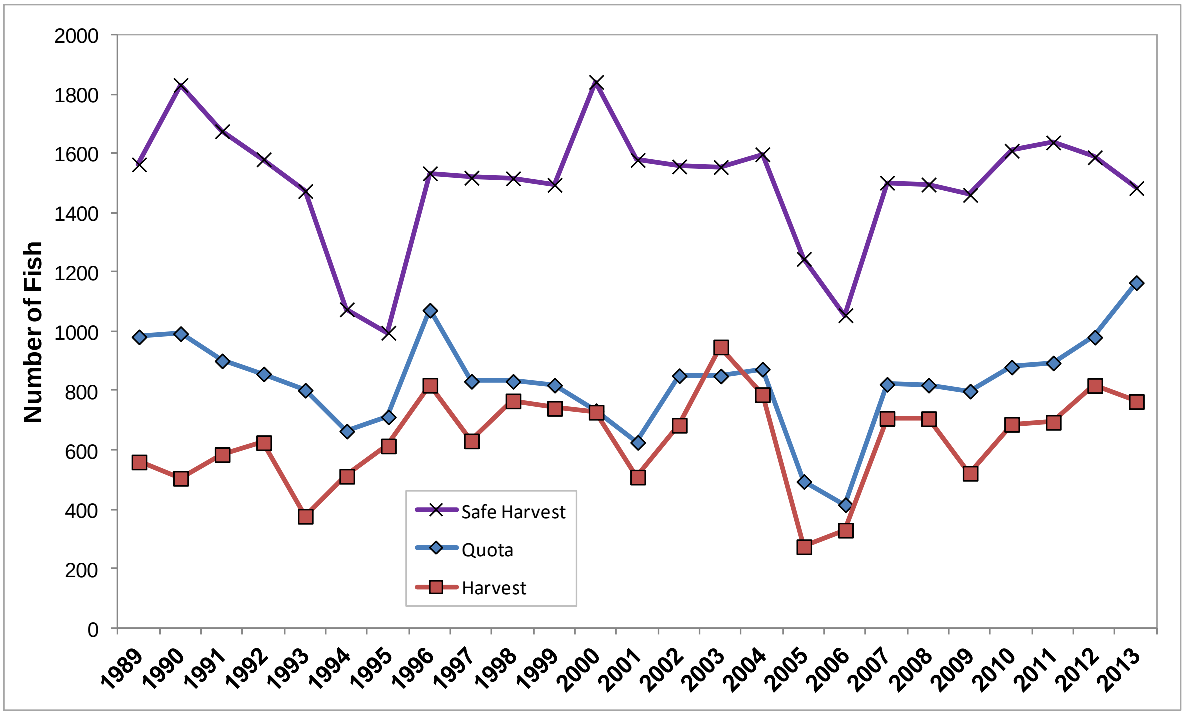


Figure 3.5-3. Total chain-wide walleye spear harvest statistics. Annual Native American walleye spear harvest statistics are summarized for 10 lakes in the Manitowish Waters Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

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.

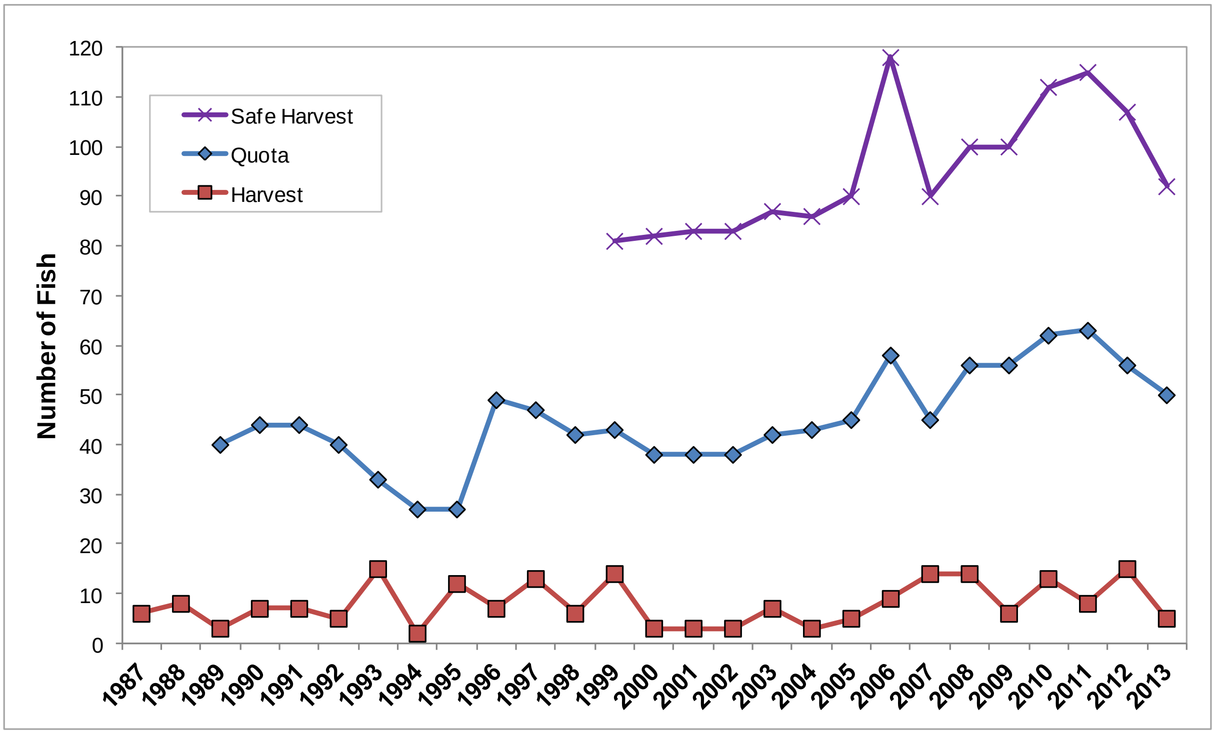


Figure 3.5-4. Total chain-wide muskellunge spear harvest statistics. Annual Native American muskellunge spear harvest statistics are summarized for 10 lakes in the Manitowish Waters Chain of Lakes. Data provided by WDNR fisheries staff (T. Cichosz, personal communication).

Overview of the Manitowish Waters Chain of Lakes Fishery

Currently, 35 species of fish have been documented within the Manitowish Waters Chain. 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.

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

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

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

Manitowish Waters Chain of Lakes 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			
	Fawn Lake			
Phase III – 2014	Alder Lake			
	Wild Rice Lake			
Phase IV – 2015	Little Star Lake			
	Manitowish Lake			
Phase V – 2016	Benson Lake			
	Stone Lake			
	Sturgeon Lake			
	Vance Lake			

**WDNR data, 2011*

4.0 SUMMARY AND CONCLUSIONS

While this project was spurred about largely due to the discovery of curly-leaf pondweed on the Manitowish Waters Chain of Lakes, the design of the phased approach captured detailed information about a wealth of components. These include aquatic invasive species inventories, of course, but also much baseline data on the Manitowish Waters Chain ecosystem as well as sociological information from Manitowish Waters Chain stakeholders regarding their use of the chain and its management. The objectives filled during this planning process have provided the NLDC, MWLA and other management entities with the information and guidance needed to manage the Manitowish Waters Chain 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 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 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. 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 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.	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.
Town of Boulder Junction	General Town Chair (Dennis Reuss, 715.385.2220, 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 (Karen Dixon, 715.543.8141)	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 (Azael Meza, 715.543.2085, azael@discoverycenter.net) Aquatic Invasive Species Coordinator (Anne Kretschmann, 715.543.2085, anne@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) Boulder Junction Executive Director (Kristen Tichacek, 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 / Data Manager (Celeste Hockings 715.588.4163, chockings@ldftribe.com)	Manages reservation water resources	As needed.	Collaborate on lake management activities including grants, monitoring, and implementation within tribal waters.
Great Lakes Indian Fish and Wildlife Commission	General (715.682.6619)	Resource management within Ceded Territory	As needed.	May be contacted to 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 (Catherine 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 genetic work, 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) (Laura Herman, 715.365.8998)	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. In order to retain volunteer help and recruit more volunteers for these tasks, the MWLA 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. NLDC serves as volunteer coordinator. The coordinator's duties are to recruit, train, supervise 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.

2. 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.
3. 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.
4. 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.
5. 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.
6. 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 more 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 6.6 miles (24%) of the Manitowish Waters Chain of Lakes shoreline (Phase I 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 about, 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 (Rest Lake Park) 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 such as Rest Lake Park, as needed

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

Timeframe: Initiate 2014.

Facilitator: MWLA Board of Directors with assistance from NLDC

Description: Despite the developed shoreland that surrounds the Manitowish Waters Chain of Lakes, a fair amount (12 miles or 44% of shoreline on Phase I 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/source a

Management Action: Investigate algal blooms on the Manitowish Waters Chain.

Timeframe: Initiate 2014.

Facilitator: NLDC; MWLA Board of Directors

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

There are thousands of species of algae world-wide in fresh and marine waters. The most common groups of freshwater algae include green algae, diatoms and cyanobacteria (blue-green algae). Green algae are the most abundant and can be found singly, in spherical colonies, filaments or in round clouds. Diatoms appear as yellow/green/brown algae and are rarely found in colonies. Their cell walls contain silica, which allows them to leave behind shells in lake sediments. These silica shells can be unearthed and examined by scientists to understand what past conditions were on a lake. Blue-green algae are found in Wisconsin and contain blue, red and green pigments. They are of concern when found in excess because some species can produce potentially dangerous toxins. Dogs and other domestic animals drinking water from the lakes can be adversely affected by these toxins. Blue-green algae blooms can be found in nutrient rich standing water, particularly in shallow waters with low flow such as ponds, sewage lagoons, or embayments of rivers and lakes. The chemical and physical factors needed for a bloom to form or to produce toxins are not entirely understood by scientists; not all algae blooms are blue-green algae and not all blue-green algae blooms produce toxins.

In 2013, some residents had concerns over an algae bloom in Papoose

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

Should Manitowish Waters Chain of Lakes residents encounter an algae bloom in the future, a sample will be collected by MWLA or NLDC staff and taken to Jim Kreitlow, WDNR Water Resources Management Specialist by NLDC staff. Jim is an expert in algae identification and biology and will be able to identify the algal species as well as assess the situation fully.

Action Steps:

1. MWLA Board of Directors appoint volunteer as point-of-contact for algae issues.
2. Volunteer establishes contact with NLDC and subsequently Jim Kreitlow (751.365.8947) 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. Lake stewardship: This includes preservation of the natural watershed, enhance lake habitat along the shoreland, volunteering opportunities for lake monitoring, etc. Additional lake stewardship responsibilities include following posted ordinances or courtesy codes for noise, light, etc.

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

3. Lake ecology: This category may include aquatic invasive species, native plant communities, water quality, fisheries management and habitat enhancement, etc. Many of the sources listed within the table under Management Goal 1 are

good resources for information on lake ecology. More information can be found on the WDNR's website for:

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

With advances in technology, sharing informational material has become multi-faceted. With many means of information dispersal, it takes time and technological know-how to update events and actions as they occur. 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: Continue control strategy for curly-leaf pondweed on the Manitowish Waters Chain of Lakes.

Timeframe: Continuation of current effort.

Facilitator: NLDC with assistance from TAISP

Description: Curly-leaf pondweed and Eurasian water milfoil have arguably become the most troublesome and concerning of all of Wisconsin's aquatic invasive species, due to their rapid spread across the state and impact on prime recreational areas. According to the WDNR website (accessed Nov. 2013) curly-leaf pondweed can now be found in 525 lakes and rivers throughout Wisconsin, while Eurasian water milfoil has been documented in 653 of these waterbodies. While these species have been found in the Midwest for decades, much is still being learned about their distribution, environmental preferences/tolerances, interaction with native species, and overall management.

With regards to aquatic invasive species management, early detection of pioneer colonies commonly leads to successful control and, in cases of very small infestations, possibly even eradication. When the level of invasive plant colonization reaches a widespread level, more time and capital investment is required to bring populations down to an acceptable level. The curly-leaf pondweed infestation within the Manitowish Waters Chain of Lakes currently resides in what can be considered three stages of development: early stage (Manitowish Lake, Manitowish River, Stone Lake- Rest Lake channel, Stone Lake and Island Lake) advanced stage (Island Lake) and well-established (Spider Lake – Island Lake channel and Rice Creek). Because there are several stages of curly-leaf pondweed colony growth within the chain, several control methodologies may be warranted to tackle each colony appropriately.

Hand removal of aquatic invasive species

Manual removal of aquatic invasive species is legal in Wisconsin, and does not require a permit from the WDNR or other entities. Manual removal methods must be conducted through hand pulling or hand-held devices that do not use external power sources, and the native plant population of the local area must not be excessively harmed.

In order for this technique to be successful, the entire plant (including the root) needs to be removed. It is important to remove all plant components: stem, leaves, flowers, and roots. Careful attention is required to ensure all plant fragments that may detach are collected and removed from the water. Disposal of aquatic plants should be planned before removal; locations such as gardens, flower beds or woodlots are acceptable. Local aquatic invasive species managers, including those listed on the table provided in Management Goal 1, can assist in details pertaining to this control method.

Hand removal is recommended for very early stage infestations, and can be very effective on single/few plant locations as well as small plant colonies or areas of scattered plants. When the size of an invasive plant colony increases, the size of the amount of effort must increase. At some point, the size and density of the invasive colony will become too much for hand removal efforts, which is when alternatives must be considered.

Herbicide treatments for aquatic invasive species

Traditionally, curly-leaf pondweed control consists of numerous annual herbicide treatments conducted in spring of each year. This kills each year's plants before they are able to produce reproductive turions (asexual seed-like structures). After multiple years of treatment, the turion (seed-bank) supply in the sediment becomes exhausted and the curly-leaf pondweed population decreases significantly. Normally a control strategy such as this includes five or more years of repetitive treatments to the same areas. As discussed within the Aquatic Plant Section, herbicide treatments targeting plant colonies on a spot treatment basis can be a complicated and difficult task. The dissipation of herbicides within the treatment area causes the concentration of herbicides to diminish within hours of application. Knowing this, measures must be taken with an herbicide application strategy in an effort to retain adequate concentrations for as long as possible within treatment areas.

The objective of this action is not to eradicate curly-leaf pondweed from the Manitowish Waters Chain of Lakes. The objective is to reduce curly-leaf pondweed to more manageable levels that minimally effect the aquatic ecosystem of these areas. In other words, the goal is to reduce the amount of curly-leaf pondweed in the Manitowish Waters Chain of Lakes to levels that may be suitable for smaller treatment areas or hand removal efforts to keep it under control. With this herbicide application plan, the flexibility of approaching curly-leaf pondweed colonies with a variety of tools is needed. Throughout the management process, communication between the MWLA, NLDC, the towns, Tribes and Tribal Natural Resources Departments, consultants, and the WDNR is crucial in order to determine the appropriate tools used based upon the conditions observed in the chain lakes.

Aquatic invasive species control strategy – monitoring methodology

Monitoring is a key aspect of any aquatic invasive species project, both to approach control in a strategic manner as well as to determine an action's effectiveness. The monitoring would also facilitate the "tuning" or refinement of the control strategy as the project progresses. The ability to tune the control strategies is important because it allows for the best results to be achieved within the plan's lifespan.

Using qualitative monitoring methodologies (changes in colonial density) to determine treatment success is difficult to use in curly-leaf pondweed management. Because of its unique life cycle, curly-leaf pondweed must be controlled in the spring prior to the plant reaching its peak growth stage (peak biomass), when the asexual reproductive turions are produced. Therefore, mapping of the plant at its peak growth means that no control actions can occur for a full season.

Quantitative monitoring using modified sub-sample point-intercept methodologies can be done the spring prior to treatment (pretreatment) and the next spring following the treatment (post treatment). Because of the early senescence of curly-leaf pondweed, a post treatment survey a few weeks following the treatment would not differentiate if a reduction in occurrence can be attributed to the herbicide application or the natural die-off (senescence) of the species. The frequency of curly-leaf pondweed each spring will be a direct result of the turions that sprouted the previous fall/winter. If the control strategy is effectively killing curly-leaf pondweed before it produces turions, a reduction in curly-leaf pondweed sprouting from those turions should be apparent after a few years of treatment. It must be noted that only looking at data within the confines of a single pre- and post treatment timeframe is problematic as it is suspected that the populations of curly-leaf pondweed within large, well-established colonies will be maintained for years from a large turion base that has built up over time.

Specifics on a five-year quantitative monitoring strategy for the Manitowish Waters Chain of Lakes are as follows:

1. *Mid to late June:* A lake-wide assessment of curly-leaf pondweed completed while the plant is at peak biomass, as was conducted in much of the chain in 2012 (discussed in the Aquatic Plant Section).
2. *Fall/Winter:* Treatment area delineation and control strategy determination developed based upon late-spring field assessments.
3. *Spring pre-treatment (May):* Quantitative data collected within treatment areas. Treatment area extents verified, known locations of smaller curly-leaf populations visited to determine if further growth (if any) warrants treatment.
4. *May/June:* Updated treatment areas submitted to the WDNR to serve as the final treatment permit, followed by completion of a curly-leaf pondweed herbicide treatment. Treatment occurs before surface water temperatures reach 60°F. Attention will be

paid to flow rates surrounding potential treatment dates.

5. *Years 2-4:* Treatment areas revisited in May/June to confirm growth of curly-leaf pondweed, quantitative data collected. New areas of curly-leaf pondweed growth visited to determine colonial extents and to determine if possible herbicide treatment warranted.

The sub-sampling of select proposed treatment areas, would occur during spring following a protocol developed by the WDNR. In general, control areas would be quantitatively monitored before and after treatments through data collection at specified locations within the treatment area. At each point, a rake would be used to sample the aquatic vegetation at the location. If curly-leaf pondweed is located, its abundance on the rake would be estimated using a scale of 1-3. Depth and substrate would be noted for each point. These data would then be used for comparisons with similar data collected after the treatment.

Funds from the WDNR Aquatic Invasive Grant Program were awarded to fund an initial control program in 2012 and 2013. Funds were secured by the NLDC under an Early Detection and Response Grant category which is available to sponsors dealing with an early infestation of aquatic invasive species. The NLDC and MWLA should be prepared to submit a grant application for a longer term monitoring and control program through the WDNR's Aquatic Invasive Species Established Population Control grant program. This grant would solidify funding for monitoring and treatment expenses in a five year program.

<u>*Success criteria*</u>

It is anticipated that through targeted control efforts against curly-leaf pondweed colonies located within the Manitowish Waters Chain of Lakes, a reduction in curly-leaf pondweed abundance and density will occur. Though this may be able to be observed through qualitative means, quantitative monitoring would be the primary means in treatment efficacy would be analyzed as it would be consistently measured through the course of the project. A successful treatment would include a significant reduction in curly-leaf pondweed frequency through a 50% decrease in frequency of occurrence. On existing treatment areas, this analysis would be examined over a five year basis. Newer colonies are expected to have less of a turion base due to relatively less plant density. For new treatment area sites that may come about during the course of the project, the 50% decrease in frequency success criteria would be implemented after two years of treatment.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the methods described above.
2. Apply for a WDNR Aquatic Invasive Species Established Population Control Grant based on developed project design.

3. Initiate control plan.
4. Revisit control plan in 5-6 years.

Management Action: Work with management partners to monitor curly-leaf pondweed and wild rice interactions within the Manitowish Waters Chain while assessing future management options.

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 currently unknown if 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. 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.

<u>Management Action:</u> 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/bouys 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/bouy that was created. For example, waterway marker bouys 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 bouy 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 AIS Coordinator Ted Ritter 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 bouys 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 and Japanese knotweed are known to exist in close proximity to the chain as well. 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. In the future, the NLDC will be looking to monitor against emerging plant and animal threats, such as spiny waterflea (*Bythotrephes longimanus*).

The NLDC has great capacity to lead efforts against these species. The NLDC will continue leading this initiative, while collaborating with the MWLA and Towns of Manitowish Waters and Boulder Junction on volunteer recruitment, funding and educational outreach.

Action Steps:

1. NLDC continues spearheading aquatic invasive species efforts through activities discussed above.
2. MWLA recruits volunteers and assists with outreach projects as needed.

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 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 Ted Ritter.
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.

Management Action: Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.

Timeframe: Continuation of current effort.

Facilitator: NLDC with assistance of TAISP

Description: Aquatic invasive species management has utilized many “tools” by lake managers, state legislators, and lake stakeholders. As a result of the spread of these species, programs such as Clean Boats Clean Waters have developed, educational media such as signs, posters, billboards and television commercials have been crafted, and laws have been generated to reduce the spread of these species. Some programs have been developed to take another step in stopping the spread of aquatic invasives, such as providing boat and trailer washing stations at public boat landings.

The aforementioned techniques may be categorized as preventative actions. Control actions for reducing aquatic invasive species include mechanical harvesting, aquatic herbicide applications, and hand removal through SCUBA or snorkeling. These techniques are not appropriate for all lakes or situations. In some cases, monitoring of an infestation is the most appropriate action. As management of aquatic invasive species continues, managers are learning more about the applicability of techniques and how they may be refined for better control. It is expected that time moves forward, these techniques will become more effective as managers develop better and creative ways to control aquatic invasive species.

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

Action Steps:

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

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

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

Timeframe: Enhancement of current effort.

Facilitator: NLDC and MWLA Committee

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

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

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

The importance of diversity in fish habitat cannot be stressed enough. As the Shoreland Condition Section and Fisheries Data Integration Section explains, coarse woody habitat, rocky shoals, organic silty substrate, and other factors are necessary to sustain a fishery of many species. Human disturbance of these aspects can translate upwards to a fish population, impacting spawning, predation, and food availability. Understanding this, the MWLA has undertaken a fish crib project which has generated much support from volunteers around the chain. In 2011, 17 cribs were added to Rest and Spider Lakes. 22 cribs were placed in Alder and Manitowish Lakes in 2012, and 12 cribs placed in Little Star Lake in 2013. 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. Along with other management partners, such as the WDNR or Vilas County Land and Water Conservation Department, TAISP will strive for open communication 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 continue to be facilitators of the discussion of habitat enhancement. 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. 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 and Zach Lawson. Mr. Gilbert (715.356.5211) oversees the lakes upstream of the Rest Lake Dam while Mr. Lawson (715.476.7847) oversees the lakes downstream of the 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.

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 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 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 Hydrolab DataSonde 5.

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 Bay	25	85	July 24, 2012
	Spider Lake	35	913	July 25, 2012
	Island Lake	73	655	WDNR July 5&8, 2011

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.

7.0 LITERATURE CITED

Becker, G.C. 1983. Fishes of Wisconsin. The University of Wisconsin Press. London, England.

Canter, L.W., D.I. Nelson, and J.W. Everett. 1994. Public Perception of Water Quality Risks – Influencing Factors and Enhancement Opportunities. Journal of Environmental Systems. 22(2).

Carpenter, S.R., Kitchell, J.F., and J.R. Hodgson. 1985. Cascading Trophic Interactions and Lake Productivity. BioScience, Vol. 35 (10) pp. 634-639.

Carlson, R.E. 1977 A trophic state index for lakes. Limnology and Oceanography 22: 361-369.

Christensen, D.L., B.J. Herwig, D.E. Schindler and S.R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. Ecological Applications. Vol. 6, pp 1143-1149.

Dinius, S.H. 2207. Public Perceptions in Water Quality Evaluation. Journal of the American Water Resource Association. 17(1): 116-121.

Elias, J.E. and M.W. Meyer. 2003. Comparisons of Undeveloped and Developed Shorelands, Northern Wisconsin, and Recommendations of Restoration. Wetlands 23(4):800-816. 2003.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Garn, H.S. 2001. Effects of Lawn Fertilizer on Nutrient Concentration in Runoff from 2Lakeshore Lawns, Lauderdale Lakes, Wisconsin. USGS Water-Resources Investigations Report 02-4130.

Garrison, P., Jennings, M., Mikulyuk, A., Lyons, J., Rasmussen, P., Hauxwell, J., Wong, D., Brandt, J. and G. Hatzenbeler. 2008. Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest. PUB-SS-1044.

Gettys, L.A., W.T. Haller, & M. Bellaud (eds). 2009. *Biology and Control of Aquatic Plants: A Best Management Handbook.* Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp. Available at http://www.aquatics.org/bmp.htm.

Graczyk, D.J., Hunt, R.J., Greb, S.R., Buchwald, C.A. and J.T. Krohelski. 2003. Hydrology, Nutrient Concentrations, and Nutrient Yields in Nearshore Areas of Four Lakes in Northern Wisconsin, 1999-2001. USGS Water-Resources Investigations Report 03-4144.

Great Lakes Indian Fish and Wildlife Service. 2013A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2013.

Great Lakes Indian Fish and Wildlife Service. 2013B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2013.

Hanchin, P.A., Willis, D.W. and T.R. St. Stauver. 2003. Influence of introduced spawning habitat on yellow perch reproduction, Lake Madison South Dakota. Journal of Freshwater Ecology 18.

Hauxwell, J., S. Knight, K.I. Wagner, A. Mikulyuk, M.E. Nault, M. Porzky and S. Chase. 2010. Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data entry and Analysis, and Applications. WDNR, Madison, WI. PUB-SS-1068 2010.

Jennings, M. J., E. E. Emmons, G. R. Hatzenbeler, C. Edwards and M. A. Bozek. 2003. Is littoral habitat affected by residential development and landuse in watersheds of Wisconsin lakes? Lake and Reservoir Management. 19(3):272-279.

Lathrop, R.D., and R.A. Lillie. 1980. Thermal Stratification of Wisconsin Lakes. Wisconsin Academy of Sciences, Arts and Letters. Vol. 68.

Lindsay, A., Gillum, S., and M. Meyer 2002. Influence of lakeshore development on breeding bird communities in a mixed northern forest. Biological Conservation 107. (2002) 1-11.

Madsen, J.D., R.M. Wersal, K.D. Getsinger, and L.S. Nelson. 2008. Sensitivity of Wild Rice (*Zizania palustris*) to the Aquatic Herbicide Triclopyr. J. Aquat. Plant Manage. 46: 150-154.

Netherland, M.D. 2009. Chapter 11, “Chemical Control of Aquatic Weeds.” Pp. 65-77 in *Biology and Control of Aquatic Plants: A Best Management Handbook*, L.A. Gettys, W.T. Haller, & M. Bellaud (eds.) Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210 pp

Nelson, L.S., C.S. Owens, and K.D. Getsinger. 2003. Response of Wild Rice to Selected Aquatic Herbicides. US Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-03014.

Newbrey, M.G., Bozek, M.A., Jennings, M.J. and J.A. Cook. 2005. Branching complexity and morphological characteristics of coarse woody structure as lacustrine fish habitat. Canadian Journal of Fisheries and Aquatic Sciences. 62: 2110-2123.

Nichols, S.A. 1999. Floristic quality assessment of Wisconsin lake plant communities with example applications. Journal of Lake and Reservoir Management 15(2): 133-141

Panuska, J.C., and J.C. Kreider. 2003. Wisconsin Lake Modeling Suite Program Documentation and User’s Maunal Version 3.3. WDNR Publication PUBL-WR-363-94.

Public Service Commission. 1939. Rest Lake Dam Operating Order 2-WP-295.

Radomski P. and T.J. Goeman. 2001. Consequences of Human Lakeshore Development on Emergent and Floating-leaf Vegetation Abundance. North American Journal of Fisheries Management. 21:46–61.

Reed, J. 2001. Influence of Shoreline Development on Nest Site Selection by Largemouth Bass and Black Crappie. North American Lake Management Conference Poster. Madison, WI.

Sass, G.G. 2009. Coarse Woody Debris in Lakes and Streams. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Vol. 1, pp. 60-69 Oxford: Elsevier.

Scheuerell M.D. and D.E. Schindler. 2004. Changes in the Spatial Distribution of Fishes in Lakes Along a Residential Development Gradient. Ecosystems (2004) 7: 98–106.

Shaw, B.H. and N. Nimphius. 1985. Acid Rain in Wisconsin: Understanding Measurements in Acid Rain Research (#2). UW-Extension, Madison. 4 pp.

Smith D.G., A.M. Cragg, and G.F. Croker.1991. Water Clarity Criteria for Bathing Waters Based on User Perception. Journal of Environmental Management.33(3): 285-299.

Spangler, G.R. 2009. "Closing the Circle: Restoring the Seasonal Round to the Ceded Territories". Great Lakes Indian Fish & Wildlife Commission. Available at: *www.glifwc.org/Accordian_Stories/GeorgeSpangler.pdf*

United States Department of the Interior – Bureau of Indian Affairs. 2007. Fishery Status Update in the Wisconsin Treaty Ceded Waters. Fourth Edition.

United States Environmental Protection Agency. 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

Weeks, J.G. and M.J. Hansen. 2009. Walleye and Muskellunge Movement in the Manitowish Waters Chain of Lakes, Vilas County, Wisconsin. North American Journal of Fisheries Management, Vol 29, pp. 791-804.

Wisconsin Department of Natural Resources. 2011. Wisconsin Endangered and Threatened Species Laws and List. WDNR PUBL-ER-001.

Wisconsin Department of Natural Resources. 2012. Evaluation of a New Operating Order for the Rest Lake Dam. WDNR Environmental Analysis.

Wisconsin Department of Natural Resources (WDNR). 2013. Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM). Bureau of Water Quality Program Guidance.

Wisconsin Department of Natural Resources. 2014. Fish data summarized by the Bureau of Fisheries Management. Available at: http://infotrek.er.usgs.gov/wdnr_public. Last accessed August 2014.

Woodford, J.E. and M.W. Meyer. 2003. Impact of Lakeshore Development on Green Frog Abundance. Biological Conservation. 110, pp. 277-284.

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

8.1 Rest Lake

An Introduction to Rest Lake

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

Field Survey Notes

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

Photo 8.1 Rest Lake, Vilas County

Lake at a Glance* – Rest Lake

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

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

8.1.1 Rest Lake Water Quality

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

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

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

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

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

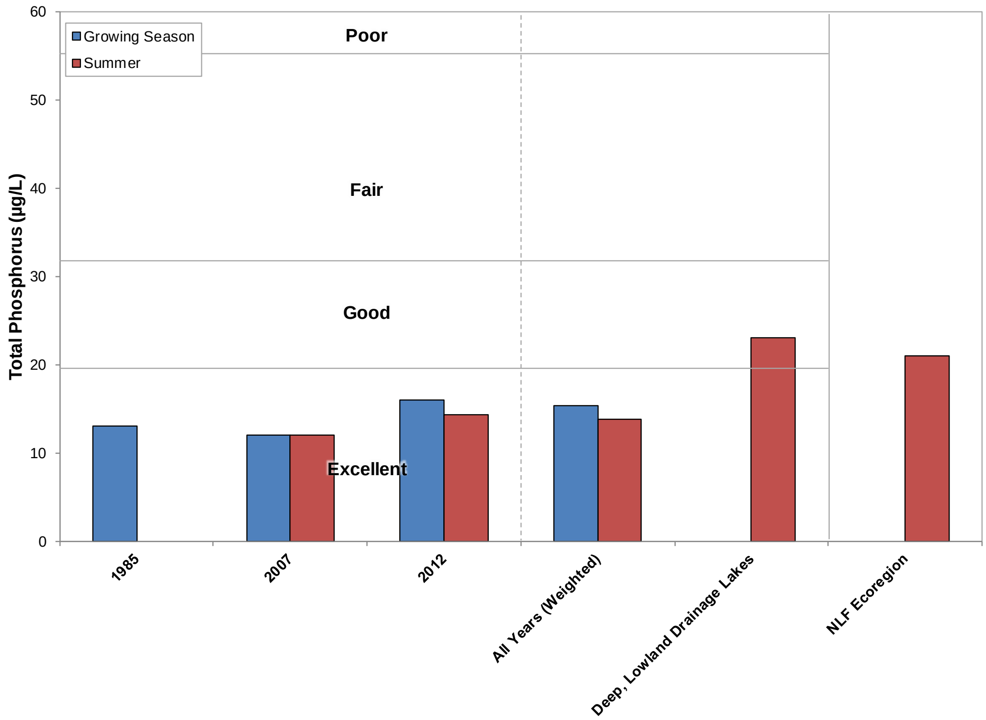


Figure 8.1.1-1. Rest Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

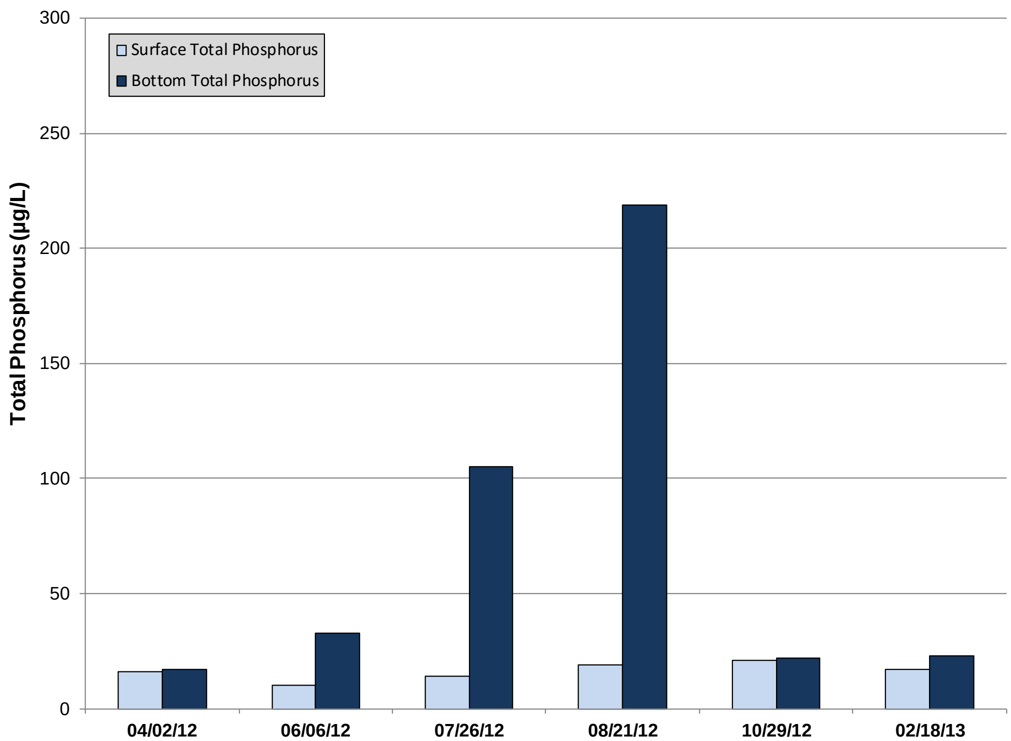


Figure 8.1.1-2. Rest Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

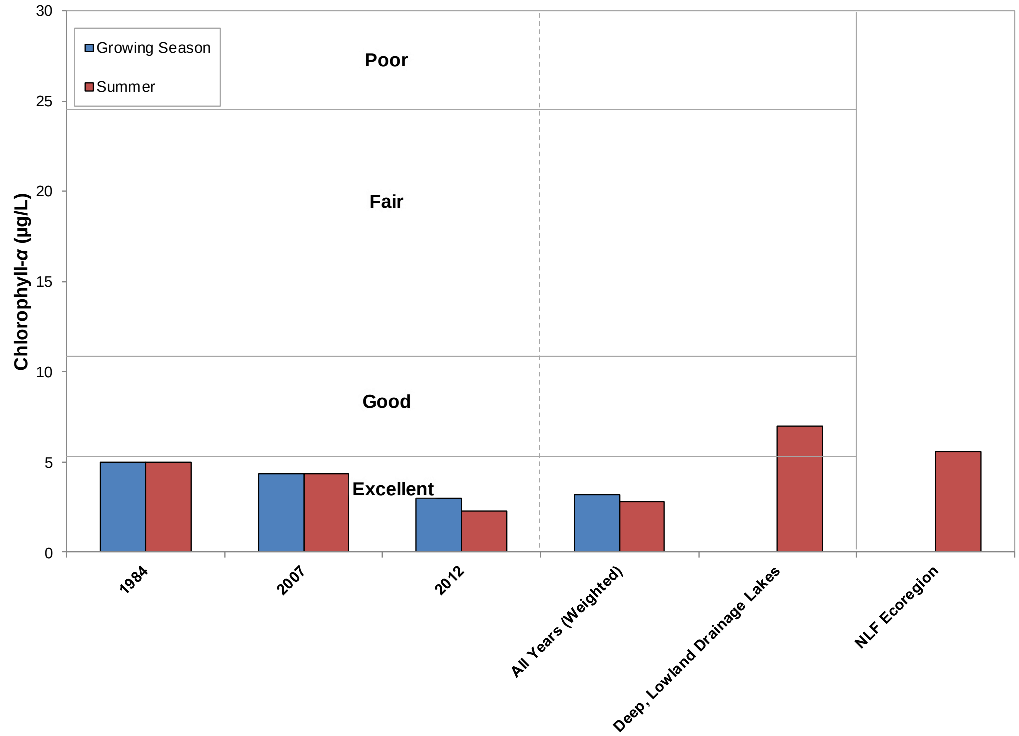


Figure 8.1.1-3. Rest Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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

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

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

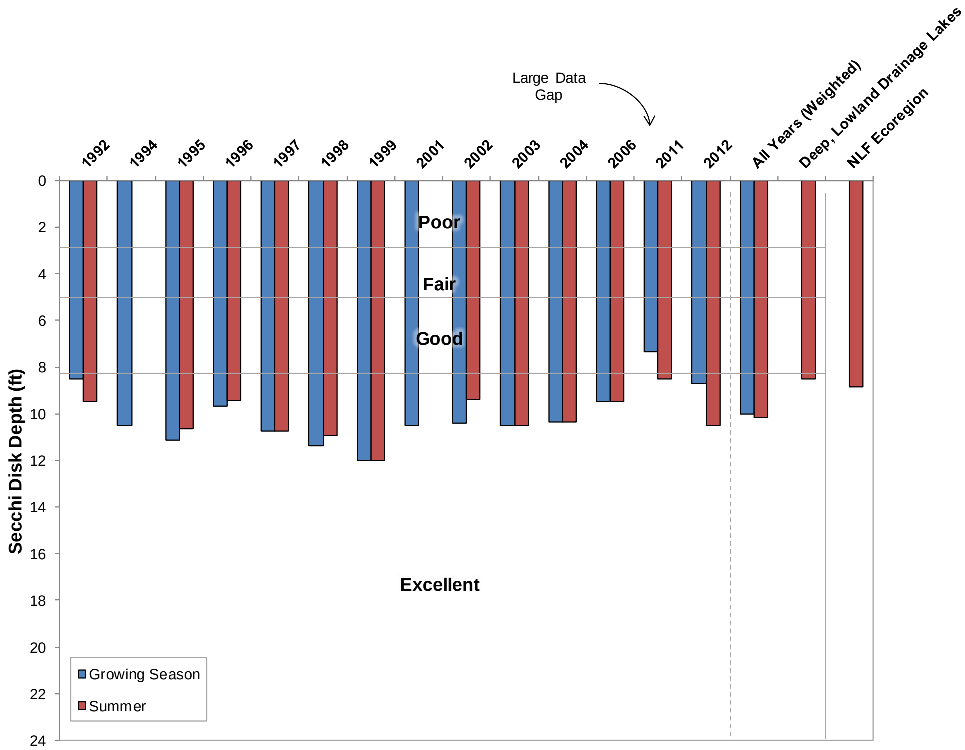


Figure 8.1.1-4. Rest Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Rest Lake Trophic State

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

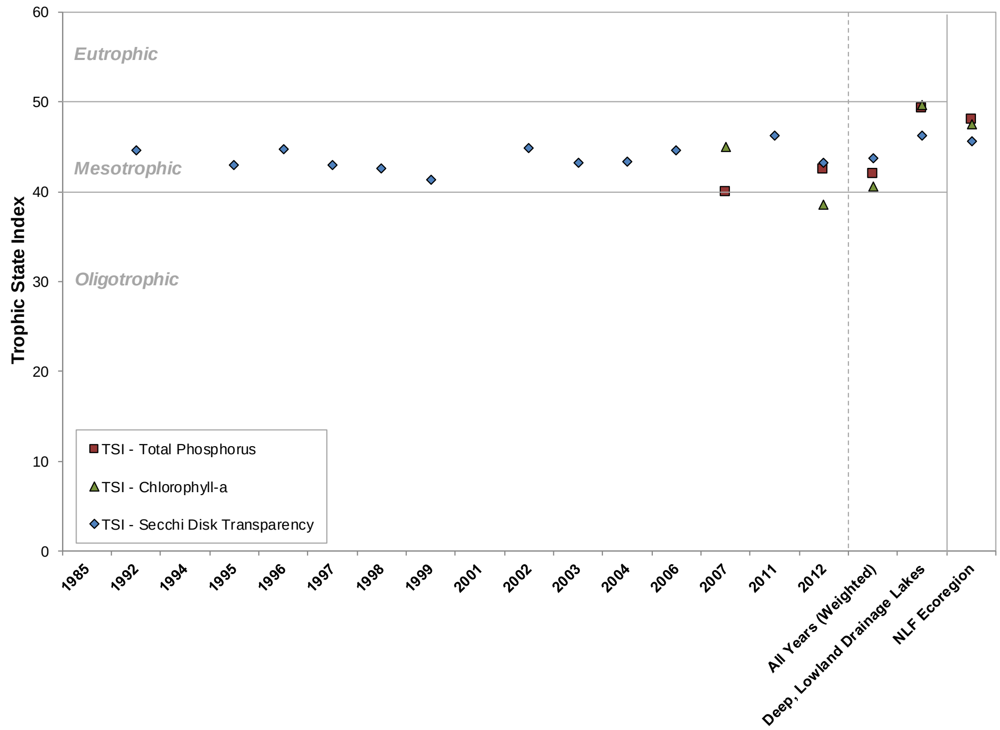


Figure 8.1.1-5. Rest Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Rest Lake

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

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

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

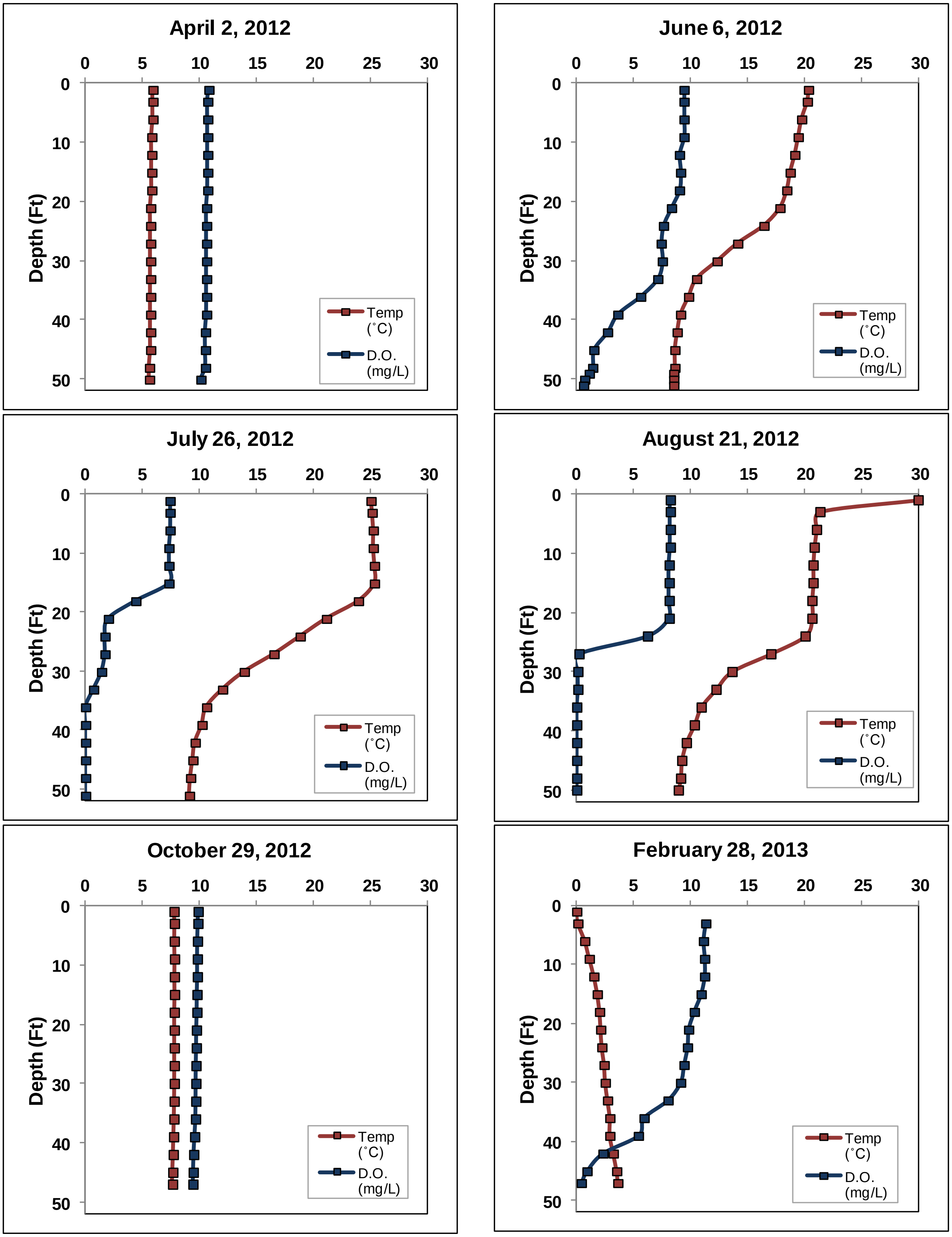


Figure 8.1.1-6. Rest Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Rest Lake

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

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

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

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

8.1.2 Rest Lake Watershed Assessment

Rest Lake's watershed is 146,515 acres in size. Compared to Rest Lake's size of 664 acres, this makes for an incredibly large watershed to lake area ratio of 223:1.

Exact land cover calculation and modeling of nutrient input to Rest Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.1.3 Rest Lake Shoreland Condition

Shoreland Development

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

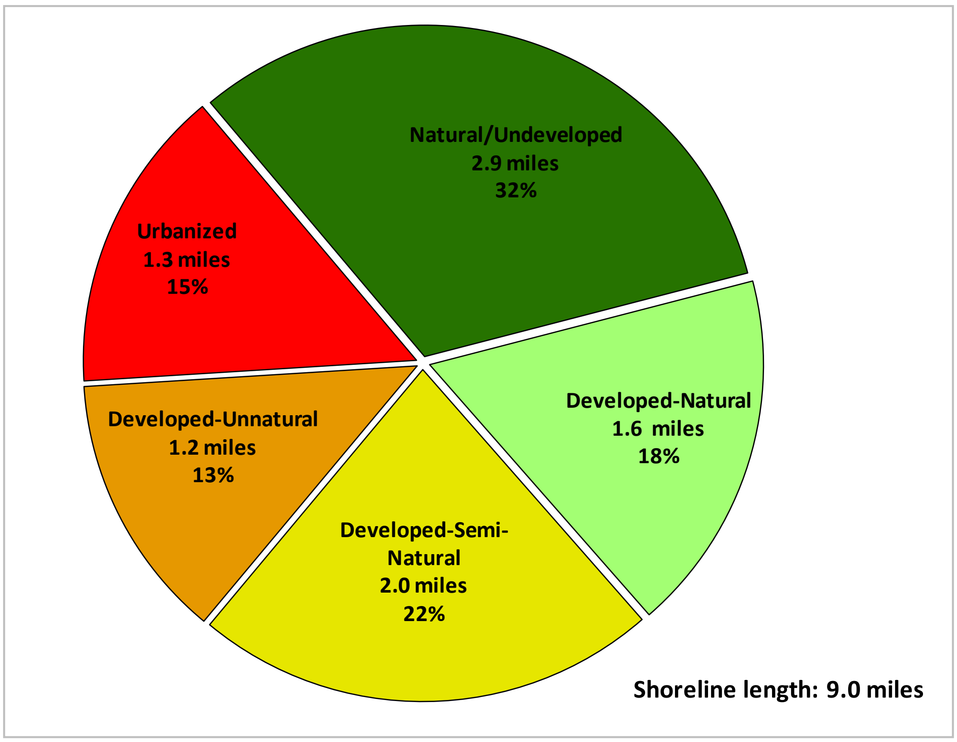


Figure 8.1.3-1. Rest Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Rest Lake Map 1.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Manitowish Waters Chain-wide document, research indicates that fish species prefer some

branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 59 total pieces of coarse woody habitat were observed along 9.0 miles of shoreline, which gives Rest Lake a coarse woody habitat to shoreline mile ratio of 7:1 (Figure 8.1.3-2). Locations of coarse woody habitat are displayed on Rest Lake Map 2. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

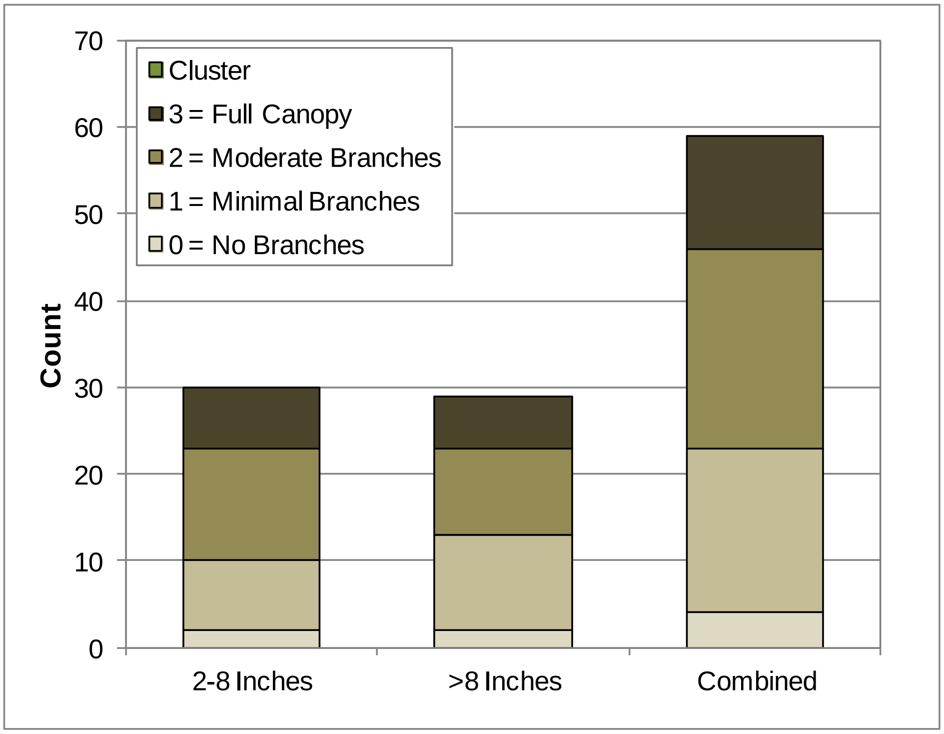


Figure 8.1.3-2. Rest Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of Rest Lake coarse woody habitat can be found on Rest Lake Map 2.

8.1.4 Rest Lake Aquatic Vegetation

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

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

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

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

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

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

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

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

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

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

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

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

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

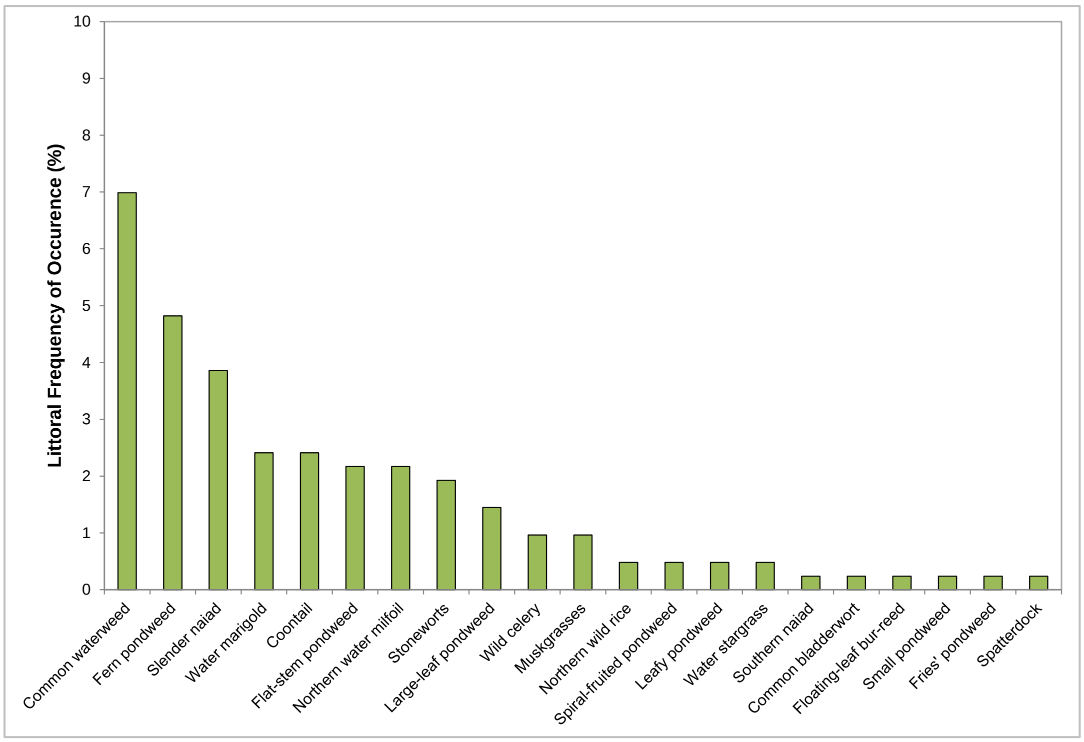


Figure 8.1.4-1. Rest Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

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

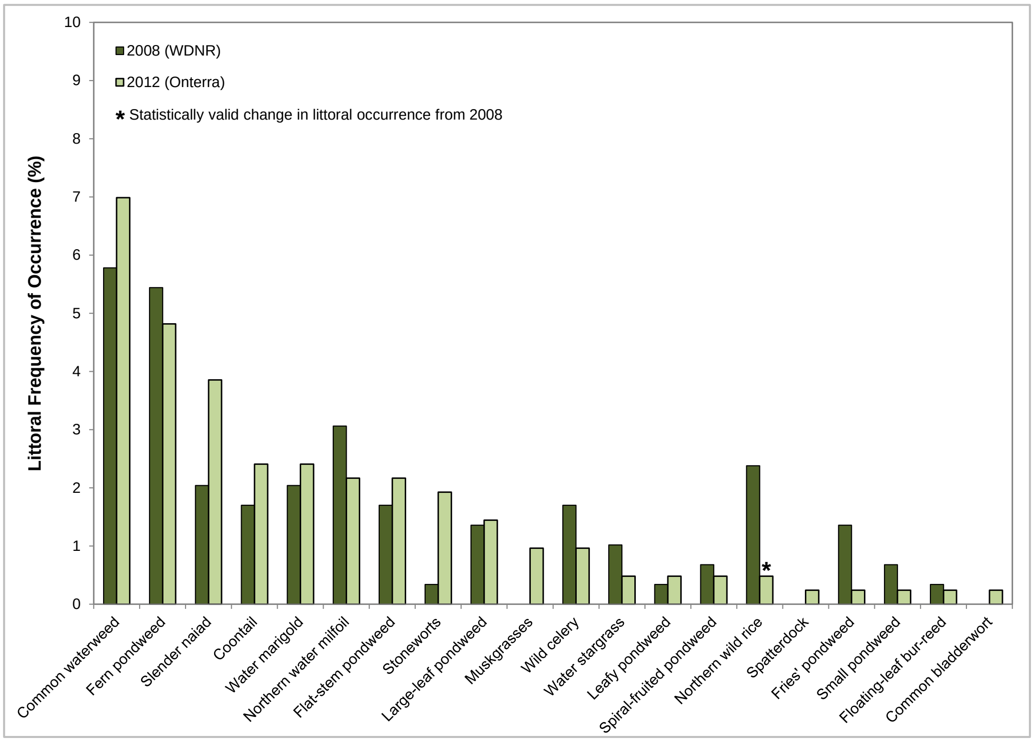


Figure 8.1.4-2. Rest Lake select aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

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

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

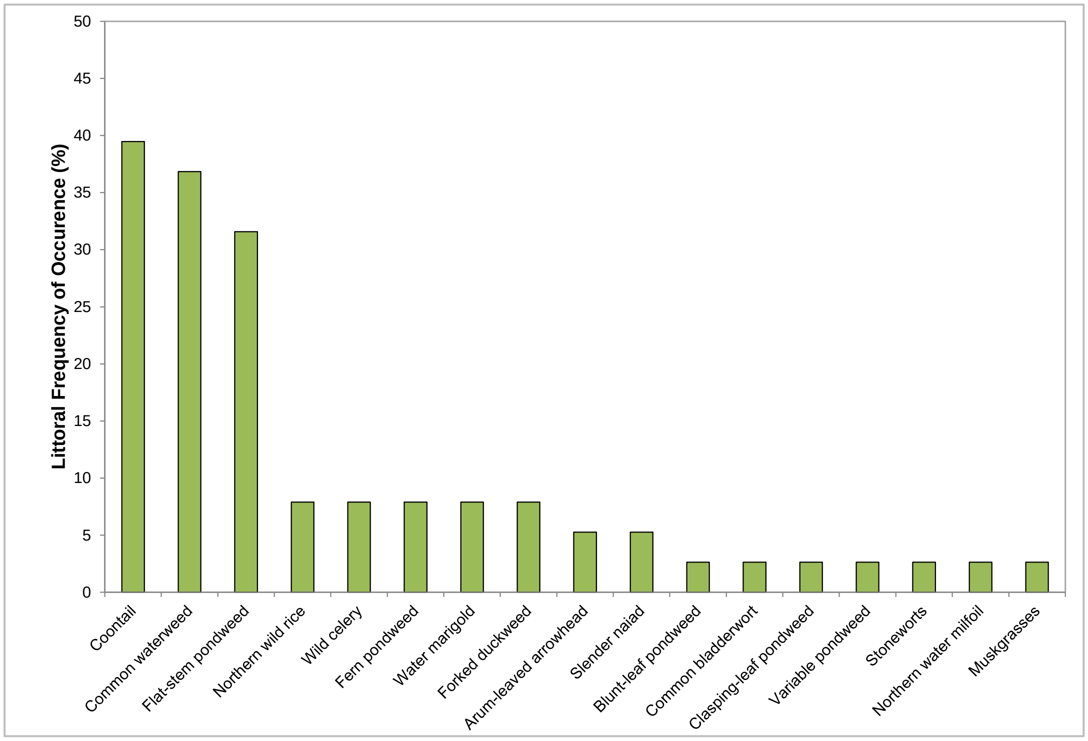


Figure 8.1.4-3. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey.

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

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

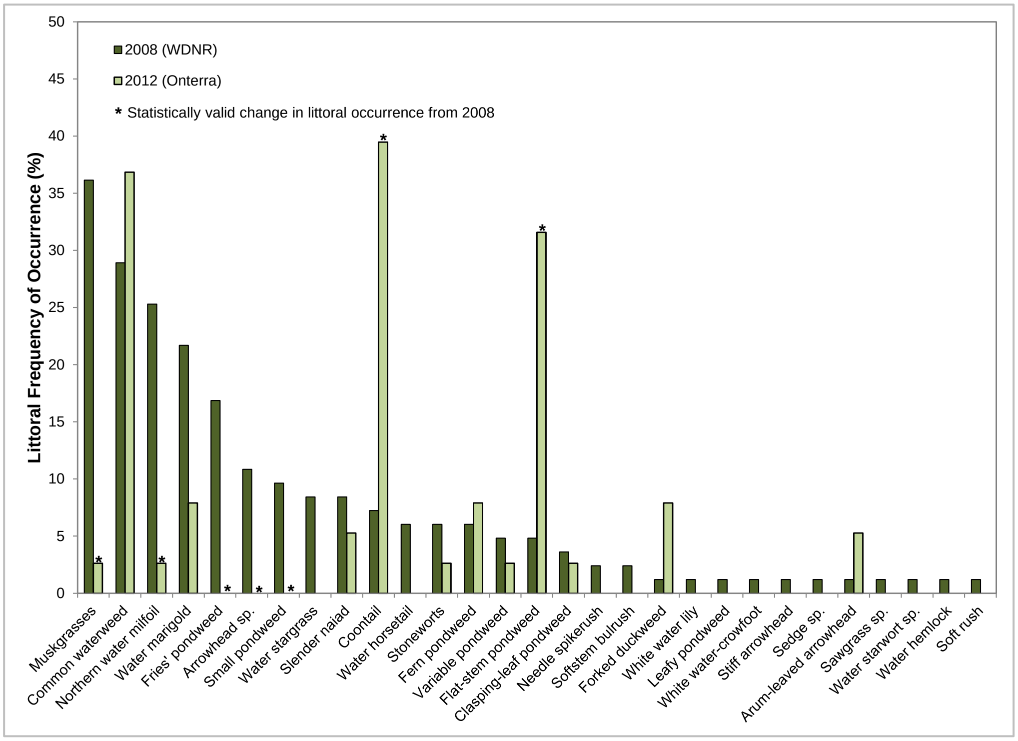


Figure 8.1.4-4. Papoose Bay aquatic plant littoral frequency of occurrence analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys.

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

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

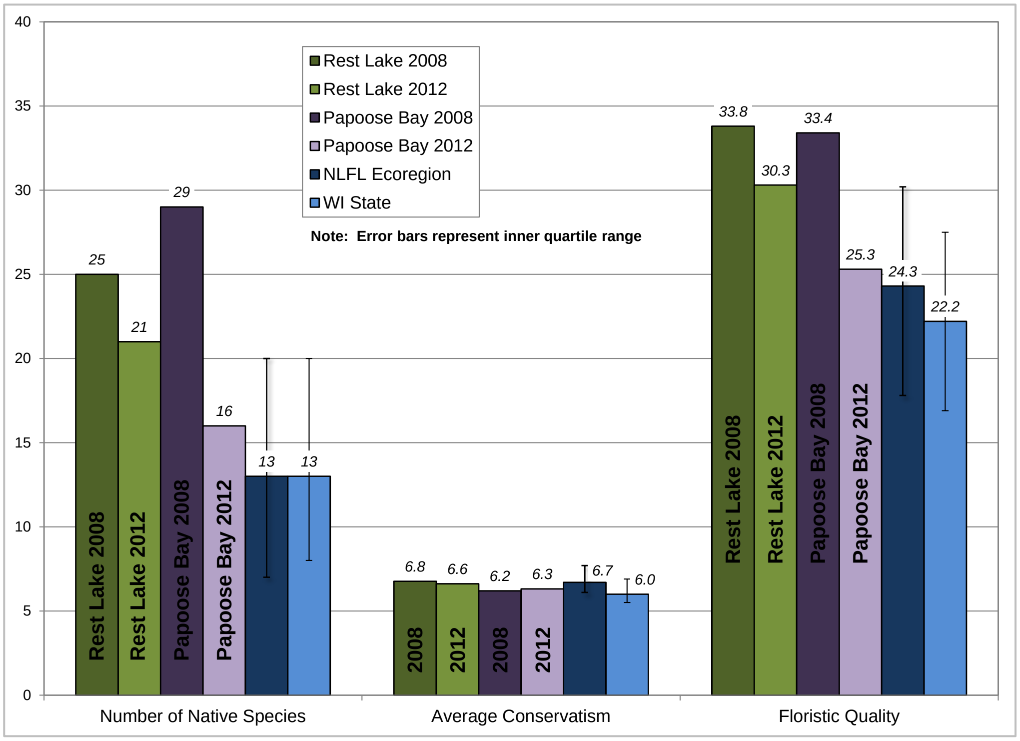


Figure 8.1.4-5. Rest Lake and Papoose Bay 2008 and 2012 Floristic Quality Analysis. Created using data from WDNR 2008 and Onterra 2012 point-intercept surveys. Analysis following Nichols (1999).

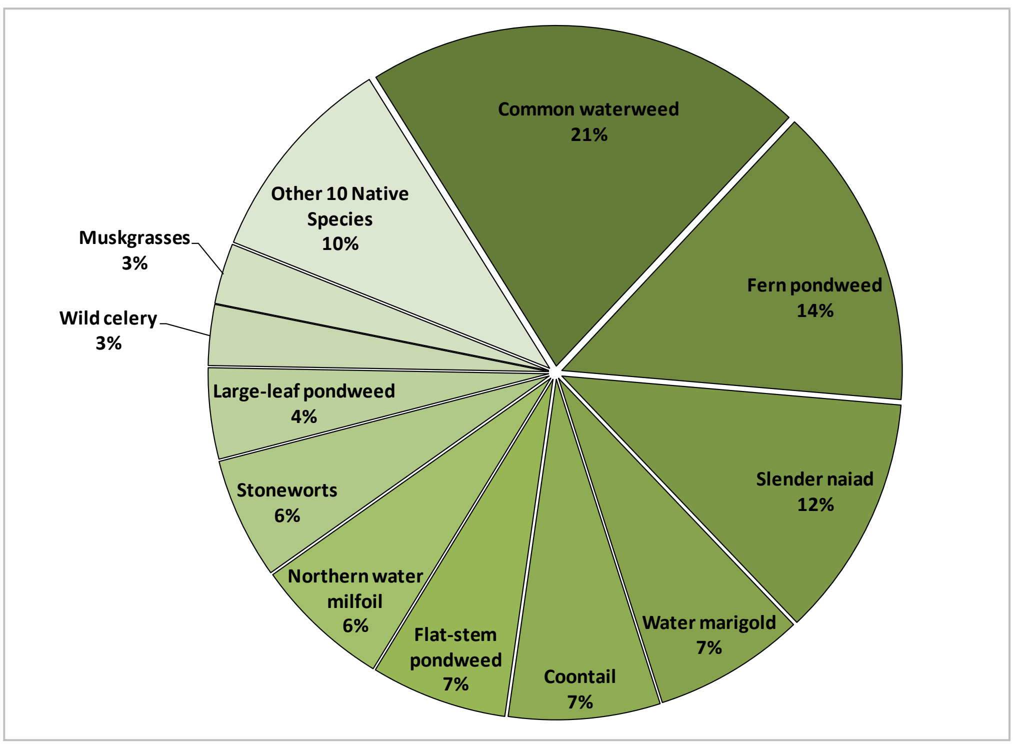


Figure 8.1.4-6. Rest Lake 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

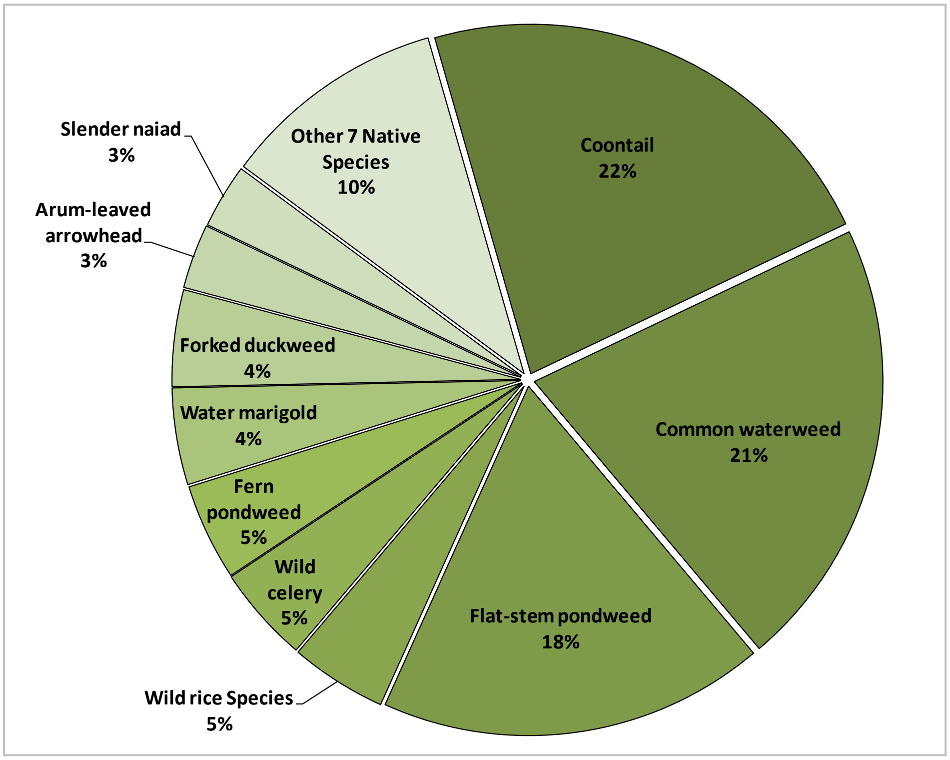


Figure 8.1.4-7. Papoose Bay 2012 aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

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

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

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

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

Papoose Bay

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

Mechanical Harvesting in Papoose Bay

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

8.1.5 Rest Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Rest Lake stakeholders, the MWLA, the NLDC, the Towns of Manitowish Waters and Boulder Junction, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Rest Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Manitowish Waters Chain of Lakes are geographically similar, they are certainly ecologically diverse, as evidenced by the studies described within this report. This diversity leads to the need for individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Manitowish Waters Chain have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Rest Lake's Implementation Plan illustrates how Rest Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Rest Lake

Chain-wide 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.**

Description: While the MWLA and NLDC are primarily responsible for facilitating partnerships with many defined management units, Rest Lake property owners may participate in this management goal by keeping the lines of communication open with the MWLA and NLDC, as well as members from other Manitowish Waters Chain lakes. This may be done through representation on the MWLA Board of Directors, active participation in the Lake Captain and Deckhand Program, involvement in MWLA and NLDC sponsored events, attending meetings, etc.

Management Action: **Increase the Manitowish Waters Chain of Lakes' volunteer base**

Description: Rest Lake property owners may assist in this management action by simply donating several hours of their time a year towards MWLA and NLDC activities including active participation in the Lake Captain and Deckhand program. While it is beneficial to volunteer on their own lake, the entire chain would benefit by having Rest Lake individuals assist with activities occurring on other lakes within the chain.

Chain-wide 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.**

Description: Currently, Rest Lake is enrolled in the CLMN's water clarity monitoring program. Although this is a great accomplishment, it must be continued in order to ensure the quality of Rest Lake is protected; the SWIMS database indicates volunteers have not collected information since 2012. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

A volunteer should be identified to continue water quality collection on Rest Lake. Volunteers from Rest Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: **Restore highly developed shoreland areas on the Manitowish Waters Chain.**

Description: As a part of this project, the entire Rest Lake shoreline was categorized in terms of its development. According to the results from this survey, 28% of the shoreline is in an urbanized or developed-unnatural state, while another 22% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

TAISP is prepared to provide Rest Lake property owners with the necessary informational resources to restore their developed shoreland, should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

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

Description: While 28% of the shoreland was found to be highly developed along Rest Lake, about 50% of the shoreland is currently in a very natural or undeveloped state. These areas are extremely important to protect for the environmental and aesthetic benefits they provide.

Rest Lake property owners interested in preserving their shoreland may contact the NLDC and Vilas County Land and Conservation office for information on land trusts, conservation easements, or best management practices. Implementing a number of these options will ensure the integrity of these undeveloped shorelands will remain well into the future.

Management Action: **Investigate algal blooms on the Manitowish Waters Chain.**

Description: While some algae blooms are natural and do not impact a lake ecosystem or human health in a negative manner, some blooms may cause recreational or health impairment. Rest Lake and Papoose Bay residents who observe algae blooms may contact the NLDC with their concerns. The NLDC can take the appropriate response in contacting WDNR officials about the matter. Residents may be asked to provide a sample of the algae for identification purposes.

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

Management Action: **Engage stakeholders on priority education items through participation in educational initiatives and efficient communication.**

Description: Rest Lake stakeholders can assist in the implementation of this action by actively participating in the MWLA and NLDC's educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events (including the Winter Rendezvous), participating in committees and the Lake Captain and Deckhand program, or simply notifying the MWLA or NLDC of concerns involving Rest Lake and its stakeholders.

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

Management Action: **Continue control strategy for curly-leaf pondweed on the Manitowish Waters Chain of Lakes.**

Description: Rest Lake residents may participate in curly-leaf pondweed control actions through a variety of passive means, such as keeping themselves up to date on aquatic invasive species matters through trainings, media releases, or participating in local meetings on the issue. Rest Lake residents can also assist by participating in the Lake Captain and Deckhand program, actively monitoring for curly-leaf pondweed. Additionally, lake users may report sightings of aquatic invasive species to the NLDC and remove floating CLP fragments when they are observed.

Management Action: **Maintain connection and open dialogue with management partners on matters pertaining to wild rice growth on the Manitowish Waters Chain.**

Description: As this is an action designed for a designated individual, there is no action necessary for Rest Lake property owners.

Management Action: **Continue control and monitoring efforts on purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris throughout the Manitowish Waters Chain of Lakes.**

Description: Emergent shoreland plants such as purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris can be easily identified and small infestations addressed through simple control methods. Rest Lake property owners may participate in this action through monitoring their shorelands and wetlands and removing plants in accordance with methods determined by the NLDC, MWLA and Vilas County Invasive Species Coordinator.

Management Action: **Continue locally-based aquatic invasive species monitoring and watercraft inspections.**

Description: Prevention of aquatic invasive species introduction remains the most effective way of minimizing the spread of this threat. Rest Lake property owners may participate in this initiative through volunteering for aquatic invasive species monitoring or Clean Boats Clean Waters inspections.

Management Action: **Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.**

Description: As this is an action designed for a designated individual, there is no action necessary for Rest Lake property owners.

Chain-wide 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.**

Description: Angling is often one of the most enjoyed recreational activities that takes place on Wisconsin lakes. A complete understanding of a lake's fishery is needed to base decisions off of, both for the fishery manager and the fisherman. Rest Lake residents can help the fishery of the Manitowish Waters Chain of Lakes by attending events aimed at educating the public about the chain's fishery, as well as volunteering for habitat improvement efforts, including shoreland preservation/remediation and coarse woody habitat projects.

Chain-wide 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 waterbodies.

Description: Though studies have been completed on Rest Lake as part of this chain-wide management planning project, it is up to Rest Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the goals described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Rest Lake may wish to revisit their lake management plan in 5-10 years or as necessary. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

Individual Rest Lake Management Goal

Management Goal 7: Maintain Reasonable Navigation within Rest Lake

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

Description: As Rest Lake stakeholders know, and this project's field studies have confirmed, the Papoose Bay area of Rest Lake is a productive system which includes abundant plant growth. So much growth, in fact, that navigation is impeded in much of this area. Papoose Bay Map 3 displays the mechanical harvesting plan that the Papoose Bay Association (PBA) has followed to ensure navigability for Papoose Bay property owners and others navigating through Rest Lake. This map illustrates two types of harvesting lanes; riparian access lanes, which are 15 feet wide, and common use lanes, which are 30 feet wide. Altogether, the total cutting area depicted consists of 1.7 acres, or 12.5% of the bay's surface area. The PBA has conducted harvesting in these areas since 2008 through annual permits that have been issued by the WDNR. These permits typically includes stipulations for harvesting activity, such as:

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

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

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

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

8.2 Island Lake

An Introduction to Island Lake

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

Field Survey Notes

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

Photo 8.2 Island Lake, Vilas County

Lake at a Glance* – Island Lake

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

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

8.2.1 Island Lake Water Quality

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

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

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

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

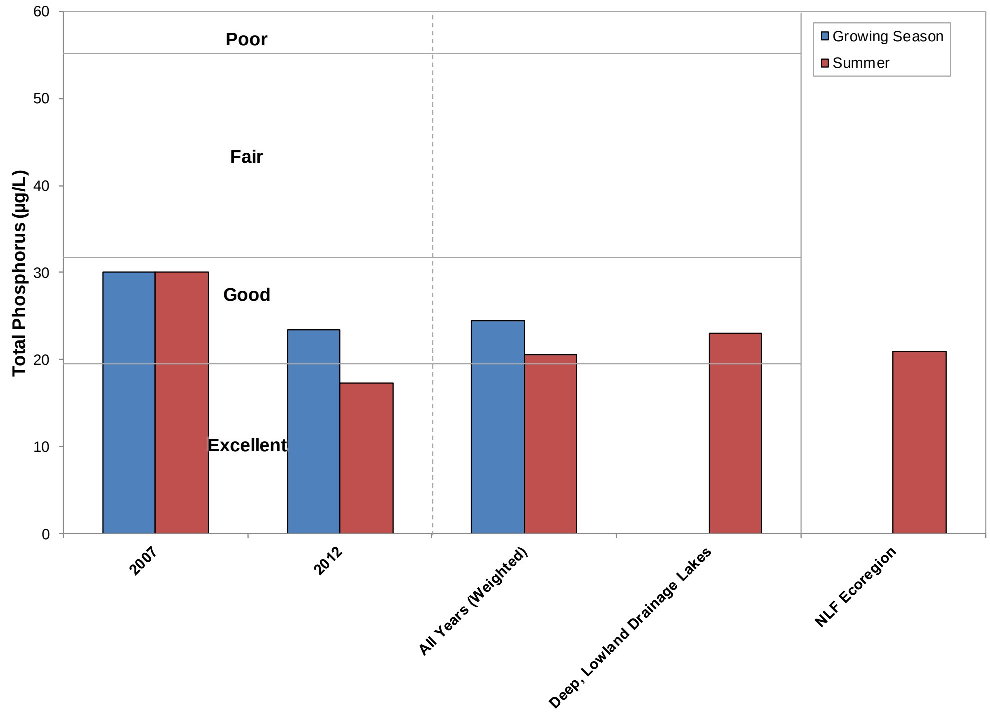


Figure 8.2.1-1. Island Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

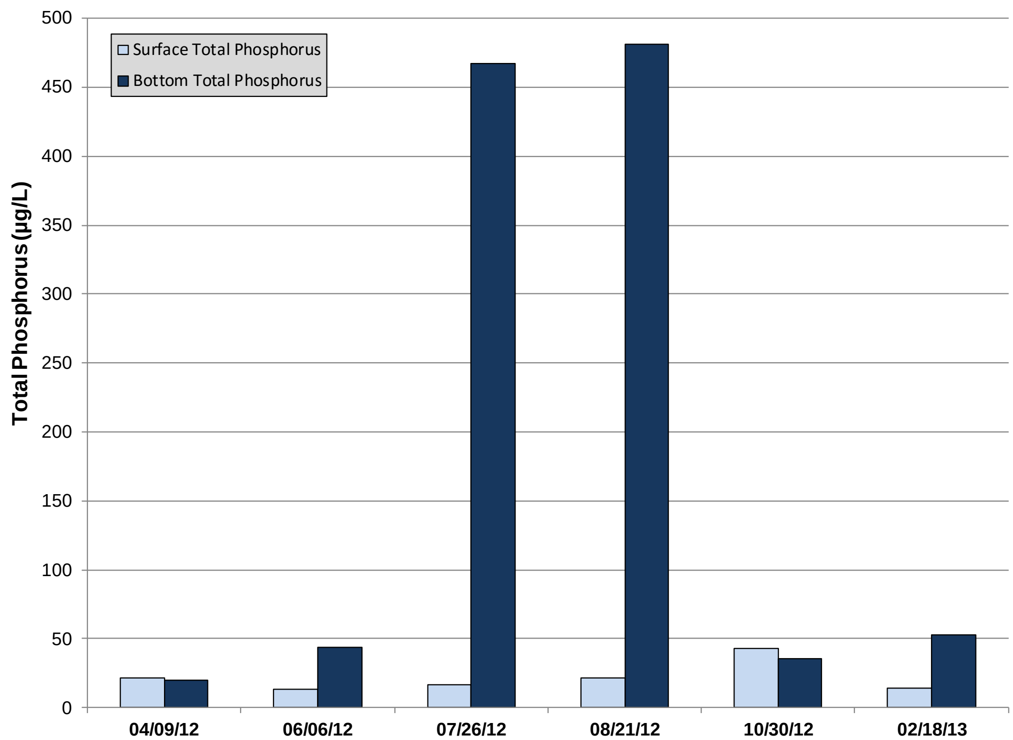


Figure 8.2.1-2. Island Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

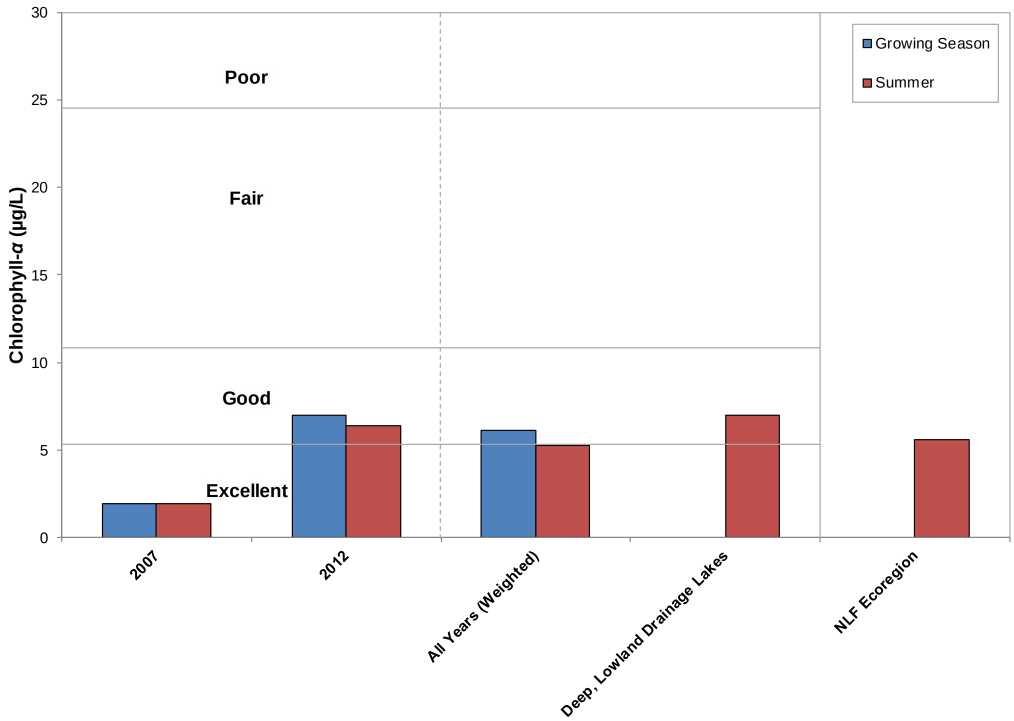


Figure 8.2.1-3. Island Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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

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

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

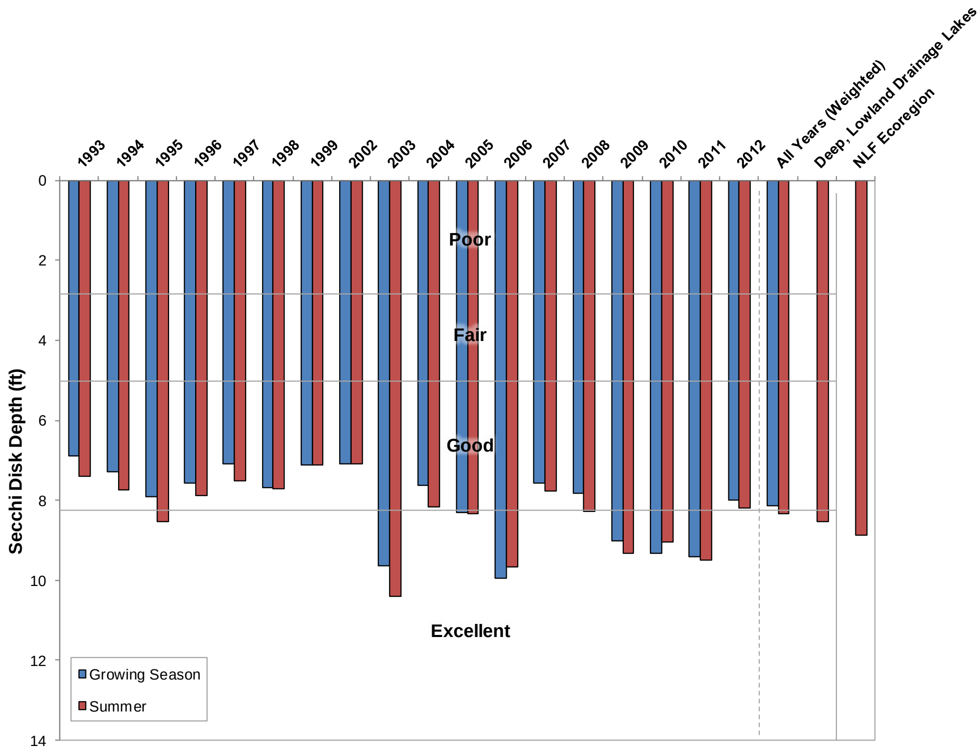


Figure 8.2.1-4. Island Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Island Lake Trophic State

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

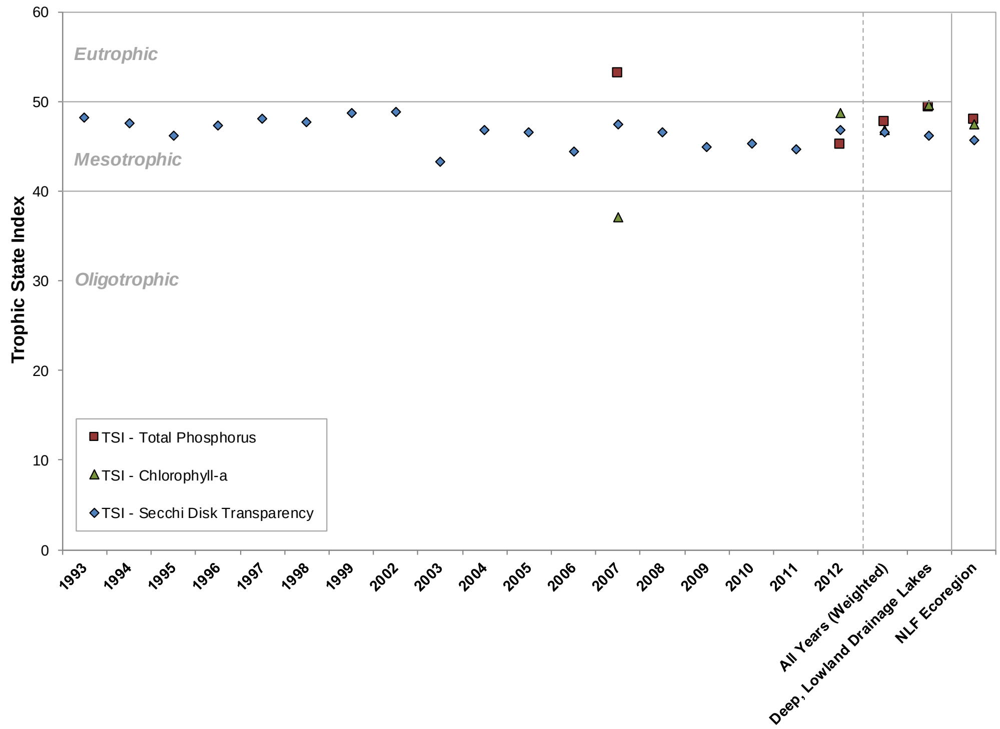


Figure 8.2.1-5. Island Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Island Lake

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

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

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

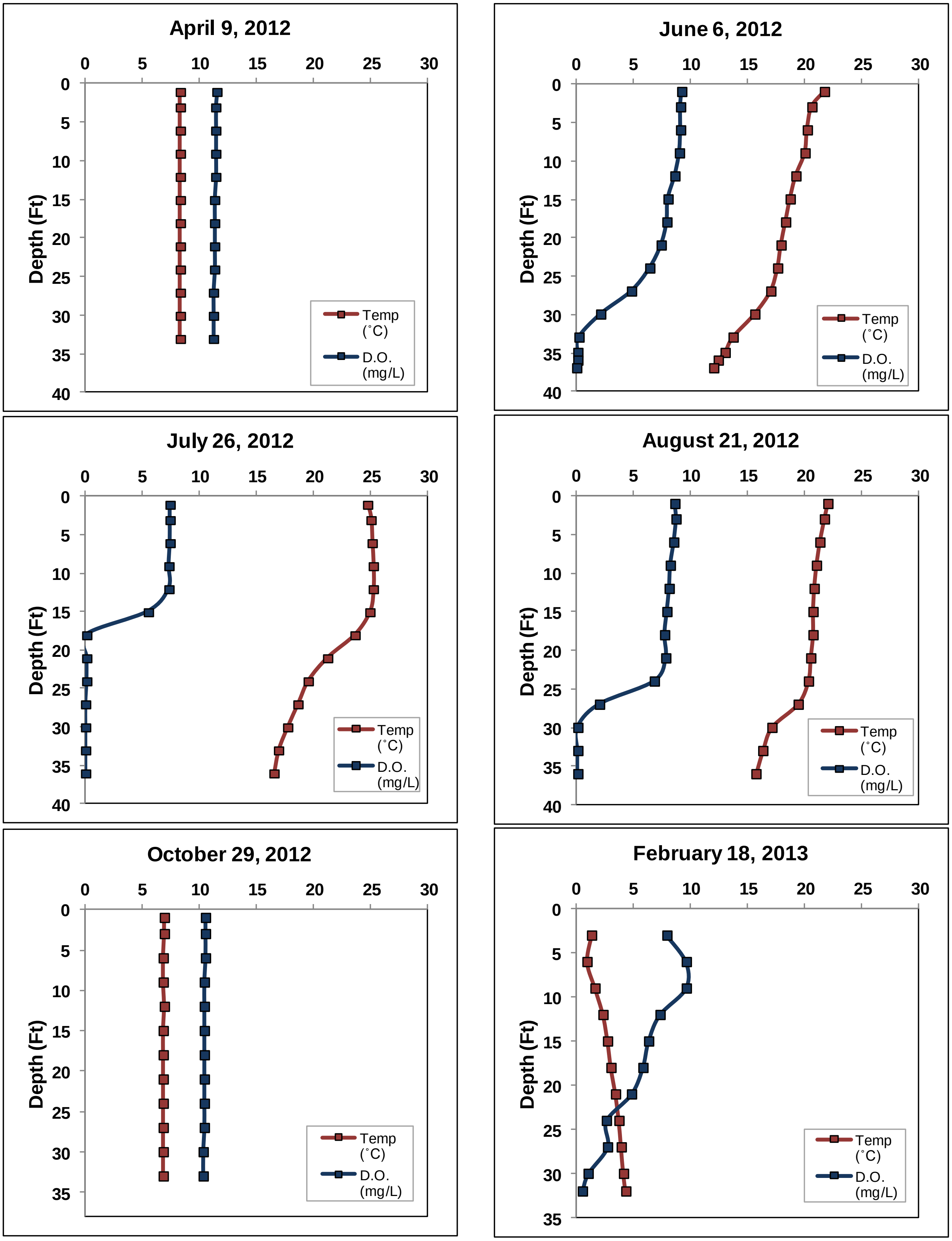


Figure 8.2.1-6. Island Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Island Lake

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

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

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

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

8.2.2 Island Lake Watershed Assessment

Island Lake's watershed is 79,573 acres in size. Compared to Island Lake's size of 918 acres, this makes for an incredibly large watershed to lake area ratio of 86:1.

Exact land cover calculation and modeling of nutrient input to Island Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.2.3 Island Lake Shoreland Condition

Shoreland Development

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

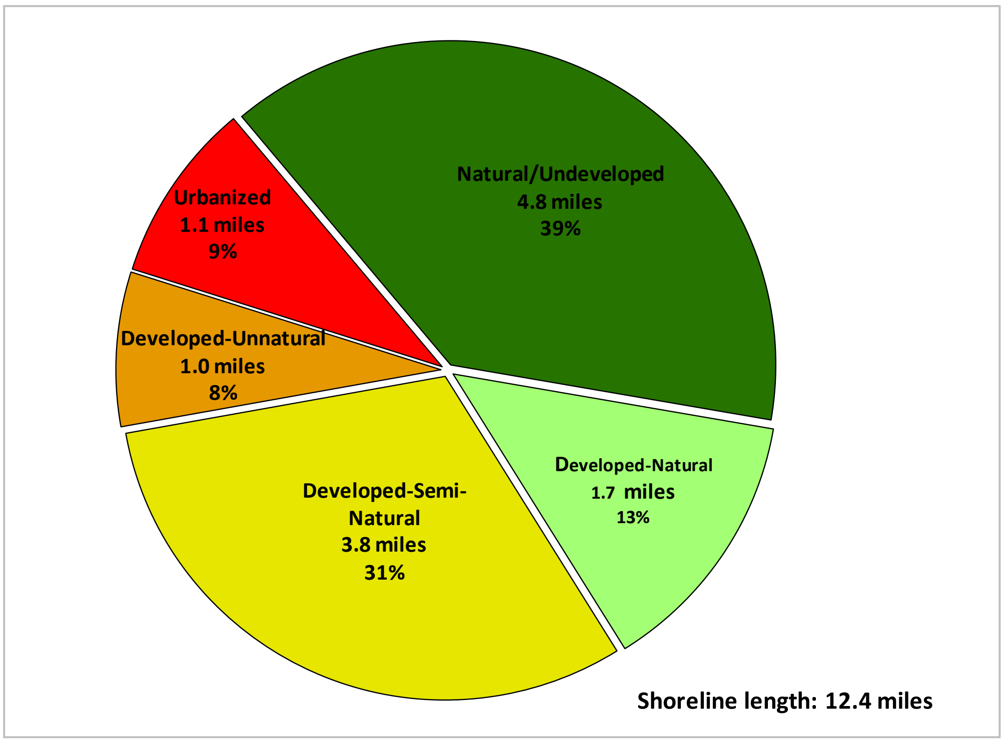


Figure 8.2.3-1. Island Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Island Lake Map 1.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Manitowish Waters Chain-wide document, research indicates that fish species prefer some

branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 83 total pieces of coarse woody habitat were observed along 12.4 miles of shoreline, which gives Island Lake a coarse woody habitat to shoreline mile ratio of 7:1. Locations of coarse woody habitat are displayed on Island Lake Map 2. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

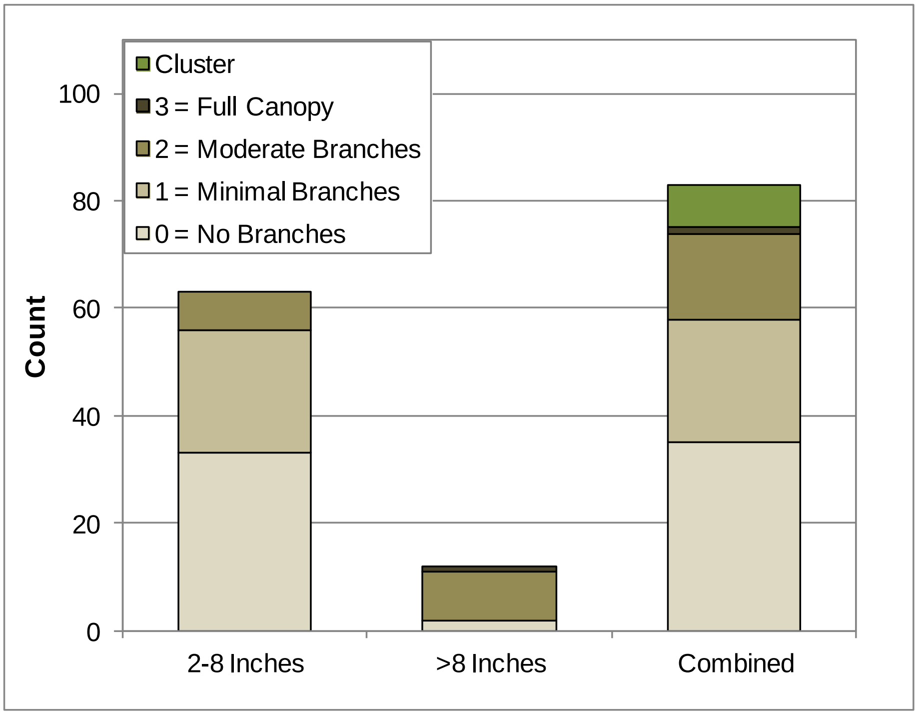


Figure 8.2.3-2. Island Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of Island Lake coarse woody habitat can be found on Island Lake Map 2.

8.2.4 Island Lake Aquatic Vegetation

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

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

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

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

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

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

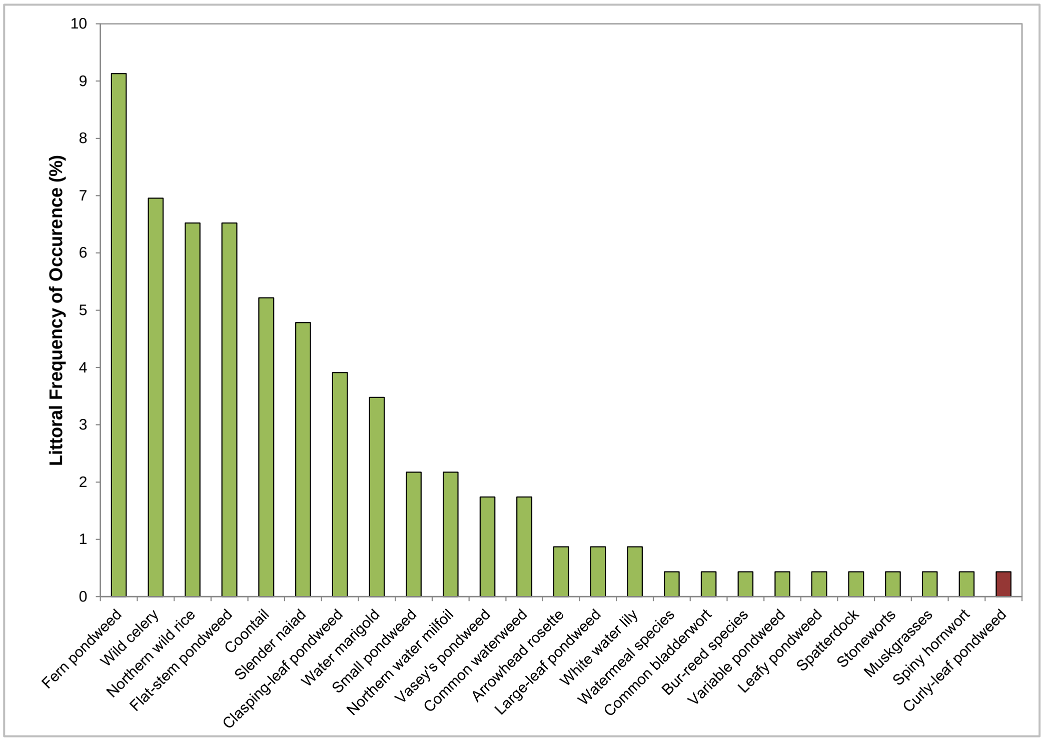


Figure 8.2.4-1. Island Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2011 WDNR point-intercept survey. Exotic species indicated in red.

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

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

During aquatic plant inventories, 40 species of native aquatic plants (including incidentals) were found in Island Lake, along with one non-native plant. Because of this, one may assume that the system would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence the diversity. The diversity index for Island

Lake's plant community (0.93) lies above the Northern Lakes and Forest Lakes ecoregion value (0.86), indicating the lake holds exceptional diversity.

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

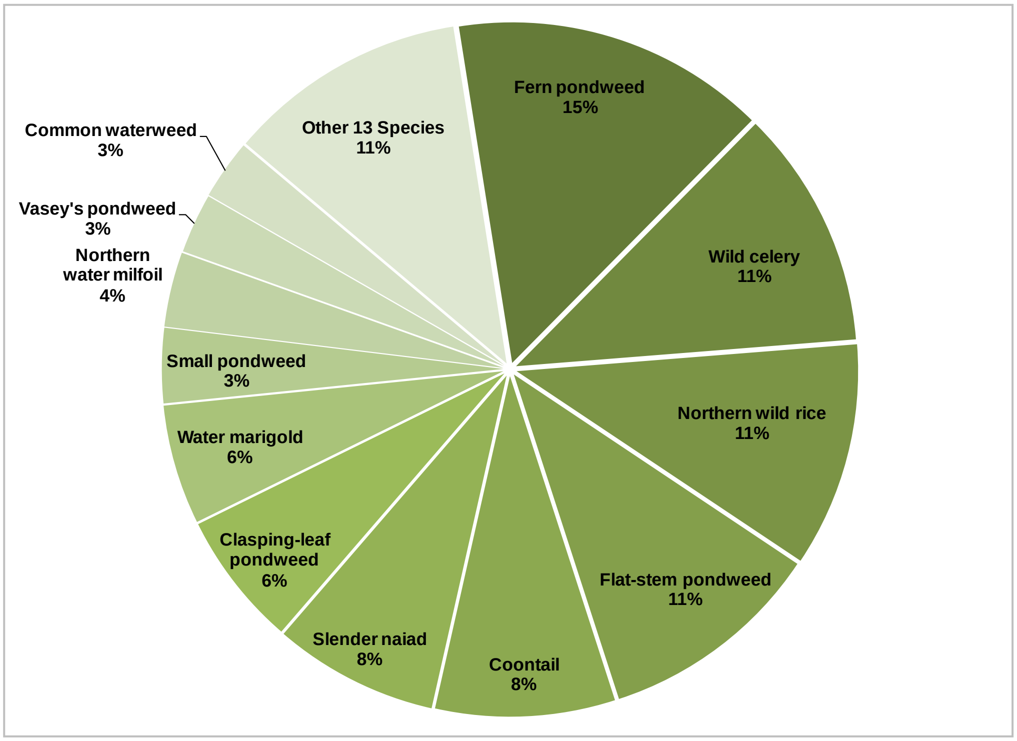


Figure 8.2.4-2 Island Lake aquatic plant relative frequency of occurrence analysis. Created using data from a 2011 WDNR point-intercept survey.

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

The quality of Island Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas. The 2012 community map indicates that approximately 298 acres of the lake contains these types of plant communities (Island Lake Map

4, Table 8.2.4-2). Twenty-two floating-leaf and emergent species were located on Island Lake (Table 8.2.4-1), all of which provide valuable wildlife habitat.

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

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

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

8.2.4 Island Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Island Lake stakeholders, the MWLA, the NLDC, the Towns of Manitowish Waters and Boulder Junction, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Island Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Manitowish Waters Chain of Lakes are geographically similar, they are certainly ecologically diverse, as evidenced by the studies described within this report. This diversity leads to the need for individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Manitowish Waters Chain have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Island Lake's Implementation Plan illustrates how Island Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Island Lake

Chain-wide 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.**

Description: While the MWLA and NLDC are primarily responsible for facilitating partnerships with many defined management units, Island Lake property owners may participate in this management goal by keeping the lines of communication open with the MWLA and NLDC, as well as members from other Manitowish Waters Chain lakes. This may be done through representation on the MWLA Board of Directors, active participation in the Lake Captain and Deckhand Program, involvement in MWLA and NLDC sponsored events, attending meetings, etc.

Management Action: **Increase the Manitowish Waters Chain of Lakes' volunteer base**

Description: Island Lake property owners may assist in this management action by simply donating several hours of their time a year towards MWLA and NLDC activities including active participation in the Lake Captain and Deckhand program. While it is beneficial to volunteer on their own lake, the entire chain would benefit by having Island Lake individuals assist with activities occurring on other lakes within the chain.

Chain-wide 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.**

Description: Currently, Island Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Island Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Island Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Island Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: **Restore highly developed shoreland areas on the Manitowish Waters Chain.**

Description: As a part of this project, the entire Island Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while another 31% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

TAISP is prepared to provide Island Lake property owners with the necessary informational resources to restore their developed shoreland, should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

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

Description: While 17% of the shoreland was found to be highly developed along Island Lake, about 52% of the shoreland is currently in a very natural or undeveloped state. These areas are extremely important to protect for the environmental and aesthetic benefits they provide.

Island Lake property owners interested in preserving their shoreland may contact the NLDC and Vilas County Land and Conservation office for information on land trusts, conservation easements, or best management practices. Implementing a number of these options will ensure the integrity of these undeveloped shorelands will remain well into the future.

Management Action: **Investigate algal blooms on the Manitowish Waters Chain.**

Description: While some algae blooms are natural and do not impact a lake ecosystem or human health in a negative manner, some blooms may cause recreational or health impairment. Island Lake residents who observe algae blooms may contact the NLDC with their concerns. The NLDC can take the appropriate response in contacting WDNR officials about the matter. Residents may be asked to provide a sample of the algae for identification purposes.

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

Management Action: **Engage stakeholders on priority education items through participation in educational initiatives and efficient communication.**

Description: Island Lake stakeholders can assist in the implementation of this action by actively participating in the MWLA and NLDC's educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in committees and the Lake Captain and Deckhand program, or simply notifying the MWLA or NLDC of concerns involving Island Lake and its stakeholders.

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

Management Action: **Continue control strategy for curly-leaf pondweed on the Manitowish Waters Chain of Lakes.**

Description: Island Lake residents may participate in curly-leaf pondweed control actions through a variety of passive means, such as keeping themselves up to date on aquatic invasive species matters through trainings, media releases, or participating in local meetings on the issue. Island Lake residents can also assist by participating in the Lake Captain and Deckhand program, actively monitoring for curly-leaf pondweed. Additionally, lake users may report sightings of aquatic invasive species to the NLDC and remove floating CLP fragments when they are observed.

Management Action: **Maintain connection and open dialogue with management partners on matters pertaining to wild rice growth on the Manitowish Waters Chain.**

Description: As this is an action designed for a designated individual, there is no action necessary for Island Lake property owners.

Management Action: **Continue control and monitoring efforts on purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris throughout the Manitowish Waters Chain of Lakes.**

Description: Emergent shoreland plants such as purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris can be easily identified and small infestations addressed through simple control methods. Island Lake property owners may participate in this action through monitoring their shorelands and wetlands and removing plants in accordance with methods determined by the NLDC, MWLA and Vilas County Invasive Species Coordinator.

Management Action: **Continue locally-based aquatic invasive species monitoring and watercraft inspections.**

Description: Prevention of aquatic invasive species introduction remains the most effective way of minimizing the spread of this threat. Island Lake property owners may participate in this initiative through volunteering for aquatic invasive species monitoring or Clean Boats Clean Waters inspections.

Management Action: **Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.**

Description: As this is an action designed for a designated individual, there is no action necessary for Island Lake property owners.

Chain-wide 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.**

Description: Angling is often one of the most enjoyed recreational activities that takes place on Wisconsin lakes. A complete understanding of a lake's fishery is needed to base decisions off of, both for the fishery manager and the fisherman. Island Lake residents can help the fishery of the Manitowish Waters Chain of Lakes by attending events aimed at educating the public about the chain's fishery, as well as volunteering for habitat improvement efforts, including shoreland preservation/remediation and coarse woody habitat projects.

Chain-wide 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 waterbodies.

Description: Though studies have been completed on Island Lake as part of this chain-wide management planning project, it is up to Island Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the goals described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Island Lake may wish to revisit their lake management plan in 5-10 years or as necessary. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.

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

8.3 Spider Lake

An Introduction to Spider Lake

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

Field Survey Notes

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

Photo 8.3 Spider Lake, Vilas County

Lake at a Glance* – Spider Lake

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

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

8.3.1 Spider Lake Water Quality

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

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

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

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

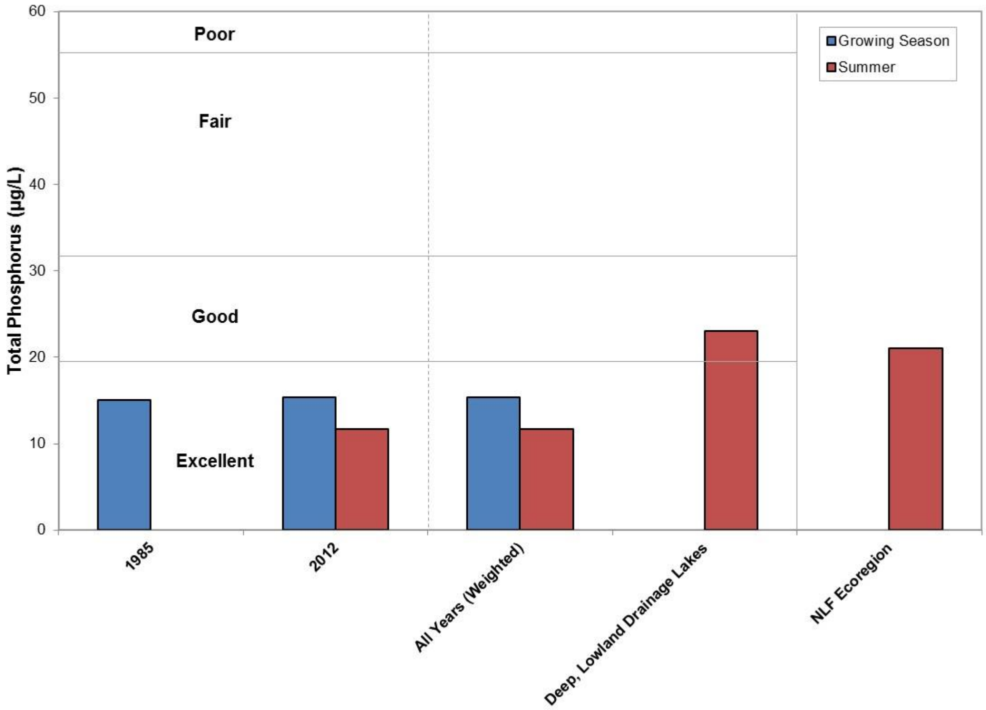


Figure 8.3.1-1. Spider Lake, state-wide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

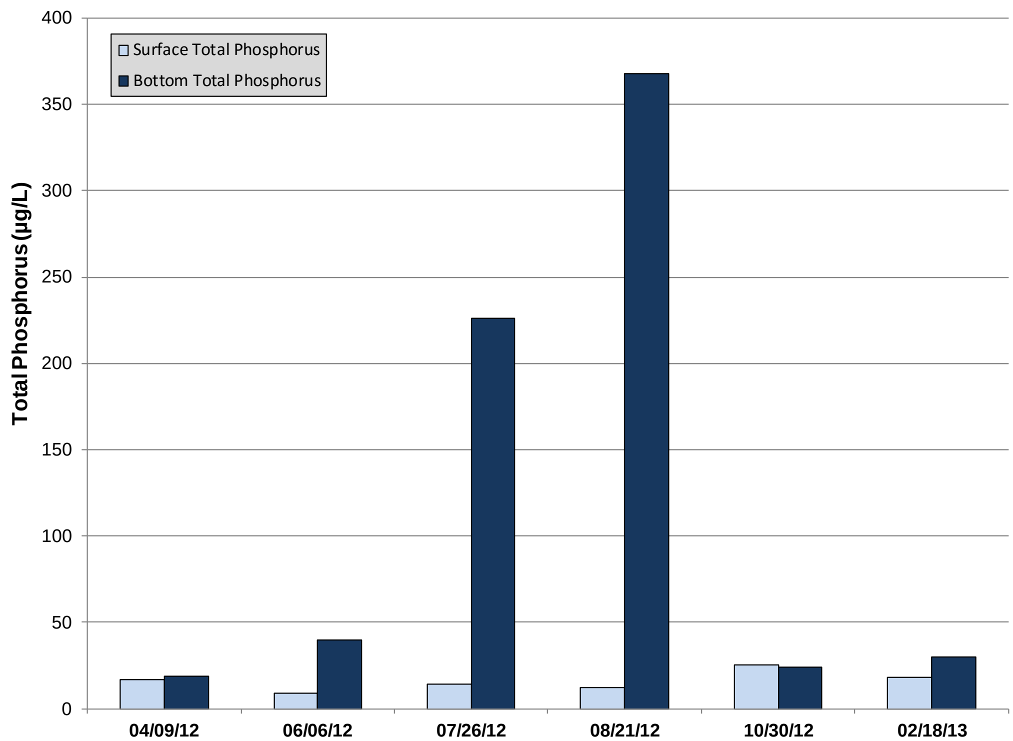


Figure 8.3.1-2. Spider Lake surface and bottom total phosphorus values, 2012-2013. Anoxia was observed in the hypolimnion of the lake during July and August sampling visits.

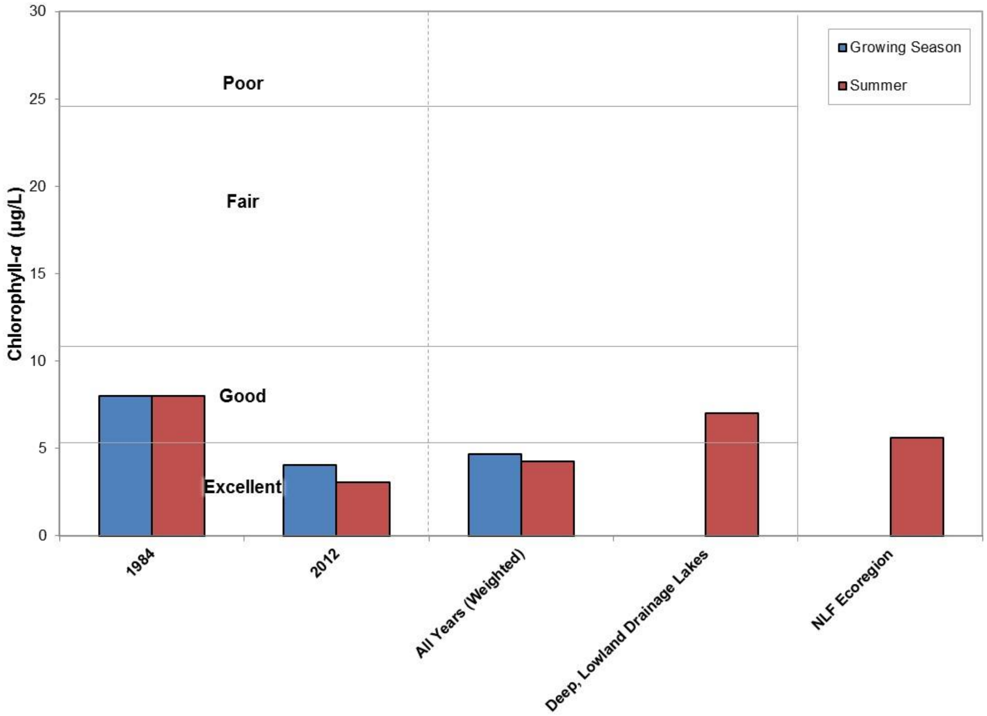


Figure 8.3.1-3. Spider Lake, state-wide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

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

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

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

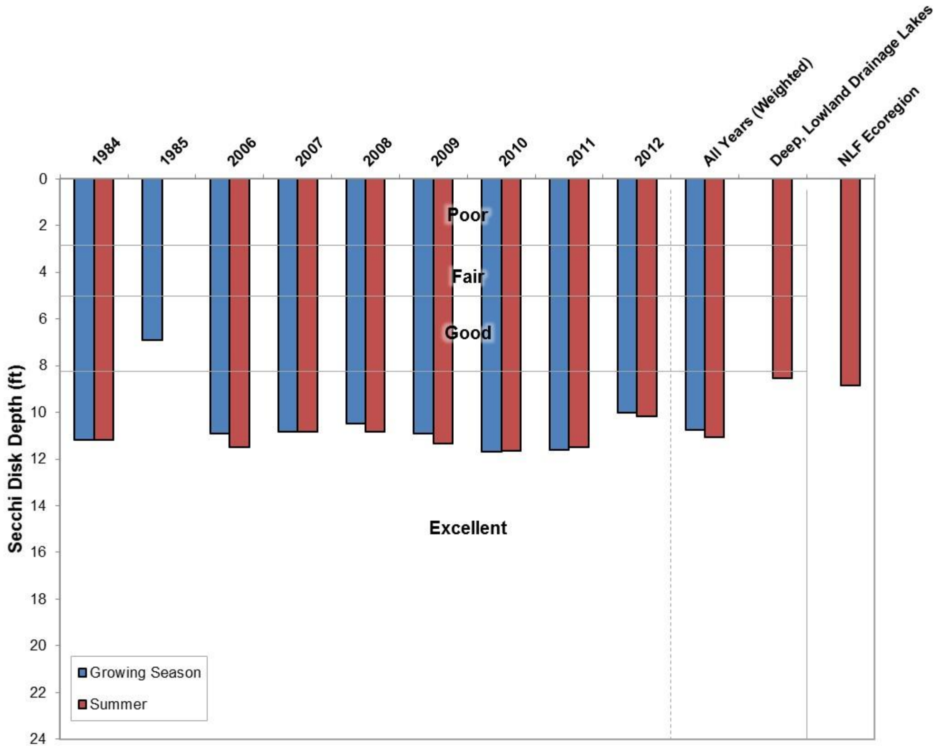


Figure 8.3.1-4. Spider Lake, state-wide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Spider Lake Trophic State

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

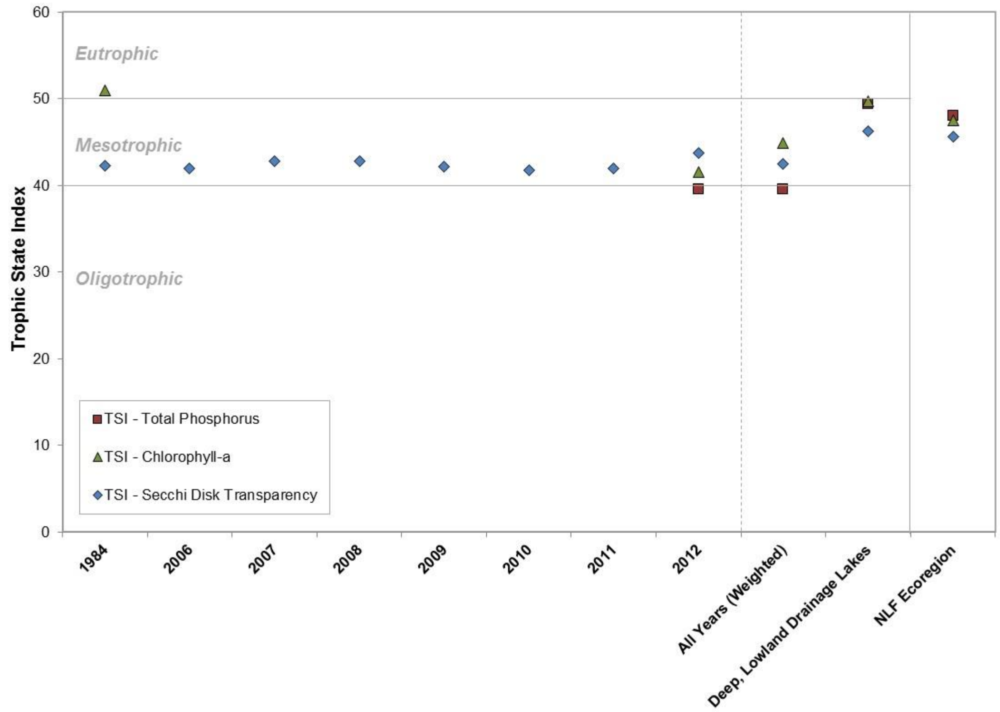


Figure 8.3.1-5. Spider Lake, state-wide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Spider Lake

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

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

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

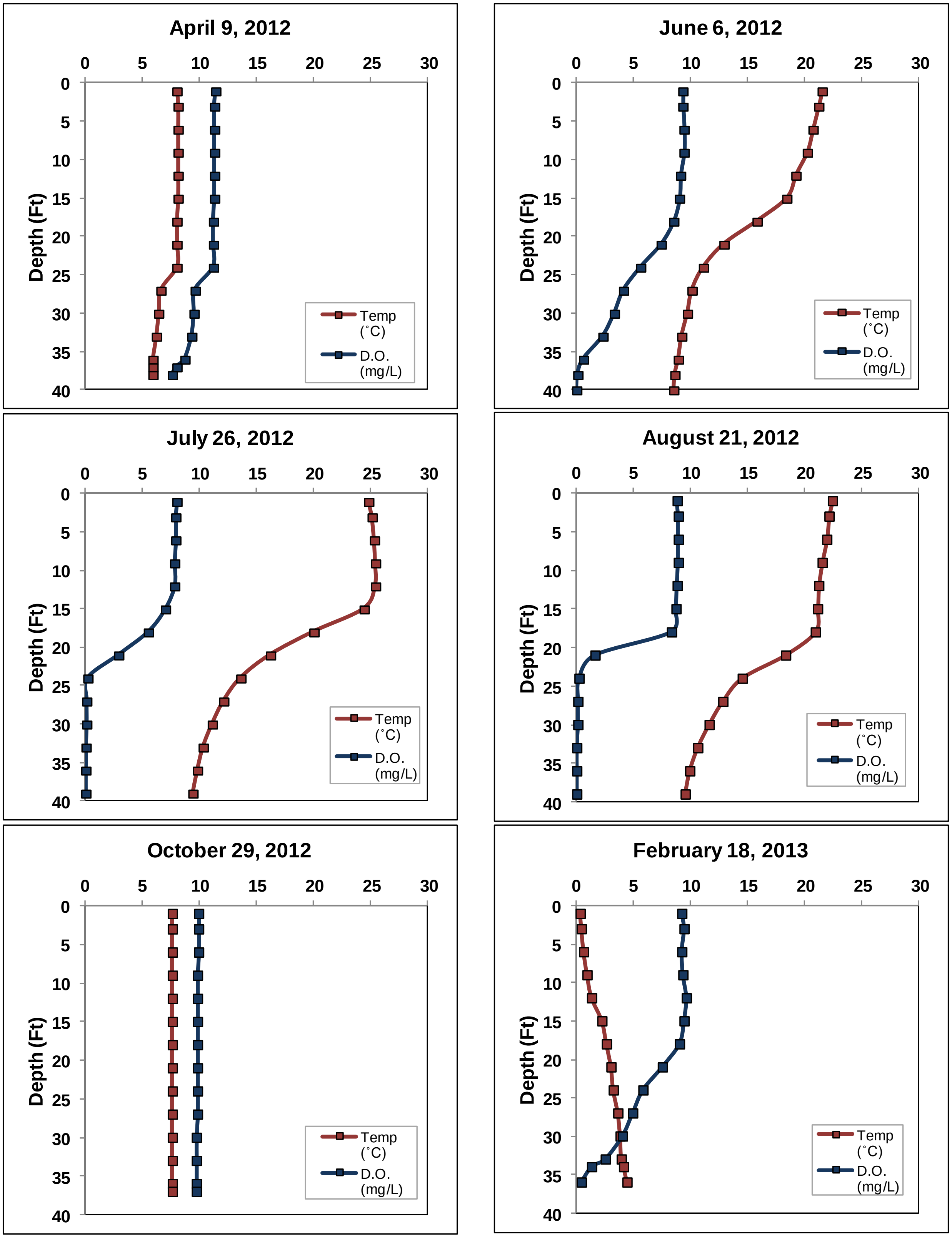


Figure 8.3.1-6. Spider Lake dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Spider Lake

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

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

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

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

8.3.2 Spider Lake Watershed Assessment

Spider Lake's watershed is 134,039 acres in size. Compared to Spider Lake's size of 283 acres, this makes for an incredibly large watershed to lake area ratio of 472:1.

Exact land cover calculation and modeling of nutrient input to Spider Lake will be completed towards the end of this project (in 2015-2016). By this time, the latest satellite imagery (and thus the most accurate land cover delineation) will be available. Additionally, when water quality sampling of the upper reaches of the chain is completed, these results will be input to predictive models and thus make the modeling of nutrient input to the entire chain more accurate.

8.3.3 Spider Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section, one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is the last source of protection for a lake against surface water runoff, and is also a critical area for wildlife habitat. In late summer of 2012, Spider Lake's immediate shoreline was assessed in terms of its development. Spider Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 6.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.3.3-1). This constitutes about 52% of Spider Lake's shoreline. These shoreland types provide the most benefit to the lake and should be left in their natural state if at all possible. During the survey, 2.1 miles of urbanized and developed–unnatural shoreline (17%) was observed. If restoration of the Spider Lake shoreline is to occur, primary focus should be placed on these shoreland areas as they currently provide little benefit to, and actually may harm, the lake ecosystem. Spider Lake Map 1 displays the location of these shoreline lengths around the entire lake.

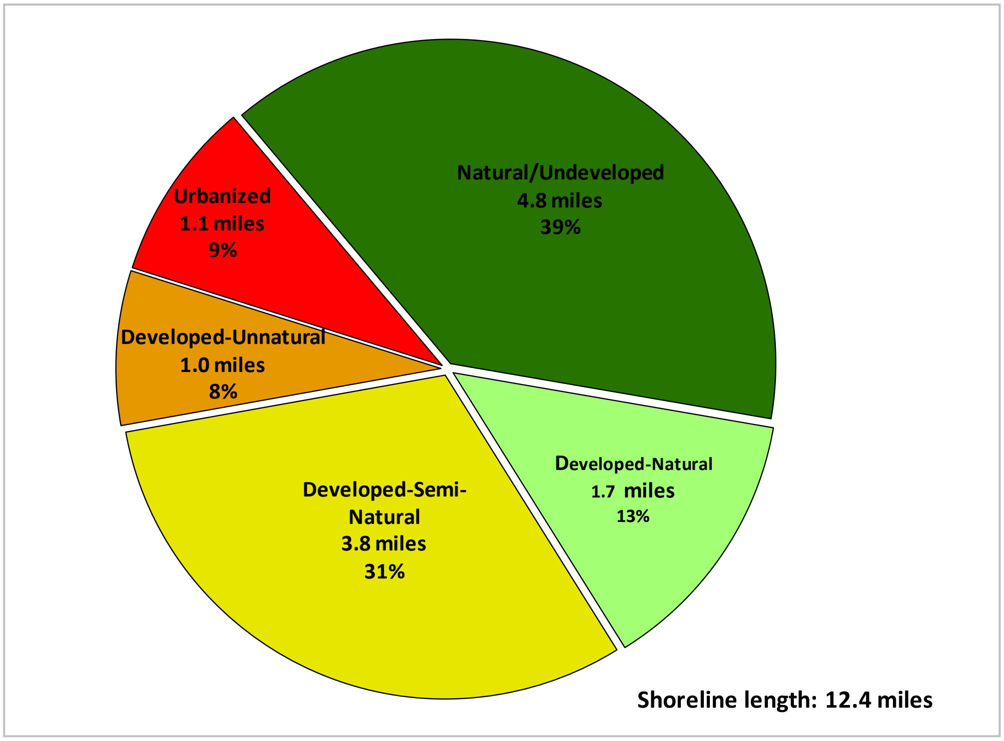


Figure 8.3.3-1. Spider Lake shoreland categories and total lengths. Based upon a late summer 2012 survey. Locations of these categorized shorelands can be found on Spider Lake Map 1.

Coarse Woody Habitat

A survey for coarse woody habitat was conducted in conjunction with the shoreland assessment (development) survey. Coarse woody habitat was identified, and classified in several size categories (2-8 inches diameter, >8 inches diameter and cluster) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. As discussed in the Manitowish Waters Chain-wide document, research indicates that fish species prefer some

branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance.

During this survey, 83 total pieces of coarse woody habitat were observed along 12.4 miles of shoreline, which gives Spider Lake a coarse woody habitat to shoreline mile ratio of 7:1 (Figure 8.3.3-2). Locations of coarse woody habitat are displayed on Spider Lake Map 2. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996).

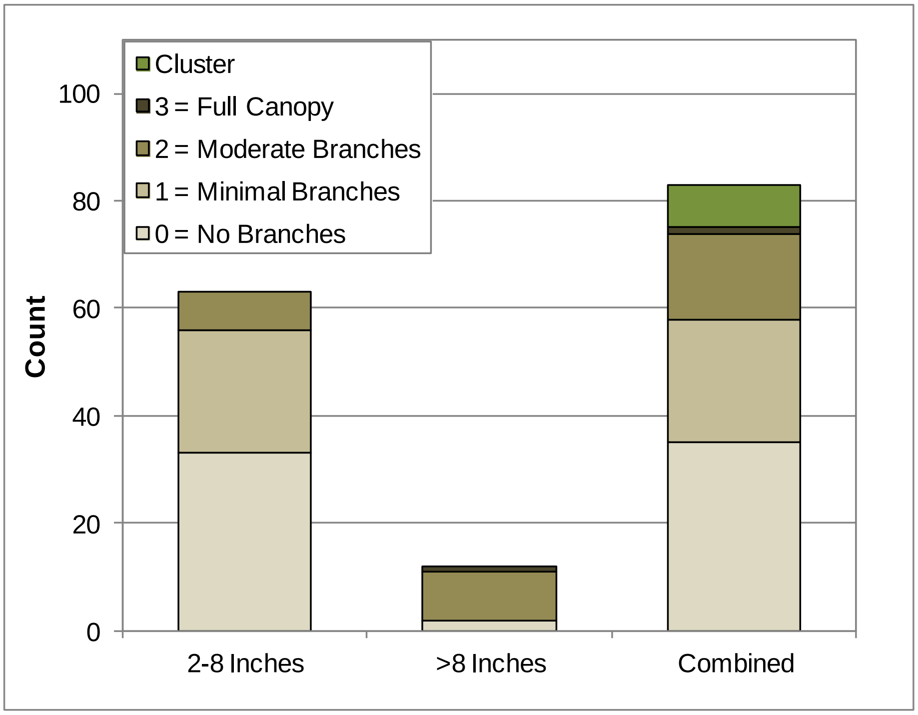


Figure 8.3.3-2. Spider Lake coarse woody habitat survey results. Based upon a late summer 2012 survey. Locations of Spider Lake coarse woody habitat can be found on Spider Lake Map 2.

8.3.4 Spider Lake Aquatic Vegetation

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

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

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

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

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

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

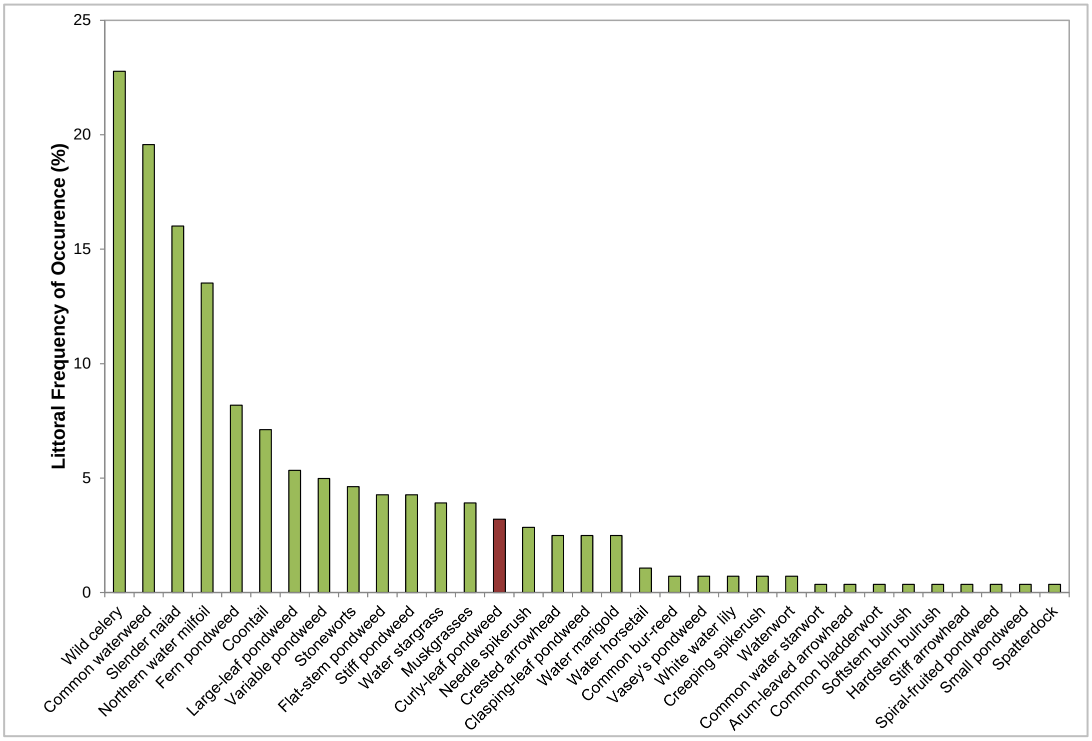


Figure 8.3.4-1. Spider Lake aquatic plant littoral frequency of occurrence analysis. Created using data from a 2012 point-intercept survey. Exotic species indicated in red.

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

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

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

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

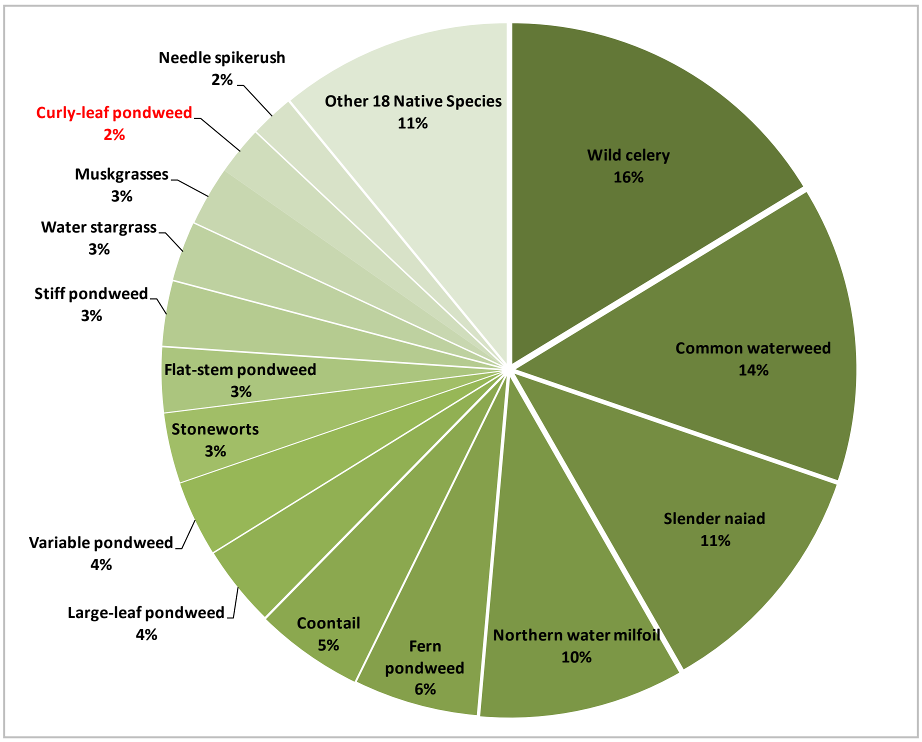


Figure 8.3.4-2 Spider Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2012 point-intercept survey.

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

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

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

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

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

8.3.5 Spider Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Spider Lake stakeholders, the MWLA, the NLDC, the Towns of Manitowish Waters and Boulder Junction, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Spider Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities.

While the Manitowish Waters Chain of Lakes are geographically similar, they are certainly ecologically diverse, as evidenced by the studies described within this report. This diversity leads to the need for individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Manitowish Waters Chain have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake as opposed to performing activities aimed at enhancing or resolving particular issues. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Spider Lake's Implementation Plan illustrates how Spider Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Spider Lake

Chain-wide 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.**

Description: While the MWLA and NLDC are primarily responsible for facilitating partnerships with many defined management units, Spider Lake property owners may participate in this management goal by keeping the lines of communication open with the MWLA and NLDC, as well as members from other Manitowish Waters Chain lakes. This may be done through representation on the MWLA Board of Directors, active participation in the Lake Captain and Deckhand Program, involvement in MWLA and NLDC sponsored events, attending meetings, etc.

Management Action: **Increase the Manitowish Waters Chain of Lakes' volunteer base**

Description: Spider Lake property owners may assist in this management action by simply donating several hours of their time a year towards MWLA and NLDC activities including active participation in the Lake Captain and Deckhand program. While it is beneficial to volunteer on their own lake, the entire chain would benefit by having Spider Lake individuals assist with activities occurring on other lakes within the chain.

Chain-wide 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.**

Description: Currently, Spider Lake is enrolled in the CLMN's water clarity monitoring program. This means that Secchi disk clarity data is collected several times during the year on Spider Lake. Although this is a great accomplishment, it must be continued in order to ensure the quality of Spider Lake is protected. Additionally, a better understanding of the lake's water quality would be obtained from volunteers enrolling in the CLMN's advanced water quality monitoring program. In this program, phosphorus and chlorophyll-*a* data is collected from the lake as well.

Volunteers from Spider Lake must also be proactive in recruiting others to participate. This will ensure that the program will continue after the current volunteers have retired their commitments to monitoring the lake's water quality.

Management Action: **Restore highly developed shoreland areas on the Manitowish Waters Chain.**

Description: As a part of this project, the entire Spider Lake shoreline was categorized in terms of its development. According to the results from this survey, 17% of the shoreline is in an urbanized or developed-unnatural state, while another 31% of the shoreline is currently in a semi-natural state. Continuing research indicates that the shoreland zone is a critical part of determining a lake's ecology, through providing both pollutant buffering wildlife habitat. The natural vegetative scenery provides an additional aesthetic benefit.

The TAISP is prepared to provide Spider Lake property owners with the necessary informational resources to restore their developed shoreland, should they be interested. Interested property owners may contact the NLDC and Vilas County Land and Conservation office for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

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

Description: While 17% of the shoreland was found to be highly developed along Spider Lake, about 52% of the shoreland is currently in a very natural or undeveloped state. These areas are extremely important to protect for the environmental and aesthetic benefits they provide.

Spider Lake property owners interested in preserving their shoreland may contact the NLDC and Vilas County Land and Conservation office for information on land trusts, conservation easements, or best management practices. Implementing a number of these options will ensure the integrity of these undeveloped shorelands will remain well into the future.

Management Action: **Investigate algal blooms on the Manitowish Waters Chain.**

Description: While some algae blooms are natural and do not impact a lake ecosystem or human health in a negative manner, some blooms may cause recreational or health impairment. Spider Lake residents who observe algae blooms may contact the NLDC with their concerns. The NLDC can take the appropriate response in contacting WDNR officials about the matter. Residents may be asked to provide a sample of the algae for identification purposes.

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

Management Action: **Engage stakeholders on priority education items through participation in educational initiatives and efficient communication.**

Description: Spider Lake stakeholders can assist in the implementation of this action by actively participating in the MWLA and NLDC's educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in committees and the Lake Captain and Deckhand program, or simply notifying the MWLA or NLDC of concerns involving Spider Lake and its stakeholders.

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

Management Action: **Continue control strategy for curly-leaf pondweed on the Manitowish Waters Chain of Lakes.**

Description: Spider Lake residents may participate in curly-leaf pondweed control actions through a variety of passive means, such as keeping themselves up to date on aquatic invasive species matters through trainings, media releases, or participating in local meetings on the issue. Spider Lake residents can also assist by participating in the Lake Captain and Deckhand program, actively monitoring for curly-leaf pondweed. Additionally, lake users may report sightings of aquatic invasive species to the NLDC and remove floating CLP fragments when they are observed.

Management Action: **Maintain connection and open dialogue with management partners on matters pertaining to wild rice growth on the Manitowish Waters Chain.**

Description: As this is an action designed for a designated individual, there is no action necessary for Spider Lake property owners.

Management Action: **Continue control and monitoring efforts on purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris throughout the Manitowish Waters Chain of Lakes.**

Description: Emergent shoreland plants such as purple loosestrife, Japanese knotweed, phragmites, and pale yellow iris can be easily identified and small infestations addressed through simple control methods. Spider Lake property owners may participate in this action through monitoring their shorelands and wetlands and removing plants in accordance with methods determined by the NLDC, MWLA and Vilas County Invasive Species Coordinator.

Management Action: **Continue locally-based aquatic invasive species monitoring and watercraft inspections.**

Description: Prevention of aquatic invasive species introduction remains the most effective way of minimizing the spread of this threat. Spider Lake property owners may participate in this initiative through volunteering for aquatic invasive species monitoring or Clean Boats Clean Waters inspections.

Management Action: **Investigate feasibility of alternative aquatic invasive species control methodologies for applicability to the Manitowish Waters Chain of Lakes.**

Description: As this is an action designed for a designated individual, there is no action necessary for Spider Lake property owners.

Chain-wide 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.**

Description: Angling is often one of the most enjoyed recreational activities that takes place on Wisconsin lakes. A complete understanding of a lake's fishery is needed to base decisions off of, both for the fishery manager and the fisherman. Spider Lake residents can help the fishery of the Manitowish Waters Chain of Lakes by attending events aimed at educating the public about the chain's fishery, as well as volunteering for habitat improvement efforts, including shoreland preservation/remediation and coarse woody habitat projects.

Chain-wide 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 waterbodies.

Description: Though studies have been completed on Spider Lake as part of this chain-wide management planning project, it is up to Spider Lake stakeholders to continue monitoring and protecting the lake through the initiatives set forth by the goals described in this management plan. Additionally, these efforts may be extended to other lakes within the chain as needed.

In addition to current monitoring and protection, Spider Lake may wish to revisit their lake management plan in 5-10 years or as necessary. Comprehensive studies undertaken at that time would be able to point towards trends or changes in the lake with regards to water quality, watershed land use, aquatic plants, etc.