Eagle River Chain of Lakes
Vilas & Oneida Counties, Wisconsin
Comprehensive Management Plan – Phase III
March 2018

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Funded by: Eagle River Chain of Lakes Association
Wisconsin Dept. of Natural Resources Lakes Grant Program
(AEPP-388-13; AEPP-433-14)

Acknowledgements

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

Eagle River Chain of Lakes Planning Committee

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

Cranberry Lake
Catfish Lake
Voyageur Lake
Eagle Lake
Scattering Rice Lake
Otter Lake
Lynx Lake
Duck Lake

Wisconsin Dept. of Natural Resources

Kevin Gauthier

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APPENDICES

1.0 INTRODUCTION

The Lower Eagle River Chain of Lakes is comprised of ten lake basins located within the Wisconsin River Drainage Basin in Vilas and Oneida Counties, Wisconsin (Map 1). This system includes 62 miles of shoreline and over 3,500 acres of surface water. The entire Eagle River Chain, which includes the upstream lakes known as the Three Lakes Chain of Lakes, encompasses approximately 11,295 acres. The Lower Eagle River Chain of Lakes is comprised of Cranberry Lake, Catfish Lake, Voyageur Lake, Eagle Lake, Scattering Rice Lake, Otter Lake, Lynx Lake, Duck Lake, Yellow Birch Lake, and Watersmeet. Watersmeet, the downstream-most lake in chain, represents the convergence of the Eagle River, the Wisconsin River, Rice Creek, and Mud Creek.

The non-native, invasive plant Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first documented in the Lower Eagle River Chain in 1992, and since 2001, various lake groups throughout the chain have recognized the negative impacts the EWM population was imparting on the lakes. In 2005, the Town of Washington successfully applied for multiple Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grants to fund the development of an aquatic plant management plan for each of the chain's lakes. Understanding that the degradation of the Lower Eagle River Chain of Lakes ecology and recreational impairment would be disastrous for the local and county economies, four municipalities including the Towns of Washington, Lincoln, and Cloverland, and the City of Eagle River partnered to fund the completion of the aquatic plant management plans. During the development of the aquatic plant management plans, it was realized that the Lower Eagle River Chain of Lakes must be viewed as one system if aquatic invasive species (AIS) were to be effectively managed. In 2006, following public discussion, the parties involved agreed to form a public/private partnership out of which a joint powers agreement was made forming the Unified Lower Eagle River Chain of Lakes Commission (ULERCLC).

The ULERCLC is a unique partnership and the first of its kind in the State of Wisconsin, consisting of representatives from each of the four municipalities bordering the Lower Eagle River Chain of Lakes and from each of the ten main waterbodies that comprise the chain. Following the completion of the aquatic plant management plans in 2007, the ULERCLC's primary concern were the impacts the EWM was having on the ecological stability of the Lower Eagle River Chain of Lakes, and the potential effects it could have on the chain's fishery, aesthetics, and the economic vitality of the area.

It was evident from the 2006 plant surveys completed by Northern Environmental, Inc. that EWM comprised a significant portion of the chain's aquatic plant community. In 2007, Onterra, LLC ecologists completed an EWM peak-biomass survey of the entire Lower Eagle River Chain of Lakes and located approximately 278 acres of colonized EWM. In 2008, the ULERCLC successfully applied for a WDNR AIS Control Grant to initiate a multi-phased project with a goal of reducing the EWM population to more manageable levels and restore the ecological integrity of the chain. Following annual herbicide applications over areas of EWM, colonial Eurasian watermilfoil acreage has been reduced from the 278 acres in 2007 to 12 acres in 2015.

The Eagle River Chain of Lakes Association (ERCLA), this project's sponsor, understands the importance of the Eagle River Chain, not only in terms of local and state economies, but also its importance in the lives of people from the area and well beyond. ERCLA knows that when large-scale management of AIS is conducted on a lake ecosystem, it is important to periodically assess the health of the native aquatic plant community and other components of the chain's ecology. With this understanding, ERCLA elected to complete lake management plan updates for the ten lakes in the Lower Eagle River Chain. Due to the size of the chain and the time needed for studies, the plans were proposed to be completed in blocks (phases) of two to three lakes per year, starting at the upstream-most end of the chain and working downstream (Map 1). This study design allows for water quality information collected from the upstream lakes usable during the watershed modeling of downstream lakes, and will lead to more accurate modeling on a chain-wide basis.

In addition, developing management plans for a subset of lakes each year within the chain would allow for financial savings to be realized in project costs while creating a manageable project that would allow for sufficient attention to be applied to each lake's needs. This is opposed to completing all of the plans simultaneously, which would lead to more generic plans for each lake and the chain as a whole. Financial assistance was obtained through the Wisconsin Department of Natural Resources' Lake Management Grant Program for each phase of the project.

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

The Eagle River Chain is a highly sought after location amongst recreationists and anglers. These intense public use opportunities most likely contributed to the introduction and spread of EWM throughout the lakes in the Lower Eagle River Chain. Throughout the project, Onterra staff and ERCLA volunteers continued to monitor these known infestations as well as sweeping new areas for signs of invasive species.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa. The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through multiple meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of 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 20, 2013, a project kick-off meeting was held at the Lincoln Town Hall to introduce the project to the general public. The attendees observed a presentation given by Tim Hoyman, an aquatic ecologist with Onterra. Mr. Hoyman's presentation started with an educational component regarding general lake ecology and ended with a detailed description of the project including opportunities for stakeholders to be involved. The presentation was followed by a question and answer session. On July 16, 2016, Brenton Butterfield led the Phase III kick-off meeting which updated the public on the progress of the project as well as introduced the work to be completed on the Phase III project lakes.

Planning Committee Meetings

Planning meetings were conducted periodically during the chain-wide study, with meetings being held that focused on the lakes involved during each phase of the project. Tim Hoyman and/or Brenton Butterfield met with representatives from the Phase I, II and III lakes in 2014, 2015, and 2017, respectively. During these meetings, Mr. Hoyman and Mr. Butterfield presented the study results from the lakes for each respective phase. All project components including water quality analyses, watershed assessments, shoreland assessments, and aquatic plant surveys were presented in detail.

Planning meetings were also held for each phase to discuss and develop the framework for the Implementation Plan. During these meetings, the lake representatives and Onterra staff discussed lake management goals that the Eagle River Chain of Lakes Association, Inc. (ERCLA) would implement to continue the protection and enhancement of the Eagle River Chain of Lakes along with action steps that would need to be taken to reach these goals. The Implementation Plan (see Implementation Plan Section 5.0) is the result of these conversations. Within each phase, the lake representatives were asked to review the Implementation Plan and their comments were provided to Onterra staff who made revisions/additions to the Implementation Plan as needed.

Management Plan Review and Adoption Process

Prior to the first Planning Committee Meeting of each phase, the Result Section of this document (Section 3.0) as well as the individual lake sections were sent to all planning committee members for their review and preparation for the meeting. Following discussions at the second Planning Committee Meeting for each phase, Onterra staff drafted the Implementation Plan and sent it to the ERCLA Planning Committee members for their review. Their comments were then integrated into the plan, and the first official draft of the management plan was sent to the WDNR for review.

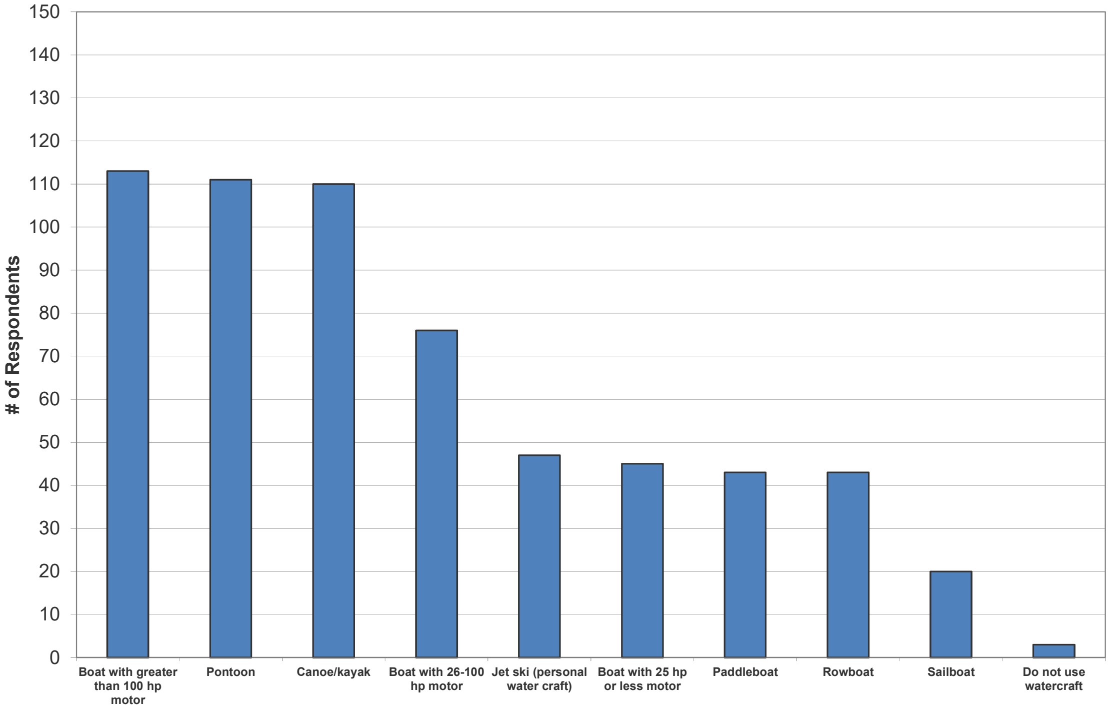
Stakeholder Survey

As part of Phase II of this project, a stakeholder survey was distributed to ERCLA member and non-member riparian property owners. This survey was designed by Onterra staff and the ERCLA Planning Committee in July of 2014. The draft survey was sent to a WDNR social scientist for review at that same time. In August 2014, the eight-page, 33-question survey was mailed to 1,623 riparian property owners along the Eagle River Chain of Lakes. Unfortunately, only 15% of the surveys were returned. Due to the low response rate, the following survey results should not be interpreted as being statistically representative of the population. At best, the results may indicate possible trends and opinions about stakeholder perceptions of the Eagle River Chain of Lakes, but cannot be stated with any statistical confidence. The full survey and results can be found in Appendix B, while discussion of these results is integrated within the appropriate sections of the management plan and a general summary is discussed here.

Based upon the results of the Stakeholder Survey, approximately 44% of stakeholders are year-round residents, 25% are seasonal residents (summer only), and 22% visit on weekends throughout the year (Appendix B, Question #2). The majority of respondents, approximately 29%, have owned their property on the Eagle River Chain of Lakes for more than 25 years (Question #3).

Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. Approximately half of survey respondents indicate that they use a canoe or kayak on the chain, pontoon boat, or a boat with a motor of greater than 100 horsepower (Question #11). The need for boating responsibly increases during weekends, holidays, and during times of nice weather or good fishing conditions as well, due to increased traffic on the lake. As seen on Question #12, several of the top recreational activities on the lake involve boat use. Watercraft traffic on the chain was ranked #3 on a list of factors believed to be negatively impacting the Eagle River Chain after aquatic invasive species and excessive aquatic plant growth (Question #18).

Question #11: What types of watercraft do you currently use on the lake?



Question #12: Rank your top three activities that important reasons for owning or renting your property on or near the Eagle River Chain, with 1 being the most important activity.

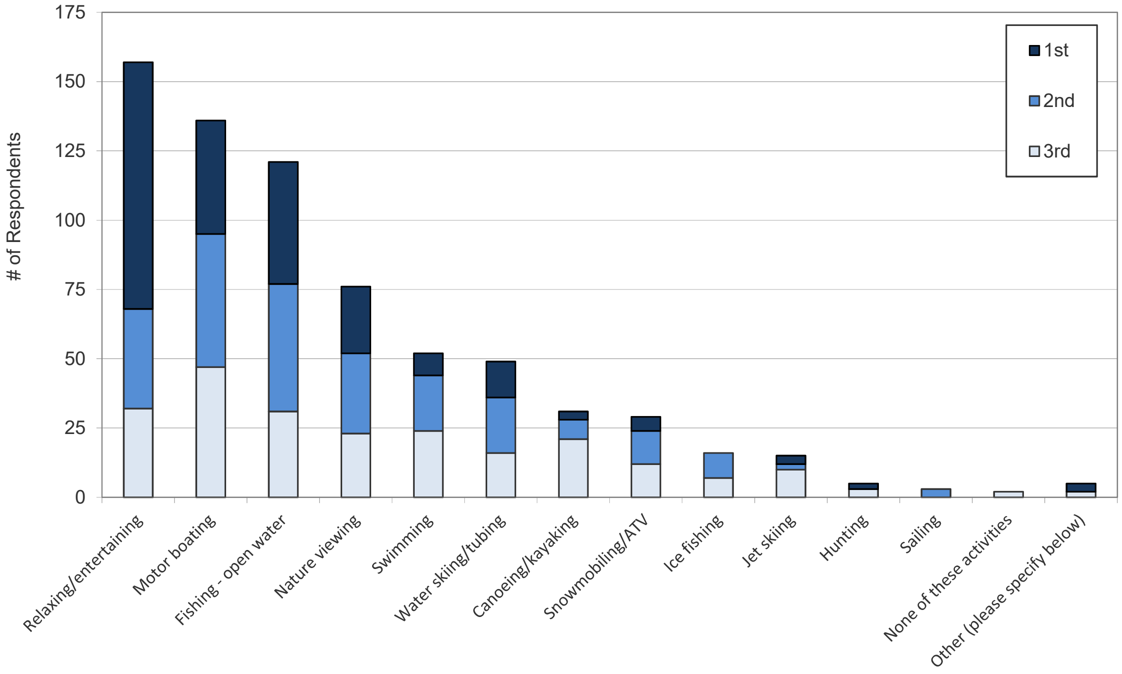


Figure 2.0-1. Select survey responses from the Eagle River Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question #18: To what level do you believe each of the following factors may currently be negatively impacting the Eagle River Chain?

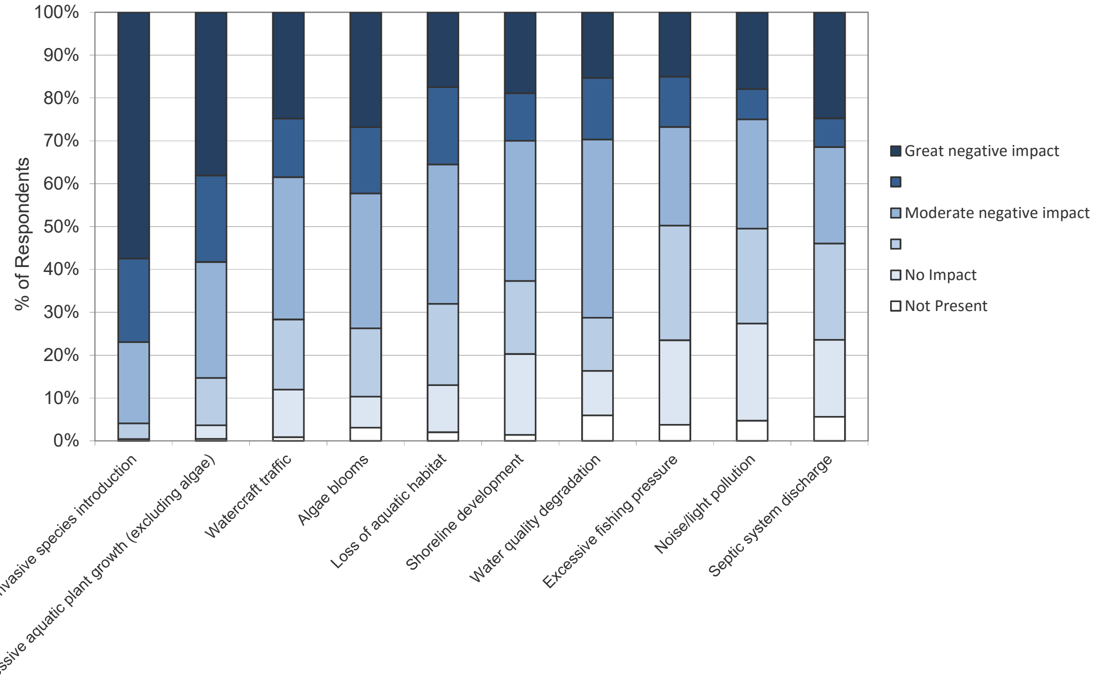


Figure 2.0-2. Select survey responses from the Eagle River Chain Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on the Lower Eagle River 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 Lower Eagle River 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.

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.

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

Internal Nutrient Loading*

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal 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 determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

- Lakes that do not experience hypolimnetic anoxia.
- Lakes that do not stratify for significant periods (i.e. days or weeks 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 publication *Implementation and Interpretation of Lakes Assessment Data for the Upper Midwest* (PUB-SS-1044 2008) 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 Lower Eagle River 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 two main groups: **shallow (mixed)** or **deep (stratified)**. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). 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.

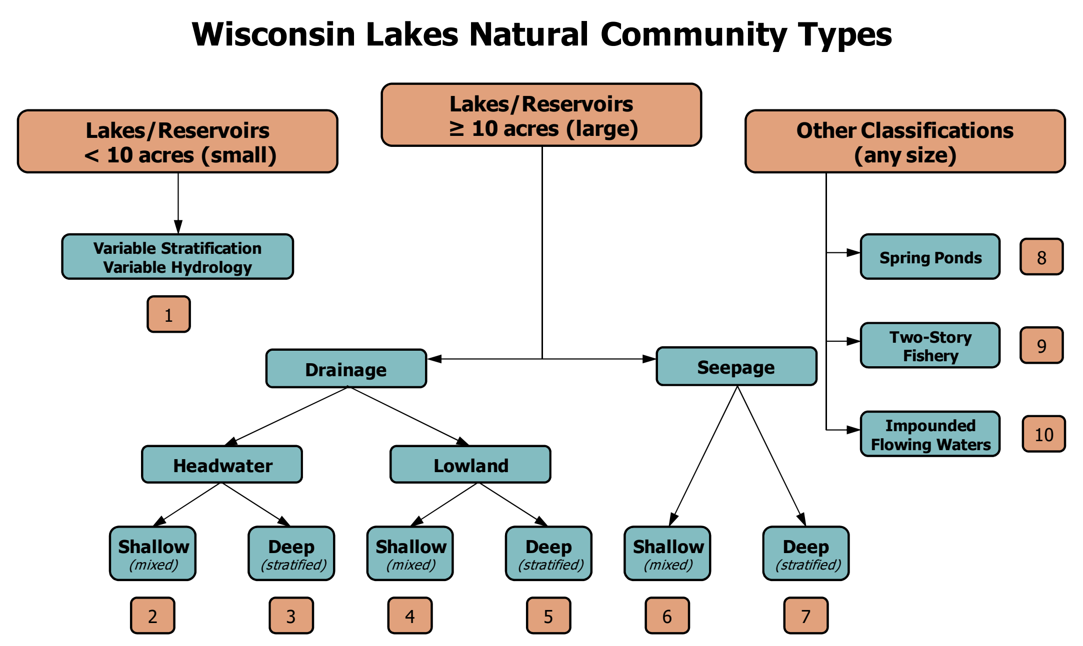


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

Both Catfish and Eagle Lake's Natural Community designation have been classified as two-story due to potential for cold-water fish species to live there (Table 3.1-1). However, for the purpose this water quality analysis, data collected from these two lakes will be compared to an applicable lake type. All of the lakes within the Lower Eagle River Chain possess both a tributary inlet and outlet, and as will be discussed in the Watershed Section, they all have watersheds much greater than four square miles classifying all of the lakes as lowland drainage lakes. However, the maximum depth and surface area varies among the lakes, indicating the stratification classification differs between the lakes; some lakes are classified as shallow (mixed) lowland drainage lakes (Class 4), while others are classified as deep (stratified) lowland drainage lakes (Class 5) (Table 3.1-1).

Table 3.1-1. Community classification of lakes within the Lower Eagle River Chain. Created using equations from WDNR 2013A.

Lake	Lake Max Depth (ft)	Lake Area (acres)	Lake Classification
Cranberry Lake	23	929	Shallow (Mixed), Lowland Drainage
Catfish Lake	30	977	Two-Story
Voyageur Lake	13	106	Shallow (Mixed), Lowland Drainage
Eagle Lake	34	581	Two-Story
Scattering Rice Lake	17	266	Shallow (Mixed), Lowland Drainage
Otter Lake	30	195	Deep (Stratified), Lowland Drainage
Lynx Lake	20	30	Deep (Stratified), Lowland Drainage
Duck Lake	20	108	Shallow (Mixed), Lowland Drainage
Yellow Birch Lake	23	238	Shallow (Mixed), Lowland Drainage
Watersmeet Lake	12	415	Shallow (Mixed), Lowland Drainage

Garrison, et. al (2008) developed statewide 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 Lower Eagle River Chain of Lakes is within the Northern Lakes and Forests Ecoregion of Wisconsin.

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

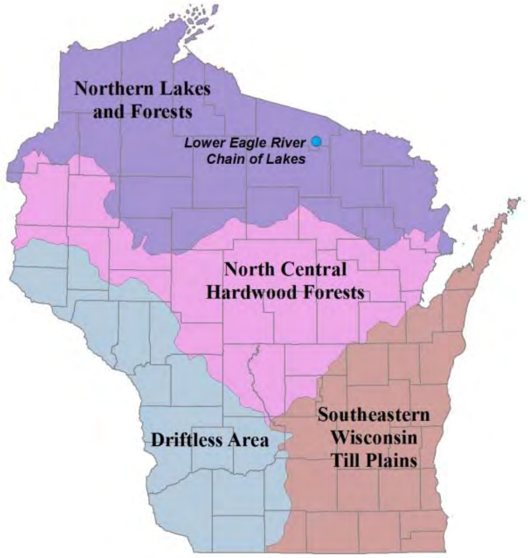


Figure 3.1-2. Location of the Lower Eagle River Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Water quality data from the Lower Eagle River Chain of Lakes data is presented along with comparable data from similar lakes throughout the state and ecoregion in Figures 3.1-3 - 3.1-10. Please note that the data in these graphs represent samples taken only during the growing season (April-October) or summer months (June-August) unless otherwise indicated. Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. 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.

Eagle River Chain of Lakes Water Quality Analysis

Eagle River Chain of Lakes Nutrient Content and Water Clarity

The amount of historical water quality data existing on the Eagle River Chain varies by lake. Some 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 historical 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 of the chain's lakes over the course of this project. Monitoring occurred during the summer and following winter of each project phase (Phase I lakes sampled in 2013/2014, Phase II lakes sampled in 2014/2015, Phase III lakes sampled in 2016/2017, Phase IV scheduled for 2017/2018). 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 are derived from the near-surface at 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. Please note on the following figures that comparisons are best made across lakes of similar classification (shallow lowland drainage lakes in light blue, deep lowland drainage lakes in dark blue).

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. Within the Phase I through Phase III lakes which have been sampled to date, average summer near-surface total phosphorus concentrations range from 25.2 µg/L in Eagle Lake to 43.5 µg/L in Scattering Rice Lake (Figure 3.1-3). With the exception of total phosphorus concentrations in Scattering Rice Lake, Otter Lake, and Lynx Lake which exceed the state-wide median concentration for their respective lake types, total phosphorus concentrations for the other Phase I, II, and III lakes fall near the state-wide median value for their respective lake type.

In general, when lakes are in a series, phosphorus concentrations tend to decrease downstream as it settles out upstream. However, the difference between summer total phosphorus concentrations in Cranberry and Catfish Lakes in 2013 cannot solely be attributed to Catfish Lake's position downstream of Cranberry. The lower phosphorus concentration in Catfish Lake when compared to Cranberry are likely due to a combination of its downstream position, the location of its water quality sampling location, and its higher water volume. The water entering Catfish Lake from Cranberry Lake on the east side may not fully mix with the water on the southwest side of the lake where the water quality sampling site is located (Map 1), and total phosphorus concentrations measured here may be different than if samples were collected within the northern portion of the lake. In addition, Cranberry Lake's volume is approximately 9,000 acre-feet compared to Catfish

Lake's approximately 12,000 acre-feet, meaning that phosphorus concentrations become slightly diluted within water flowing from Cranberry Lake into Catfish Lake. The total phosphorus concentration measured in Voyageur Lake in 2014 is likely a more representative concentration for north Catfish Lake.

As is discussed within the Scattering Rice Lake individual report section, Scattering Rice Lake has a separate watershed (Deerskin River Watershed) from the rest of the chain, and is the final recipient of water being fed from the Deerskin River. While watershed modeling will not be completed until the final phase of the project, Scattering Rice Lake's higher phosphorus concentrations are likely due in part to its shallow nature and relatively large watershed.

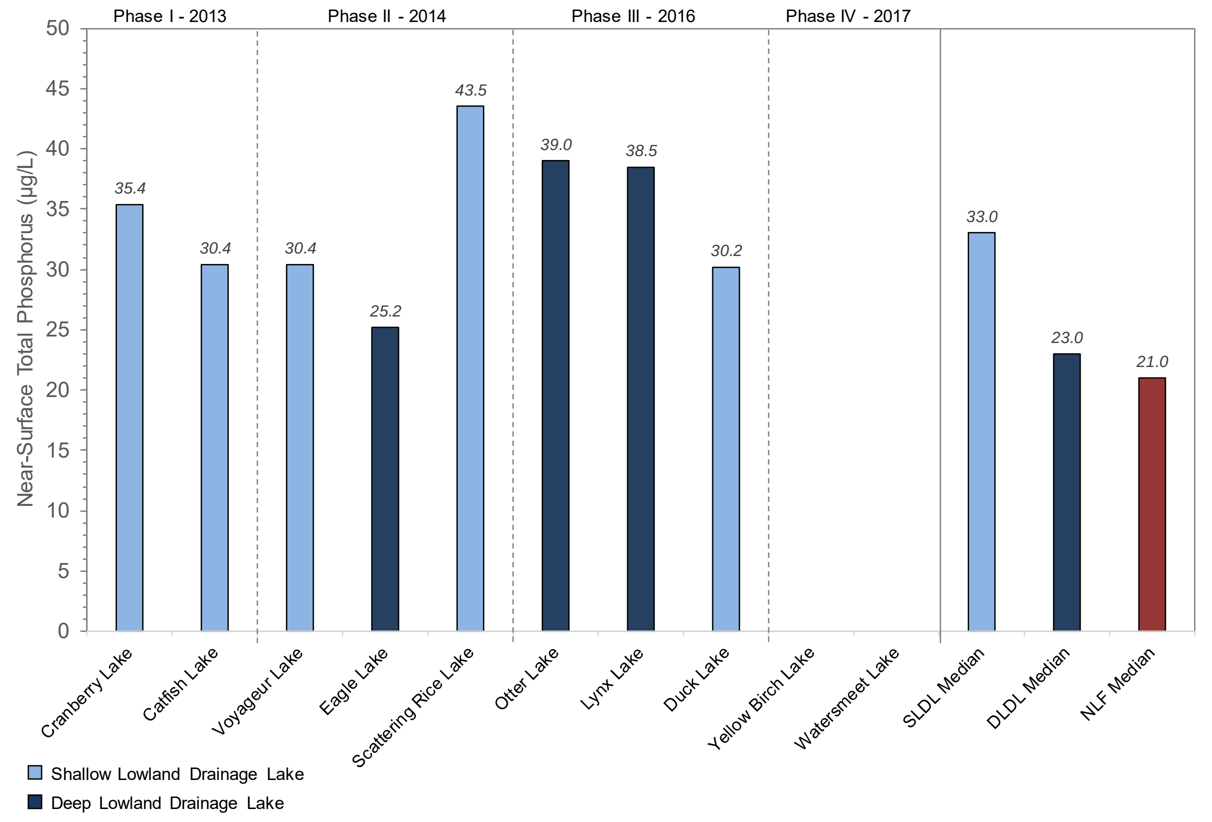


Figure 3.1-3. Lower Eagle River Chain of Lakes average summer near-surface total phosphorus concentrations and median total phosphorus concentrations from comparable lakes. Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests (NLF) ecoregion median.

Average summer chlorophyll-*a* concentrations for the Lower Eagle River Chain of Lakes are displayed in Figure 3.1-4. Like near-surface total phosphorus concentrations, chlorophyll-*a* concentrations vary among the Phase I through Phase III lakes, with summer averages ranging from 10.8 µg/L in Eagle Lake to 23.0 in Scattering Rice Lake. All of the chlorophyll-*a* concentrations within the Phase I through Phase III lakes exceed the statewide median values for the respective lake type. As is discussed within the Watershed Section, the lakes within the Lower Eagle River Chain have very large watersheds when compared to the size of the lakes. While the chain's watershed is mainly comprised of land cover types that export minimal amounts of phosphorus (forests and wetlands), the cumulative amount from the watershed is enough to create lakes with higher productivity and thus higher algal content.

The variations in chlorophyll-*a* concentrations among the Phase I through Phase III lakes is likely due to differences in morphology and their position within the chain. For instance, Cranberry Lake is the first lake in the series on the Lower Eagle River Chain and is relatively shallow (low water volume). Shallower lakes are generally more productive because they have less water volume to dilute phosphorus, and in addition, they can also experience wind-induced sediment resuspension which can deliver nutrients into the water column where it becomes available to algae. Cranberry Lake likely acts as a nutrient sink, where nutrients and sediments settle out before continuing downstream into Catfish Lake. Catfish Lake, with its deeper water and thus higher water volume, is able to dilute the nutrients coming into it and thus produces less algae. The same phenomenon is likely occurring in Eagle Lake.

While Voyageur Lake is relatively shallow, the lake is small and water likely moves through the lake relatively quickly. In lakes with lower water residence times, usually two weeks or less, algae do not have time to grow and accumulate before being flushed downstream. As mentioned earlier, Scattering Rice has a separate watershed and is similar to Cranberry Lake in that it is shallow and is the first in the series of lakes. For these reasons, phosphorus and algae concentrations are higher in Scattering Rice Lake.

As discussed previously, 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 healthy lake ecosystems. In lakes like Cranberry Lake and Scattering Rice Lake with chlorophyll-*a* concentrations near 20 μg/L, periodic perceptible algae blooms may occur.

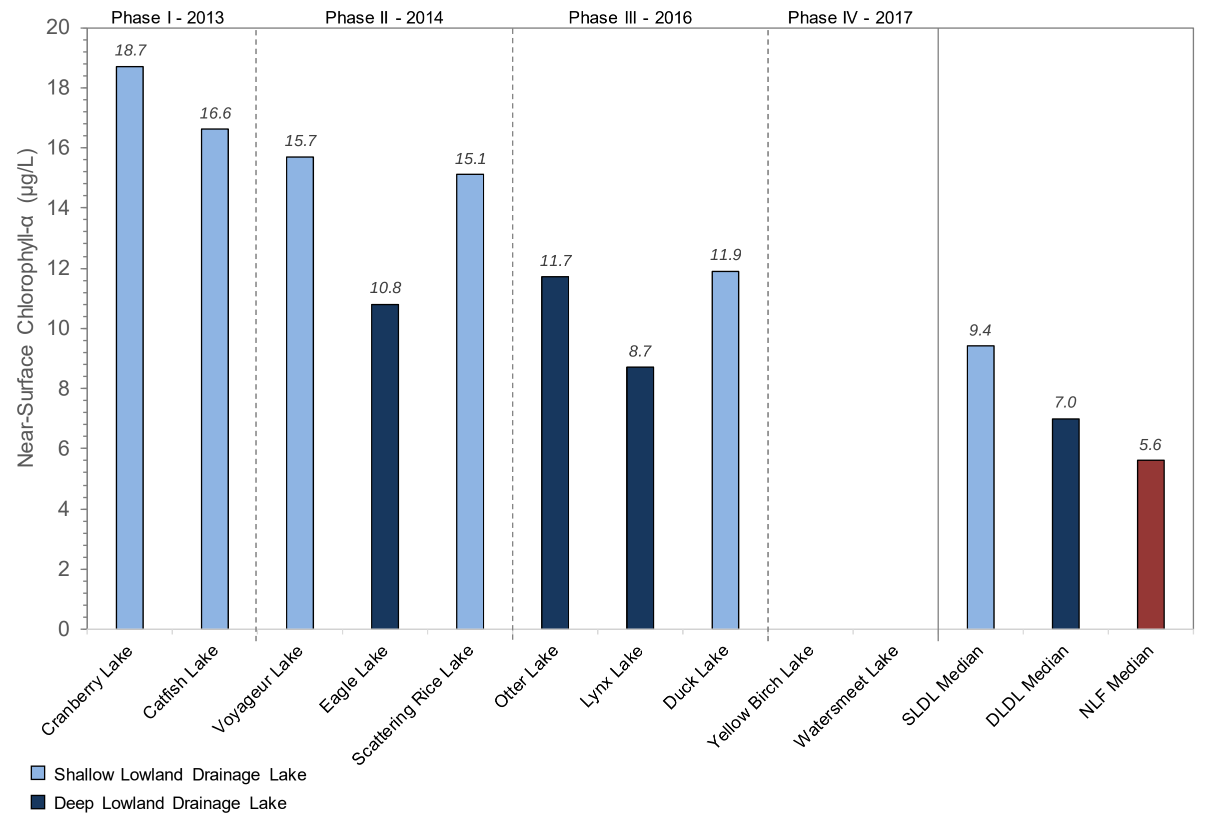


Figure 3.1-4. Lower Eagle River Chain of Lakes average summer chlorophyll-α concentrations and median chlorophyll-α concentrations for comparable lakes. Values created with summer month surface data and methodology follows WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests (NLF) ecoregion median.

Average summer Secchi disk clarity values were less variable among the Phase I through Phase III lakes, and ranged from 6.5 feet in Voyageur Lake to 4.1 feet in Scattering Rice Lake (Figure 3.1-5). Average Secchi disk clarity for the Phase I through Phase III lakes falls around the median values for the respective lake type and for lakes within the NLF Ecoregion. 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. Overall, the water clarity observed within the lakes is what is expected for lakes of their types with large watersheds.

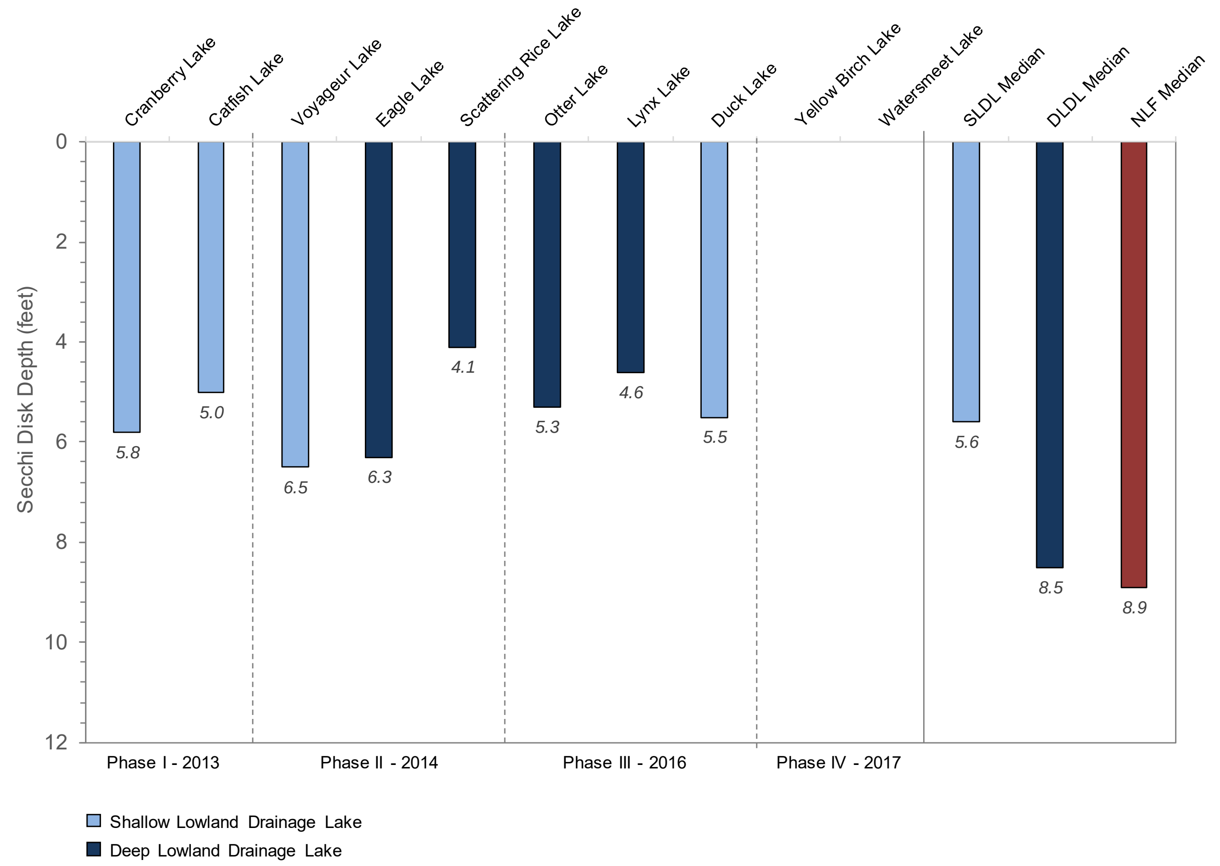


Figure 3.1-5. Lower Eagle River Chain of Lakes average summer Secchi disk transparency and median Secchi disk transparency values for comparable lakes. Methodology follows WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes and Forests (NLF) ecoregion median.

Limiting Plant Nutrient of Eagle River Chain of Lakes

Using average nitrogen and phosphorus concentrations from all lakes included in the Lower Eagle River Chain of Lakes study, a nitrogen:phosphorus ratio was calculated for each lake (Table 3.2-2). The ratios from all of the Phase I and II lakes except Scattering Rice indicate that phosphorus is the limiting nutrient and the nutrient driving algae growth within these lakes. The Phase III lakes fall between phosphorus-limited and nitrogen-limited. The lower nitrogen to phosphorus ration in Scattering Rice Lake, Otter Lake, Lynx Lake, and Duck Lake indicate that phosphorus loading may become excessive relative to nitrogen during certain points of the year, and the lake may transition between phosphorus and nitrogen limitation.

Table 3.1-2. Lower Eagle River Chain of Lakes mid-summer nitrogen:phosphorus 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 - 2013	Cranberry Lake	1,140.0	41.2	28:1
	Catfish Lake	857.0	27.7	31:1
Phase II - 2014	Voyageur Lake	631.0	34.9	18:1
	Eagle Lake	681.0	27.6	25:1
	Scattering Rice Lake	663.0	49.7	13:1
Phase III – 2016	Otter Lake	524.0	40.5	13:1
	Lynx Lake	538.0	38.7	14:1
	Duck Lake	532.0	46.4	11:1
Phase IV – 2017	Yellow Birch Lake			
	Watersmeet Lake			

Eagle River Chain of Lakes Trophic State

Figure 3.1-6 contains the TSI values for the Lower Eagle River Chain of Lakes. The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic. In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a* because water clarity can be affected by factors other than algae. The Trophic State Index indicates that all of the Phase I and Phase II lake are eutrophic, characterized by higher nutrient and algae concentrations and lower water clarity.

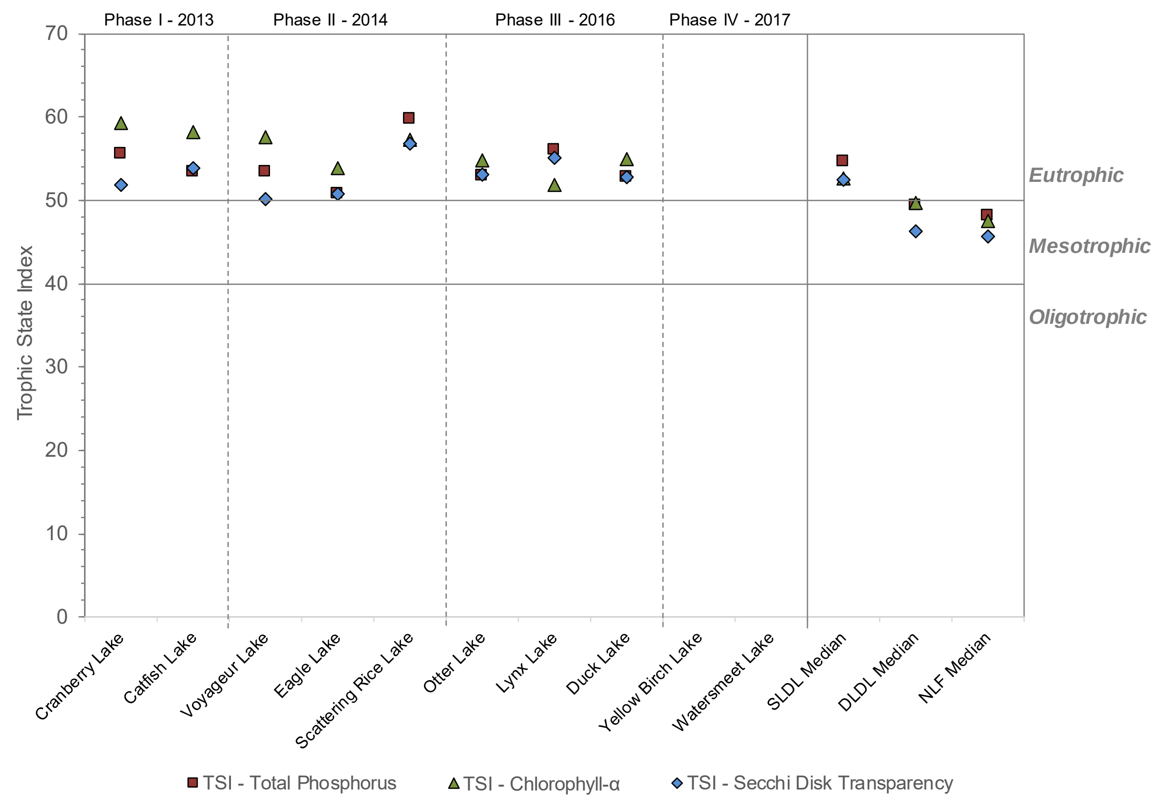


Figure 3.1-6. Lower Eagle River Chain of Lakes and comparable lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Additional Water Quality Data Collected on the Eagle River 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 Lower Eagle River Chain of Lakes water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include; pH, alkalinity, and calcium.

pH

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-), and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. 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 forms carbonic acid in water. Carbon dioxide removal through photosynthesis reduces the acidity of lake water, and so pH increases. Within the Eagle River Chain, there is little variability between lakes, as is to be expected on a string of connected waterbodies (Figure 3.1-7). The mid-summer values seen within the chain lakes are slightly alkaline and fall within the normal range for Wisconsin lakes.

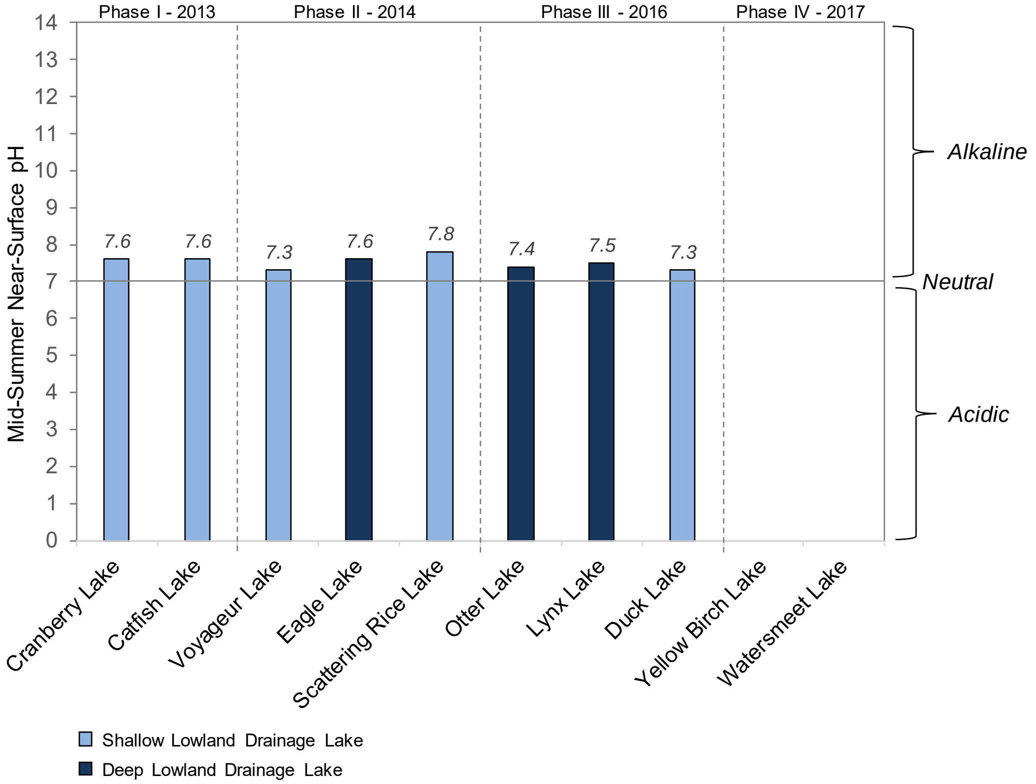


Figure 3.1-7. Lower Eagle River Chain of Lakes mid-summer pH values. Data collected from mid-summer month surface samples.

Alkalinity

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity it contains. Rainwater in northern Wisconsin is slightly acidic naturally 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. Within the Phase I through II lakes, alkalinity ranged from 40.4 mg/L as $CaCO_3$ in Scattering Rice Lake to 27.2 mg/L as $CaCO_3$ in Voyageur Lake. These values fall 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.

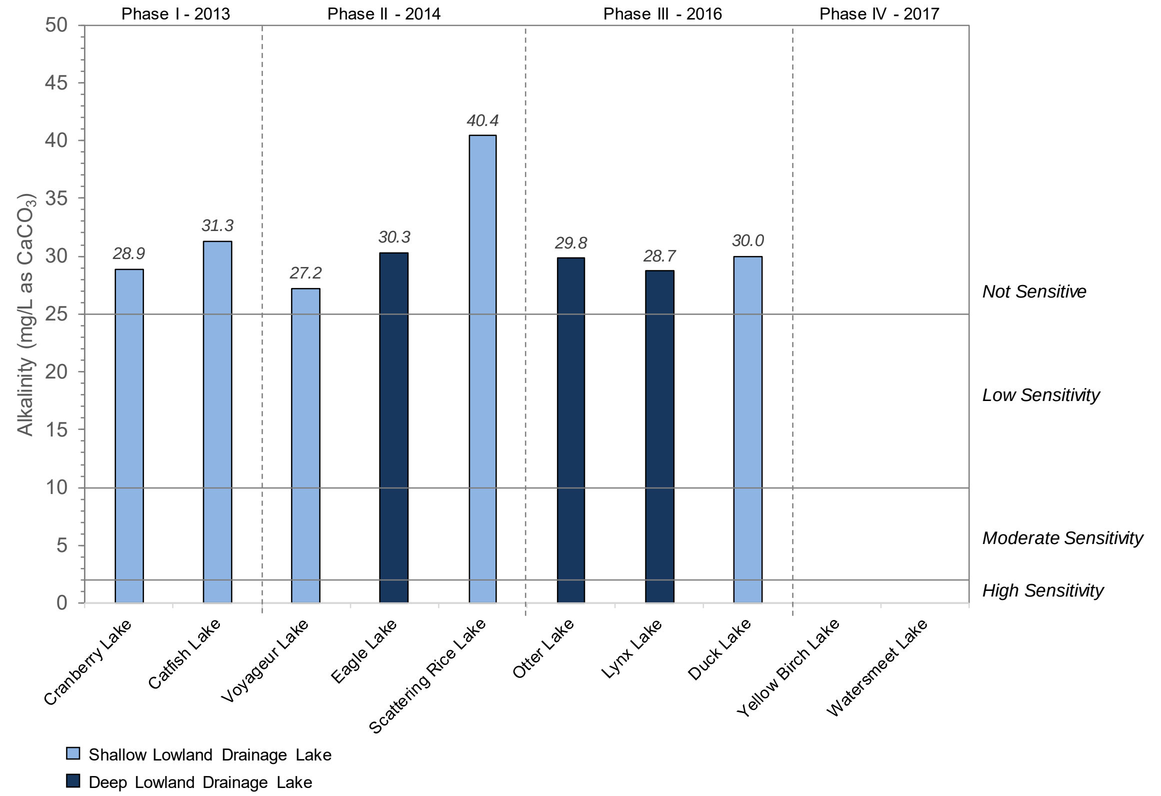


Figure 3.1-8. Lower Eagle River Chain of Lakes alkalinity values and acid rain sensitivity ranges. Data collected from mid-summer surface samples.

Calcium

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, calcium concentration has been used to determine what lakes can potentially 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). Within the Phase I through Phase III lakes, calcium concentrations ranged from 9.8 mg/L in Scattering Rice Lake to 7.2 mg/L in Voyageur Lake (Figure 3.1-9). The calcium concentrations within the Phase I through Phase III lakes are within the *very low susceptibility* category for zebra mussel suitability.

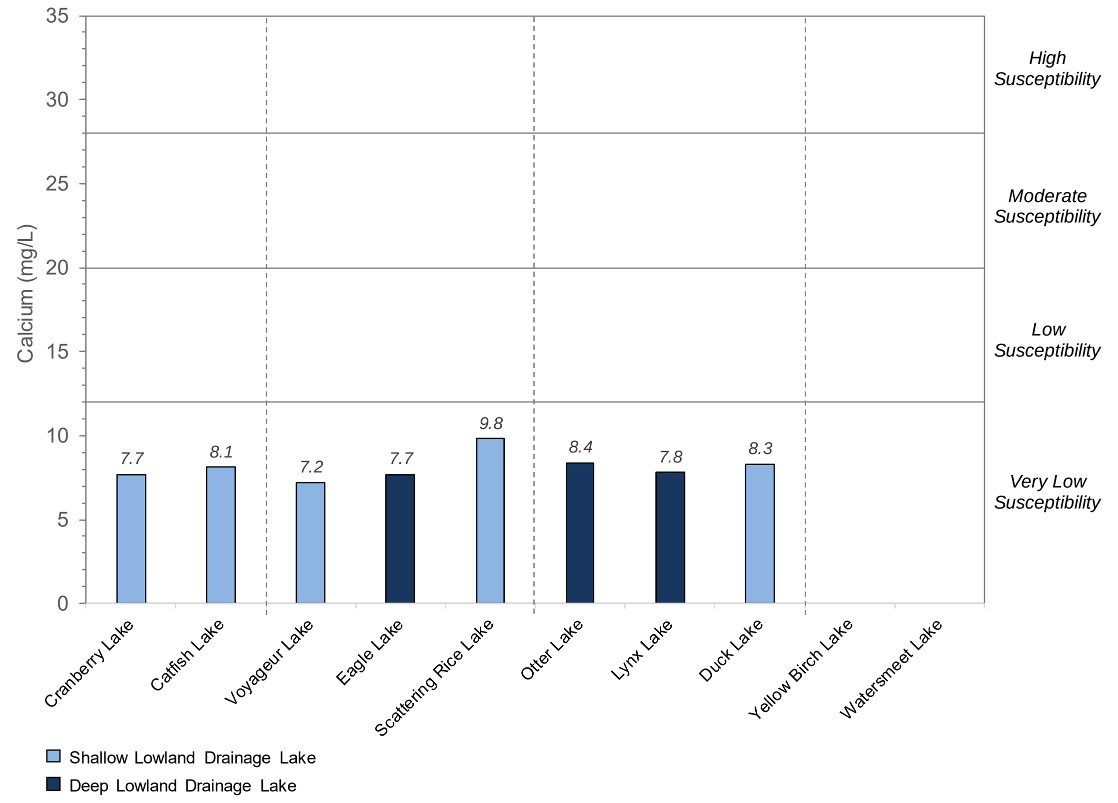


Figure 3.1-9. Lower Eagle River Chain of Lakes susceptibility to zebra mussel survivability and establishment based on calcium concentration. Created using surface calcium. Calcium susceptibility range adapted from Whittier et al. 2008.

True Color

True color is a measure of water clarity once suspended material (i.e. algae, sediments) has been removed. True color measures the amount of light scattered and absorbed by organic materials dissolved within the water. Many lakes in the northern region of Wisconsin have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These give the water a tea-like color and decrease water clarity. Among the Phase I through Phase III lakes, water color varied from 30.0 SU in Catfish Lake to 50.0 SU in Scattering Rice Lake and Lynx Lake (Figure 3.1-10). The average color value for the Phase I through Phase III lakes falls near the median value for drainage lakes throughout Wisconsin (42.0). These values indicate that the water of the Phase I through Phase III lakes is *lightly tea-colored* to *tea-colored* (UNH Center for Freshwater Biology 2014). Lakes with large areas of forests and wetlands within their watersheds tend to have this stained water, as these dissolved organic materials within the lake's water originate from decaying vegetation within the watershed.

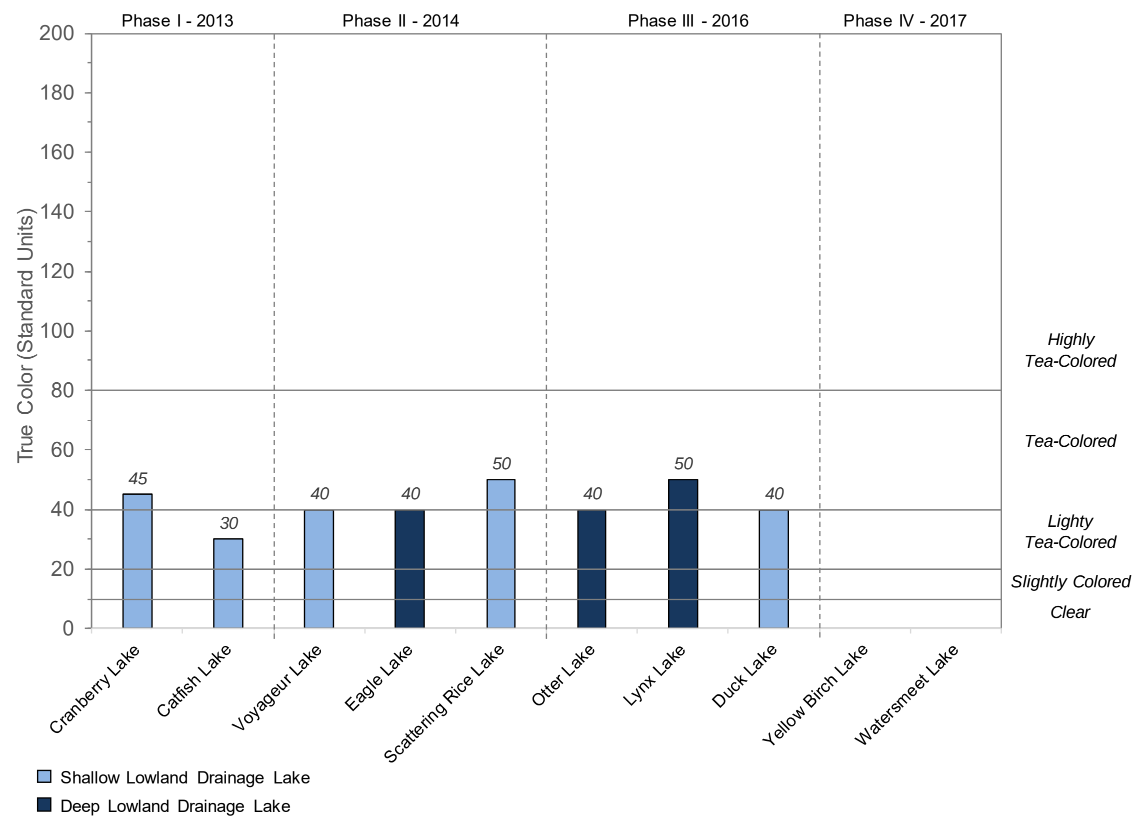


Figure 3.1-10. Lower Eagle River Chain of Lakes true color values. Created using spring and summer near-surface samples. Color range adapted from UNH Center for Freshwater Biology (2014).

Stakeholder Survey Responses to the Eagle River Chain Lakes Water Quality

As discussed in section 2.0, the stakeholder survey sent to Eagle River Chain property owners asked many questions pertaining to perception of the lake and how it may have changed over the years. Of the 1623 surveys distributed, only 238 (15%) were returned. Given the low response rate, the responses to the following questions regarding water quality cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of stakeholder perceptions of water quality in the Eagle River Chain but cannot be stated with statistical confidence.

Figure 3.1-11 displays stakeholder survey responses to questions regarding stakeholder perceptions of the Eagle River Chain's water quality. When asked how they would describe the current water quality of the chain, 62% indicated *good* or *excellent*, 28% indicated *fair*, 8% indicated *poor* to *very poor* and 2% indicated *unsure*. As discussed in the previous section, the water quality parameters used to assess the Eagle River Chain's current water quality all fall within the *good* category for Wisconsin's drainage lakes.

When asked how they believe the current water quality has changed since they first visited the lake, the largest proportion of 37% indicated it has *remained the same*, 28% indicated *somewhat degraded*, 17% indicated *somewhat improved*, 9% indicated *greatly improved*, 5% indicated *unsure*, and 4% indicated *severely degraded* (Figure 3.1-12). The historical water quality data from the Eagle River Chain do not indicate degrading water quality conditions; therefore, the respondents must be considering some other form of lake or lake water degradation that was not assessed as a part of this survey.

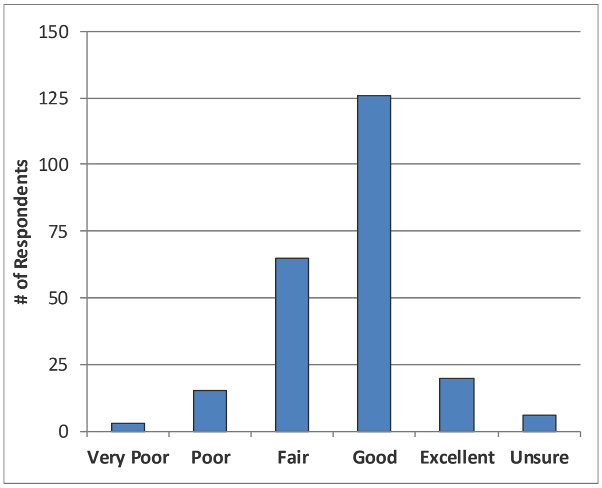


Figure 3.1-11. Stakeholder survey response Question #13. How would you describe the current water quality of the Eagle River Chain?

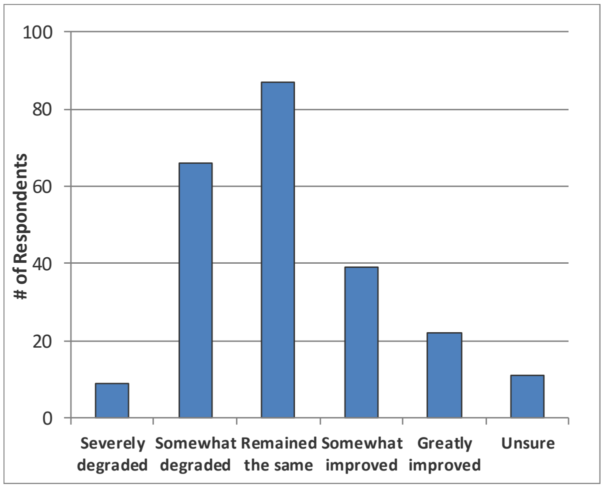


Figure 3.1-12. Stakeholder survey response Question #14. How as the water quality changed in the Eagle River Chain since you first visited the chain?

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

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

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). 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 Eagle River Chain lakes (Figure 3.2-1 and Map 2). The watershed to lake area ratios of the lakes in the Eagle River Chain range from 101:1 for Catfish Lake to 4,957:1 for Lynx Lake. In total, approximately 339,587 acres of land drains to the Eagle River Chain of Lakes, the majority (42% or 143,363 acres) of which is classified as forest (Figure 3.2-2). Wetlands account for the second largest land cover type in the watershed (36% or 124,296 acres), while open water is the third largest cover type at 38,676 acres (11%). Areas of rural open space (4%), pasture/grass (2%), row crops (2%), rural residential (0.4%), urban – medium density (0.10%), and urban – high density (0.04%), and the Eagle River Chain of Lakes' surfaces themselves (1.1%) account for the remaining land cover types within the Eagle River Chain's watershed.

Once completed near the end of this project, phosphorus modeling results will be discussed here. Watershed modeling data will be produced in Appendix D.

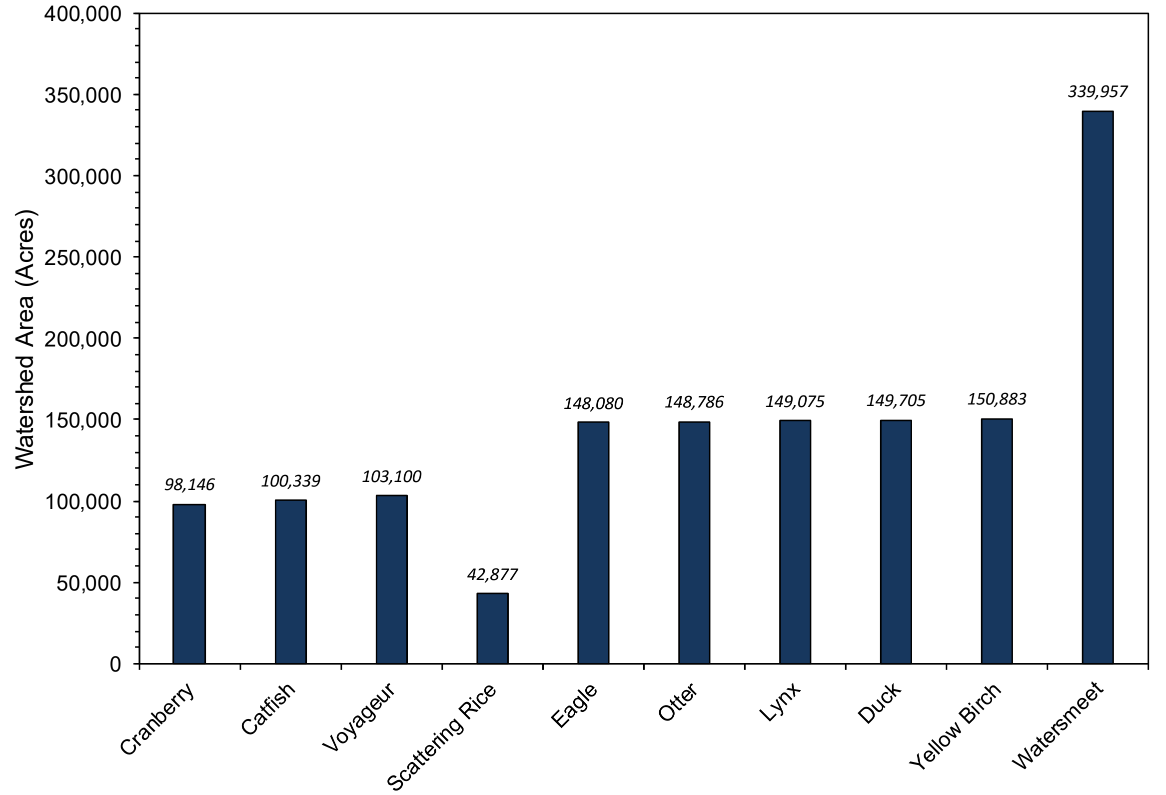


Figure 3.2-1. Lower Eagle River Chain of Lakes watershed sizes in acres.

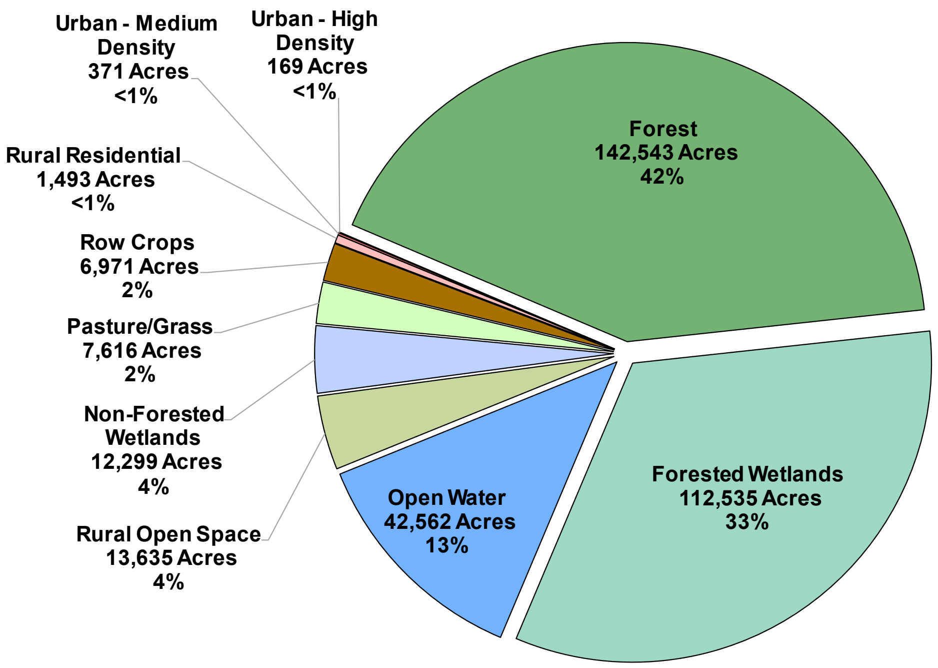


Figure 3.2-2. Lower Eagle River Chain of Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Phosphorus loading chart will be included here once completed.

Figure 3.2-3. Lower Eagle River 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.

The intrinsic value of natural shorelands is found in numerous forms. Vegetated shorelands prevent polluted runoff from entering lakes by filtering this water or allowing it to slow to the point where particulates settle. The roots of shoreland plants stabilize the soil, thereby preventing shoreland erosion. Shorelands also provide habitat for both aquatic and terrestrial animal species. Many species rely on natural shorelands for all or part of their life cycle as a source of food, cover from predators, and as a place to raise their young. Shorelands and the nearby shallow waters serve as spawning grounds for fish and nesting sites for birds. Thus, both the removal of vegetation and the inclusion of development reduces many forms of habitat for wildlife.

Some forms of development may provide habitat for less than desirable species. Disturbed areas are often overtaken by invasive species, which are sometimes termed "pioneer species" for this reason. Some waterfowl, such as geese, prefer to linger upon open lawns near waterbodies because of the lack of cover for potential predators. The presence of geese on a lake resident's beach may not be an issue; however, the feces the geese leave are unsightly and pose a health risk. Geese feces may become a source of fecal coliforms as well as flatworms that can lead to swimmer's itch. Development such as rip rap or masonry, steel or wooden seawalls completely remove natural habitat for most animals, but may also create some habitat for snails; this is not desirable for lakes that experience problems with swimmer's itch, as the flatworms that cause this skin reaction utilize snails as a secondary host after waterfowl.

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

Shoreland Zone Regulations

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

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

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

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

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

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

Wisconsin Act 31

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

Wisconsin Act 55

In July of 2015 with the passing of the state budget, the State of Wisconsin passed Wisconsin Act 55 which modified shoreland zoning provisions. Specifically, Act 55 removed authority from counties to enforce shoreland zoning ordinances that are more restrictive than the state's minimum standards contained in NR 115. Counties that had shoreland zoning ordinances that were more restrictive than state standards are no longer able to enforce those more restrictive standards. While county governments, countywide lake and river associations, individual lake associations, and lake districts across Wisconsin have moved to challenge Act 55, the Wisconsin Legislature finished its session in November of 2015 and did not take any action on shoreland zoning.

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.


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

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

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

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

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted 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 lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $1,400. The more native vegetation a site has, the lower the cost. Owners should contact the county's regulations/zoning department for all minimum requirements. The single site used for the estimate indicated above has the following characteristics:

- Spring planting 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.
  - Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
  - Soil amendment (peat, compost) would be needed during planting.
  - There is no hard-armor (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.

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Eagle River Chain of Lakes Shoreland Zone Condition

Shoreland Development

The lakes within the Eagle River 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 shoreline 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 shorelines 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 shoreline 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 shoreline that was restored would likely be included here, also.

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

Figure 3.3-1. Shoreland assessment category descriptions.

On each of Eagle River 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 Eagle River 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. Of the eight lakes in Phase I through Phase III of the project, approximately 41% (18.7 miles) of the shoreline is comprised of natural/undeveloped and developed-natural shorelines (Figure 3.3-2). These shoreland types provide the most benefit to the lakes and should be left in their natural state if at all possible. Approximately 33% (14.9 miles) of the shoreline is comprised of urbanized and developed–unnatural shorelines. Figure 3.3-3 provides a breakdown of the Phase I through Phase III lakes 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.

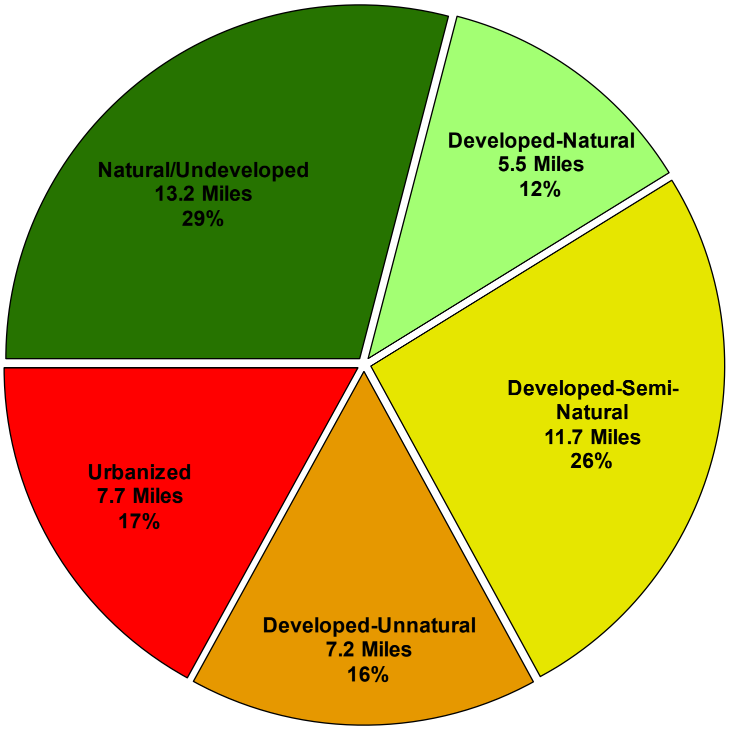


Figure 3.3-2. Combined shoreland conditions from the Lower Eagle River Chain of Lakes Phase I, II, and III lakes. Based upon field surveys conducted in late summer 2013 (Phase I), late summer 2014 (Phase II), and late summer 2016 (Phase III). Locations of these categorized shorelands can be found on maps within each individual lake section.

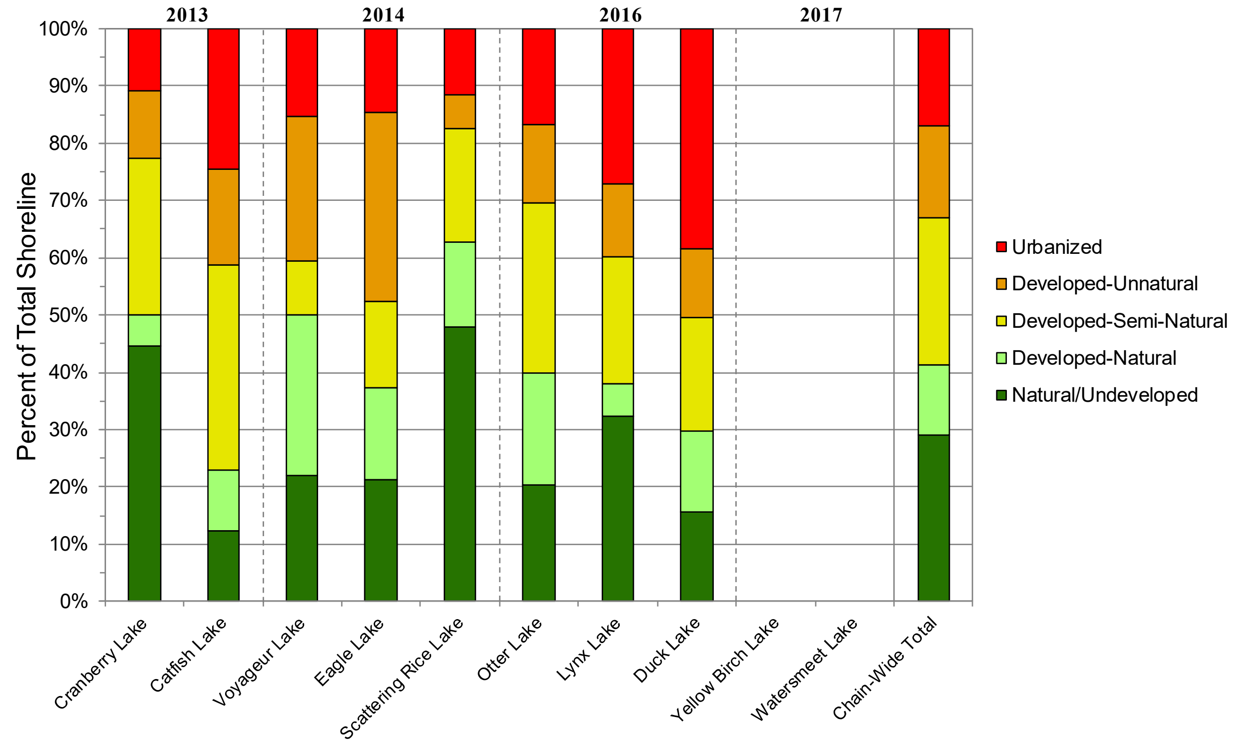


Figure 3.3-3. Lower Eagle River Chain of Lakes shoreland condition by lake. Created using data from late summer surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

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 Lower Eagle River 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 Eagle River 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 (Newbrey et al. 2005).

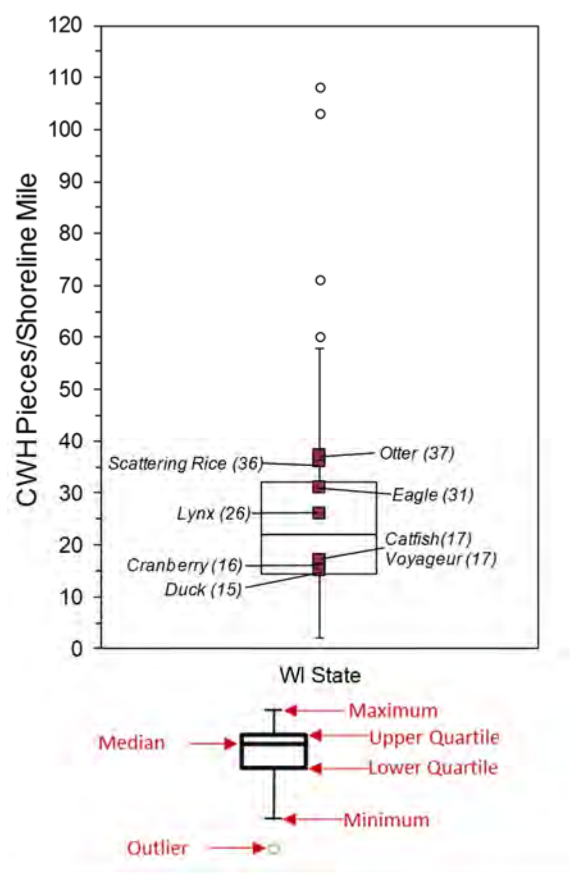


Figure 3.3-4. Lower Eagle River Chain of Lakes total number of coarse woody habitat (CWH) pieces per shoreline mile. Created using data from late summer 2013 (Phase I), late summer 2014 (Phase II), and late summer 2016 (Phase III) surveys.

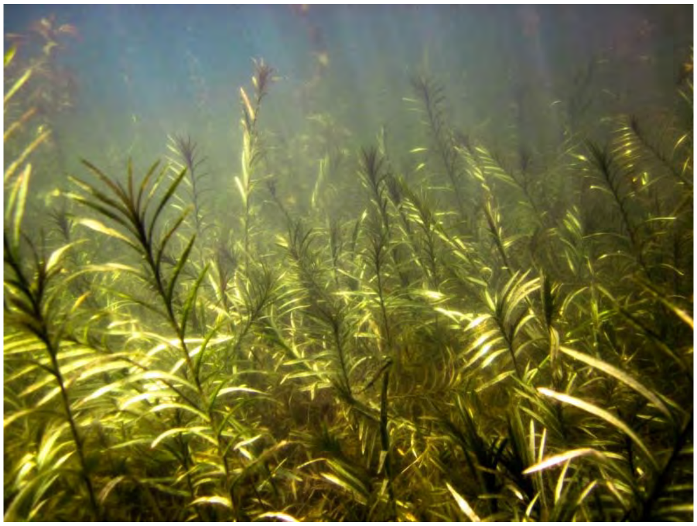
Onterra has completed coarse woody habitat surveys on 75 lakes throughout Wisconsin since 2012. Figure 3.3-4 displays the number of coarse woody habitat pieces per shoreline mile from the Eagle River Chain project lakes and how they compare with data from the 75 lakes surveyed. The number of coarse woody habitat pieces per mile ranged from 37 in Otter Lake to 15 in Duck Lake. The number of coarse woody habitat pieces per shoreline mile in Otter and Scattering Rice lakes fall above the 75th percentile. To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). Please note the methodologies between the surveys done on the Eagle River Chain and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat. Further, the data collected by Onterra is not from a group of randomly selected lakes and the vast majority of the lakes included are developed and have public access.

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

3.4 Aquatic Plants

Introduction

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



Photograph 3.4-1. Native aquatic plant community. Fern pondweed (Potamogeton robbinsii)

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife (Photograph 3.4-1). For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the periphyton attached to them as their primary food source. The plants also provide cover for feeder fish and zooplankton, stabilizing the predator-prey relationships within the system. Furthermore, rooted aquatic plants prevent shoreland erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas where plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by phytoplankton, which helps to minimize nuisance algal blooms.

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

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

Aquatic Plant Management and Protection

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

Important Note:
Even though most of these techniques are not applicable to the Eagle River 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 the Eagle River Chain are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Permits

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

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

Manual Removal

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

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

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

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

Cost

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

Advantages	*Disadvantages*
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if treatment is conducted after June 15th. • Allows for selective removal of undesirable plant species. • Provides immediate relief in localized area.	• 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.

• Plant biomass is removed from waterbody.	• 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.

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

Photograph 3.4-3. Mechanical harvester.

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

Photograph 3.4-4. Granular herbicide application.

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

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

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

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

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

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

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

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

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

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

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

Cost

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

Advantages	***Disadvantages***
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian watermilfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is no need for either biocontrol insect.

However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian watermilfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian watermilfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian watermilfoil. Currently the milfoil weevil is not a WDNR grant-eligible method of controlling Eurasian watermilfoil.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Advantages	***Disadvantages***
• Milfoil weevils occur naturally in Wisconsin. • Likely environmentally safe and little risk of unintended consequences.	• Stocking and monitoring costs are high. • This is an unproven and experimental treatment. • There is a chance that a large amount of money could be spent with little or no change in Eurasian watermilfoil density.

Wisconsin has approved the use of two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These beetles were imported from Europe and used as a biological control method for purple loosestrife. Many cooperators, such as county conservation departments or local UW-Extension locations, currently support large beetle rearing operations. Beetles are reared on live purple loosestrife plants growing in kiddy pools surrounded by insect netting. Beetles are collected with aspirators and then released onto the target wild population. For more information on beetle rearing, contact your local UW-Extension location.

In some instances, beetles may be collected from known locations (cella insectaries) or purchased through private sellers. Although no permits are required to purchase or release beetles within Wisconsin, application/authorization and release forms are required by the WDNR for tracking and monitoring purposes.

Cost

The cost of beetle release is very inexpensive, and in many cases, is free.

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations many lead to long-term control.	• Although considered “safe,” reservations about introducing one non-native species to control another exist. • Long range studies have not been completed on this technique.

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Eagle River 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

As discussed previously, whole-lake point-intercept surveys were conducted all 10 lakes of the Lower Eagle River Chain of Lakes in 2012 to assess their aquatic plant communities following five years of large-scale herbicide treatments to control Eurasian watermilfoil. Native aquatic plants are an important element in every healthy aquatic ecosystem, providing food and habitat to wildlife, improving water quality, and stabilizing bottom sediments. Because most aquatic plants are rooted in place and are unable to relocate in wake of environmental alterations, they are often the first community to indicate that changes may be occurring within the system. Aquatic plant communities can respond in variety of ways; there may be increases or declines in the occurrences of some species, or a complete loss. Or, certain growth forms, such as emergent and floating-leaf communities may disappear from certain areas of the waterbody. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide relevant information for making management decisions.

The point-intercept method as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) was used to complete the whole-lake point-intercept surveys on the Lower Eagle River Chain of Lakes in 2012. Based upon guidance from the WDNR, a point spacing (resolution) ranging from 30 to 80 meters was used resulting in 137 to 616 sampling points being evenly distributed across each lake (Table 3.4-1).

Table 3.4-1. Resolution and number of point-intercept sampling locations used in 2006 and 2012 surveys on the Lower Eagle River Chain of Lakes.

Lake	Number of Sample Locations	Resolution (m)
Cranberry	588	80
Catfish	616	80
Voyageur	232	50
Eagle	476	70
Scattering Rice	287	60
Otter	195	60
Lynx	137	30
Duck	168	50
Yellow Birch	416	45
Watersmeet	554	50

At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (muck, sand, or rock), and the plant species sampled along with their relative abundance (Figure 2.1-1) on the sampling rake was recorded. A pole-mounted rake was used to collect the plant samples, depth, and sediment information at point locations of 13 feet or less. A rake head tied to a rope (rope rake) was used at sites greater than 13 feet. Depth information was collected using graduated marks on the pole of the rake or using an onboard sonar unit at depths greater than 13 feet. Also, when a rope rake was used, information regarding substrate type was not collected due to the inability of the sampler to accurately feel the bottom with this sampling device. The point-intercept survey produces a great deal of information about a lake's aquatic vegetation and overall health. These data are analyzed and presented in numerous ways; each is discussed in more detail the following section.

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

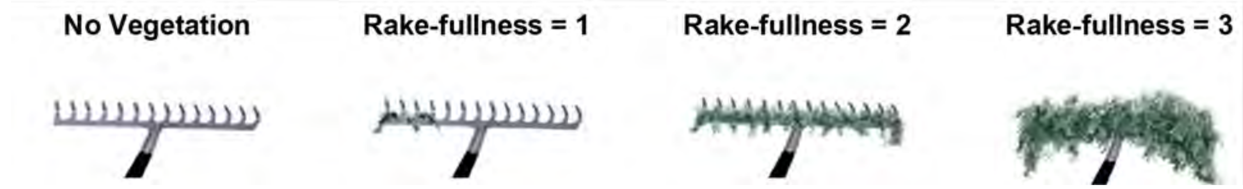


Figure 3.4-1. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

Species List

The species list is simply a list of all of the species, both native and non-native, that were located during the whole-lake point-intercept surveys 2012 on the Lower Eagle River Chain of Lakes. The list also contains the growth-form of each plant found (e.g. submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept surveys conducted in 2005/2006 and 2012 on the Lower Eagle River Chain of Lakes, plant samples were collected from plots laid out on a grid that covered each lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, the occurrences of aquatic plant species are displayed as their *littoral 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), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake is calculated using its species richness and average species conservatism. 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 (C-value) for each of those species in its calculation. A species coefficient of conservatism value indicates that species' likelihood of being found in an undisturbed system. The values range from 1 to 10. Species that can tolerate environmental disturbance and are can be located in disturbed systems have lower coefficients, while species that are less tolerant to environmental disturbance and are restricted to high quality systems have higher values. For example, coontail (*Ceratophyllum demersum*), a submergent native aquatic plant species with a C-value of 3, has a higher tolerance to disturbed conditions, often thriving in lakes with higher nutrient levels and low water clarity, while other species like algal-leaf pondweed (*Potamogeton confervoides*) with a C-value of 10, are intolerant of environmental disturbance and require high quality environments to survive.

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys. As discussed in the Water Quality Section, the Lower Eagle River Chain of Lakes falls within the Northern Lakes and Forests Ecoregion of Wisconsin, and the floristic quality of its aquatic plant community in 2005/2006 and 2012 will be compared to other lakes within this ecoregion as well as the entire state. The comparative data within this ecoregion has been divided into two groupings: Northern Lakes and Forest Lakes (NLFL) and Northern Lakes and Forest Flowages (NLFF). Although the Eagle River Chain of Lakes is an impounded system, it will be compared to other natural lakes within this ecoregion due to the fact that the majority (>50%) of each lakes' volumes are not due to the impounded condition.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. As defined previously, 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 species diversity also takes into account how evenly the species are distributed 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.

An aquatic system with high species diversity is much more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. 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

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 the Lower Eagle River Chain of Lakes. Comparisons will be displayed using *boxplots* that showing median values and upper/lower quartiles of lakes in the same ecoregion (Figure 2.1-2) and in the state. Please note for this parameter, the Northern Lakes and Forests Ecoregion data includes both natural and flowage lakes.

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.

Community Mapping

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

Exotic Plants

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

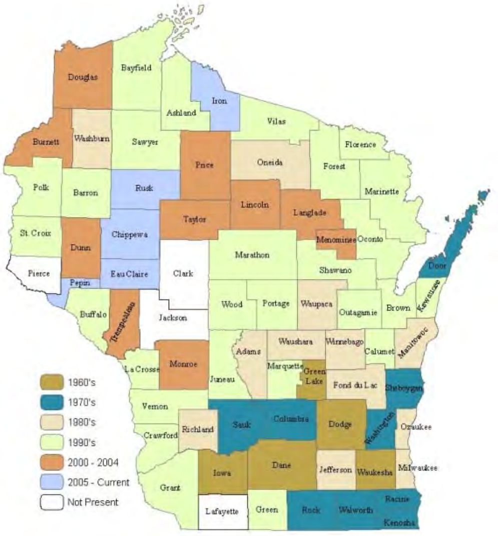


Figure 3.4-2. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

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

Aquatic Plant Survey Results

Photograph 3.4-5. Vasey's pondweed (*Potamogeton vaseyi*), native aquatic plant listed as special concern in Wisconsin. Photo credit Onterra.

The whole-lake point-intercept surveys were completed on the Lower Eagle River Chain of Lakes by Onterra on July 31, August 1, 2, 3, and 6, 2012 (Appendix E), while the community mapping surveys were conducted on each lake during the corresponding phase (2013-2016). A total of 70 aquatic plant species were located within the chain, four of which are considered to be a non-native, invasive species: Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife (Table 3.4-2 and 3.4-3). Because of their importance, these non-native species will be discussed in detail a separate section. One species, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as special concern due to uncertainty regarding its population and distribution within Wisconsin (Photograph 3.4-5). Vasey's pondweed was located in all 10 lakes in 2012, and was often one of the more dominant plant species encountered.

Eleven of the 70 plant species were located in all 10 lakes in 2012, and include: coontail, common waterweed, slender naiad, stoneworts, wild celery, Eurasian watermilfoil, northern watermilfoil, clasping-leaf pondweed, fern pondweed, flat-stem pondweed, small pondweed, and Vasey's pondweed.

Photograph 3.4-6. Alpine pondweed (*Potamogeton alpinus*), a relatively rare, native aquatic plant in Wisconsin. Photo credit Onterra.

Only two aquatic plant species present during Northern Environmental, Inc.'s (NEI) 2006 point-intercept surveys, water lobelia and white water-crowfoot, were not recorded during the 2012 surveys. During 2006, water lobelia was located at one point-intercept location in Catfish Lake, while white water-crowfoot was located at a few sampling locations in Voyageur Lake, Eagle Lake, and Watersmeet. It is not believed that these two species have disappeared from the system, but rather went undetected during the 2012 surveys because of their very low occurrence.

Fourteen native aquatic plant species were located during the 2012 surveys that were not recorded during the surveys completed in 2005/2006 (Table 3.4-2 and Table 3.4-3). Some of these include relatively rare species with high coefficients of conservatism and are only found growing in high-quality conditions. For example, alpine pondweed (Photograph 3.4-6), spiny hornwort, and small bladderwort were located in quiet, backwater areas of Cranberry Lake, Scattering Rice Lake, and Watersmeet. Small bladderwort belongs to a group of carnivorous plants in the genus *Utricularia*. These plants produce sac-like bladders to trap and digest small aquatic organisms. Another species of bladderwort, common bladderwort, was also located in five of the 10 lakes in 2012 (Table 3.4-2 and Table 3.4-3).

Table 3.4-2. Emergent, floating-leaf, and floating-leaf/emergent aquatic plant species located in the Lower Eagle River Chain of Lakes during the Onterra 2012 point-intercept surveys and Onterra 2013-2016 community mapping surveys. Note: community mapping surveys have not yet occurred on Phase IV lakes.

Growth Form	Species	Common Name	C-value	Cranberry	Catfish	Voyageur	Eagle	Scattering Rice	Otter	Lynx	Duck	Yellow Birch	Watersmeet	Present in 2005/2006
Emergent	*Calla palustris*	Water arum	9	I		I		I	I					
	Carex comosa	Bristle sedge	5	I										
	Carex crinita	Fringed sedge	6	I										
	Carex lacustris	Lake sedge	6							I				
	Carex utriculata	Common yellow lake sedge	7	I	I	I		I			I			
	Decodon verticillatus	Water willow	7	I										
	Dulichium arundinaceum	Three-way sedge	9	I										
	Eleocharis palustris	Creeping spikerush	6				X	I					X	X
	Equisetum fluviatile	Water horsetail	7	I	I								X	
	Iris pseudacorus	Pale-yellow iris	Exotic	I	I				I					
	Iris versicolor	Northern blue flag	5	I										
	Juncus effusus	Soft rush	4			I								
	Lysimachia vulgaris	Garden yellow loosestrife	Exotic	I										
	Lythrum salicaria	Purple loosestrife	Exotic	I	I	I		I						
	Pontederia cordata	Pickerelweed	9	I	I	I	I	X	I		X		X	X
	Sagittaria latifolia	Common arrowhead	3	I		I		I					X	
	Sagittaria rigida	Stiff arrowhead	8	I	I									
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A	I					I	I				
	Schoenoplectus acutus	Hardstem bulrush	5	I	I		I							
	Schoenoplectus pungens	Three-square rush	5						I	I				
	Schoenoplectus tabernaemontani	Softstem bulrush	4	I	X	I	X	I	I		I		X	X
	Scirpus atrovirens	Black bulrush	3							I				
	Typha spp.	Cattail spp.	1	I	I					I	I		X	
	Zizania palustris	Northern wild rice	8										X	X
FL	*Brasenia schreberi*	Watershield	7	X	I								X	X
	Nuphar variegata	Spatterdock	6	X	X	X	X	X	I	X	X	X	X	X
	Nymphaea odorata	White water lily	6	X	X	X	I	X	I	I	X	X	X	X
FL/E	*Sparganium americanum*	Eastern bur-reed	8	I										
	Sparganium androcladum	Shining bur-reed	8	X				X						
	Sparganium angustifolium	Narrow-leaf bur-reed	9	X	X				I		I			X
	Sparganium emersum	Short-stemmed bur-reed	8	I			X							X
	Sparganium eurycarpum	Common bur-reed	5	I	I	I	I	I	I	X				
	Sparganium fluctuans	Floating-leaf bur-reed	10	X	I	X	I		I					

FL = Floating-leaf; FL/E = Floating-leaf and Emergent
X = Located on rake during point-intercept survey; I = Incidentially located

Table 3.4-3. Submergent, submergent/emergent, and free-floating aquatic plant species located in the Lower Eagle River Chain of Lakes during the Onterra 2012 point-intercept surveys and Onterra 2013-2016 community mapping surveys.

Growth Form	Species	Common Name	C-value	Cranberry	Catfish	Voyageur	Eagle	Scattering Rice	Otter	Lynx	Duck	Yellow Birch	Watersmeet	Present in 2005/2006
Submergent	*Bidens beckii*	Water marigold	8	X	I	X	X	X					X	X
	Ceratophyllum demersum	Coontail	3	X	X	X	X	X	X	X	X	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	10	X									I	
	Chara spp.	Muskgrasses	7		X	X	X							X
	Elodea canadensis	Common waterweed	3	X	X	X	X	X	X	X	X	X	X	X
	Heteranthera dubia	Water stargrass	6	X	X	X	X	X	X				X	X
	Isoetes spp.	Quillwort species	8		X		X							X
	Lobelia dortmanna	Water lobelia	10											X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X	X	X	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X	X	X	I	X	I	X	X	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	8	X		X								X
	Najas flexilis	Slender naiad	6	X	X	X	X	X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	7	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton alpinus	Alpine pondweed	9	I		I		X						
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X	X	X	X	X	X	X		X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8	X	X	X	X	X	X	X		X	X	X
	Potamogeton foliosus	Leafy pondweed	6	X	X					X	X	X	X	
	Potamogeton friesii	Fries' pondweed	8		X					X				
	Potamogeton hybrid	Hybrid pondweed	N/A	I										
	Potamogeton natans	Floating-leaf pondweed	5										X	X
	Potamogeton praelongus	White-stem pondweed	8		X								X	X
	Potamogeton pusillus	Small pondweed	7	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	8	X	X	X	X		X	X		X		
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X	X	X	X	X	X	X	X	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X	X	X	X	X	X	X	X	X	X
	Ranunculus aquatilis	White water-crowfoot	8											X
	Utricularia minor	Small bladderwort	10					X						
	Utricularia vulgaris	Common bladderwort	7	X		X	X	X					X	X
	Vallisneria americana	Wild celery	6	X	X	X	X	X	X	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5	X	X									
	Sagittaria cristata	Crested arrowhead	9					I						
	Sagittaria sp. (rosette)	Arrowhead rosette	N/A	X	X									X
FF	*Lemna trisulca*	Forked duckweed	6	X				X						X
	Lemna turionifera	Turion duckweed	2										X	X
	Riccia fluitans	Slender riccia	7					X						
	Spirodela polyrhiza	Greater duckweed	5		X		X						X	X

S/E = Submergent and Emergent; FF = Free-floating
X = Located on rake during point-intercept survey; I = Incidentially located
** = Species listed as 'special concern' in Wisconsin*

Of the 48 aquatic plant species that were recorded on the rake during the 2012 point-intercept surveys, slender naiad and wild celery were the most abundant, with a chain-wide littoral occurrence of nearly 22% (Figure 3.4-3). Small pondweed, coontail, common waterweed, Vasey's pondweed, and spiral-fruited pondweed were also common with littoral occurrences of 11-13%. Eurasian watermilfoil had a chain-wide littoral occurrence of 1.7% in 2012. To determine if the 2008-2012 Eurasian watermilfoil control program had any detectable adverse impacts to the populations of any native aquatic plant species, Chi-square distribution analysis was used to determine if there were statistically valid differences in their occurrences from 2005/2006 to 2012.

Figure 3.4-3 displays the littoral frequency of occurrence of native aquatic plant species from the 2005/2006 and 2012 point-intercept surveys. Only those species that had a littoral occurrence of at least 4% in one of the two surveys are displayed. As illustrated, four native aquatic plant species exhibited statistically valid reductions at the chain-wide level: spatterdock, flat-stem pondweed, large-leaf pondweed, and northern wild rice. Like Eurasian watermilfoil, spatterdock is a dicot and may be susceptible to herbicide treatments that have been occurring since 2008. Unlike Eurasian watermilfoil, flat-stem pondweed and large-leaf pondweed are monocots, and were not historically believed to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research from the WDNR and US Army Corps of Engineers is indicating that some of these species may be prone to decline following these treatments. Northern wild rice is also a monocot, and studies have shown that it too is sensitive to 2,4-D applications. All of the northern wild rice documented in 2006 and 2012 was located in Watersmeet, and a more detailed discussion surrounding the northern wild rice population can be found in the Watersmeet individual lake section.

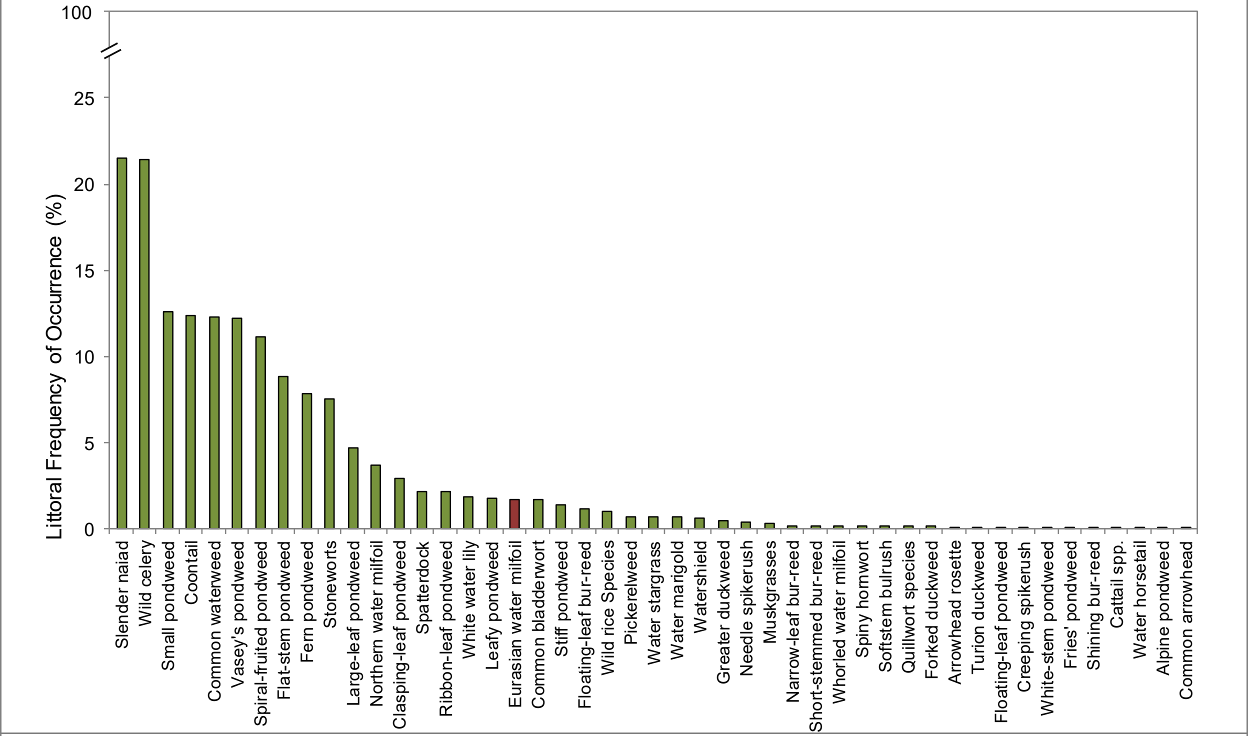


Figure 3.4-3. Littoral frequency of occurrence of aquatic plant species in the Lower Eagle River Chain of Lakes in 2012. Non-native species indicated with red. Created using data from 2012 point-intercept survey.

Figure 3.4-4 also indicates that four native aquatic plant species exhibited statistically valid increases in their occurrence from 2005/2006 to 2012, and include: wild celery, fern pondweed, slender naiad, and Vasey's pondweed. The occurrences of four other native aquatic plant species, coontail, northern watermilfoil, small pondweed, and common waterweed were not statistically different from the 2005/2006 and 2012 surveys.

Figure 3.4-5 shows that of the 2,539 point-intercept sampling locations that fell at or below the maximum depth of aquatic plant growth within the chain in 2005/2006, 1,209 contained native aquatic vegetation. The total number of sampling locations that contained aquatic vegetation within the chain in 2012 fell to 1,007. The number of point-intercept locations containing native aquatic vegetation increased from 2005/2006 to 2012 in Cranberry, Otter, Lynx, and Yellow Birch Lakes, while Catfish, Eagle, Scattering Rice, Duck, and Watersmeet Lakes saw reductions in the number of points containing native vegetation. The number of sampling locations with native vegetation remained the same in Voyageur Lake (Figure 3.4-5).

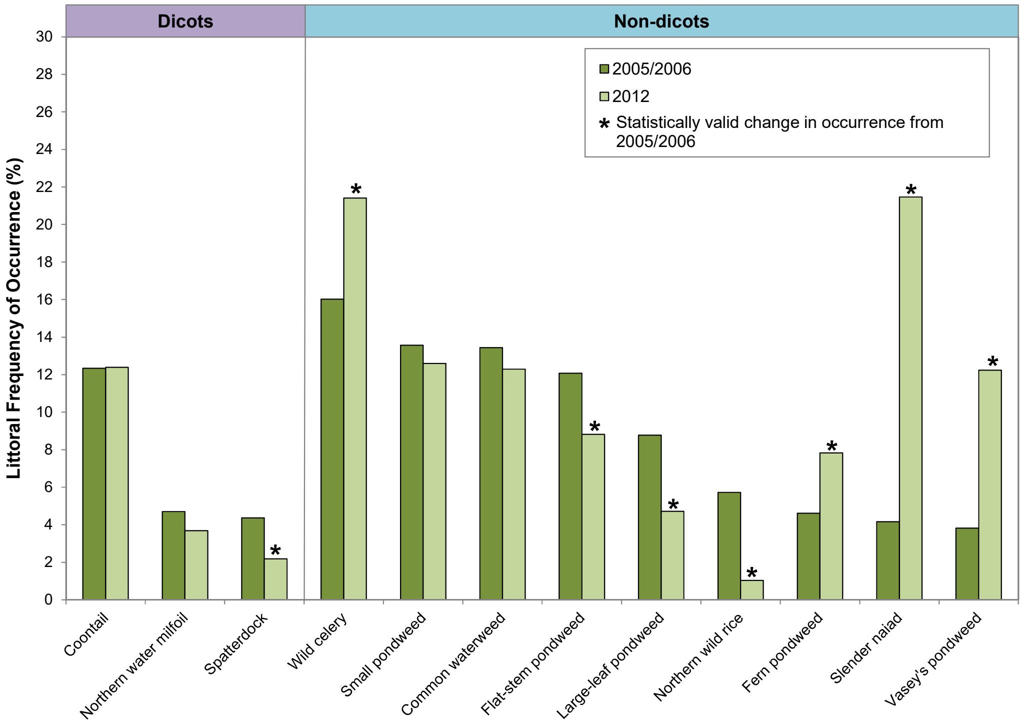


Figure 3.4-4. Lower Eagle River Chain of Lakes littoral occurrence of native aquatic plant species from 2005/2006 and 2012 point-intercept surveys. Please note that only those species with an occurrence of at least 4% in either survey are displayed. Created using data from 2005/2006 and 2012 point-intercept surveys. Chi-Square α = 0.05.

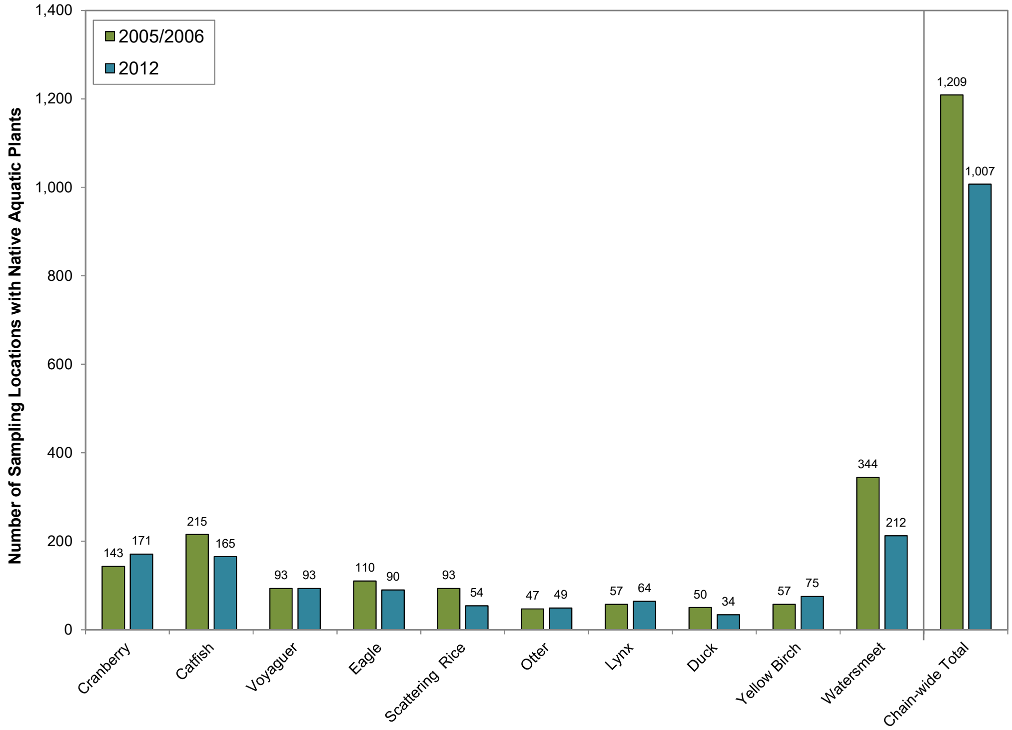


Figure 3.4-5. Number of point-intercept sampling locations containing native aquatic vegetation in 2005/2006 and 2012 point-intercept surveys. Created using data from 2005/2006 and 2012 point-intercept surveys.

In 2012, 1,929 point-intercept locations fell at or below the maximum depth of plant growth. Of these points that fell within the chain's littoral zone, 52% contained aquatic vegetation (Figure 3.4-6). Looking at the total rake fullness (TRF) ratings, 21% had a total rake fullness of 1, 17% had a total rake fullness rating of 2, and 14% had a total rake fullness rating of 3. The fact that 31% of the point-intercept sampling locations had a total rake fullness rating of 2 or 3 indicates that aquatic vegetation in the chain is relatively dense where it occurs.

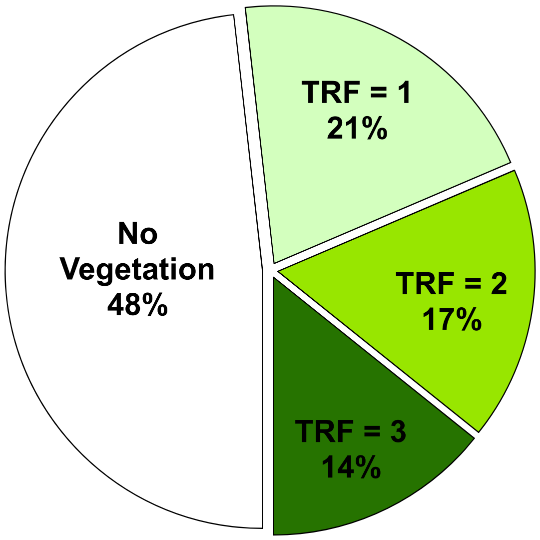


Figure 3.4-6. Lower Eagle River Chain of Lakes total rake fullness ratings of aquatic vegetation from the 2012 point-intercept surveys. Created using data from 2012 point-intercept surveys.

Figure 3.4-7 illustrates that the average number of native aquatic plant species encountered at each point-intercept sampling location increased from an average of 1.3 in 2005/2006 to 1.7 in 2012. Cranberry, Catfish, Voyageur, Eagle, Otter, Lynx, Yellow Birch, and Watersmeet Lakes all saw increases in the number of native aquatic plant species per site, while Scattering Rice and Duck Lakes were the only ones to exhibit a reduction.

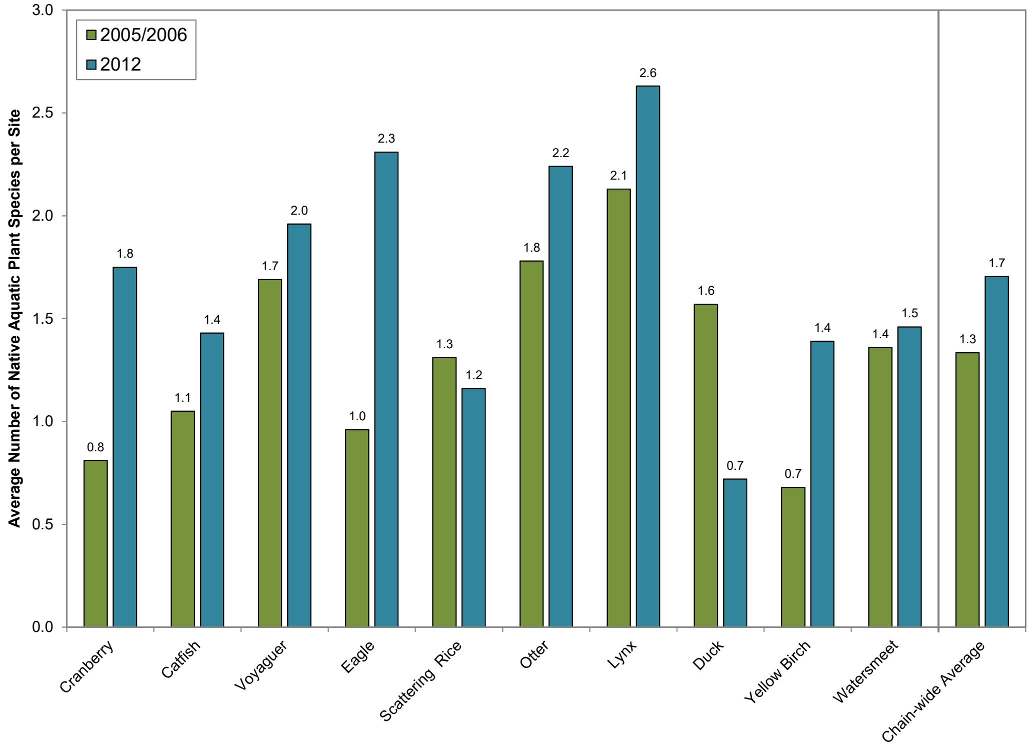


Figure 3.4-7. Lower Eagle River Chain of Lakes average number of native aquatic plant species per site. Created using data from 2005/2006 and 2012 point-intercept surveys.

In the Lower Eagle River Chain of Lakes, the number of plant species within each lake varied from 34 species in Watersmeet Lake to 16 species in Duck Lake, with an average of 24 species per lake in 2012; an increase of six species per lake from the average in 2005/2006. Figure 3.4-8 displays the native aquatic plant species richness values from the 2005/2006 and 2012 surveys. Only those species physically encountered on the rake during the point-intercept surveys are included in the species richness value; incidentally located species are not included. Since the 10 lakes that comprise the Lower Eagle River Chain of Lakes are interconnected, they have relatively similar water chemistry and water clarity. The differences in the number of aquatic plant species between lakes is likely due to morphological attributes of the lakes themselves and the different habitat types they possess.

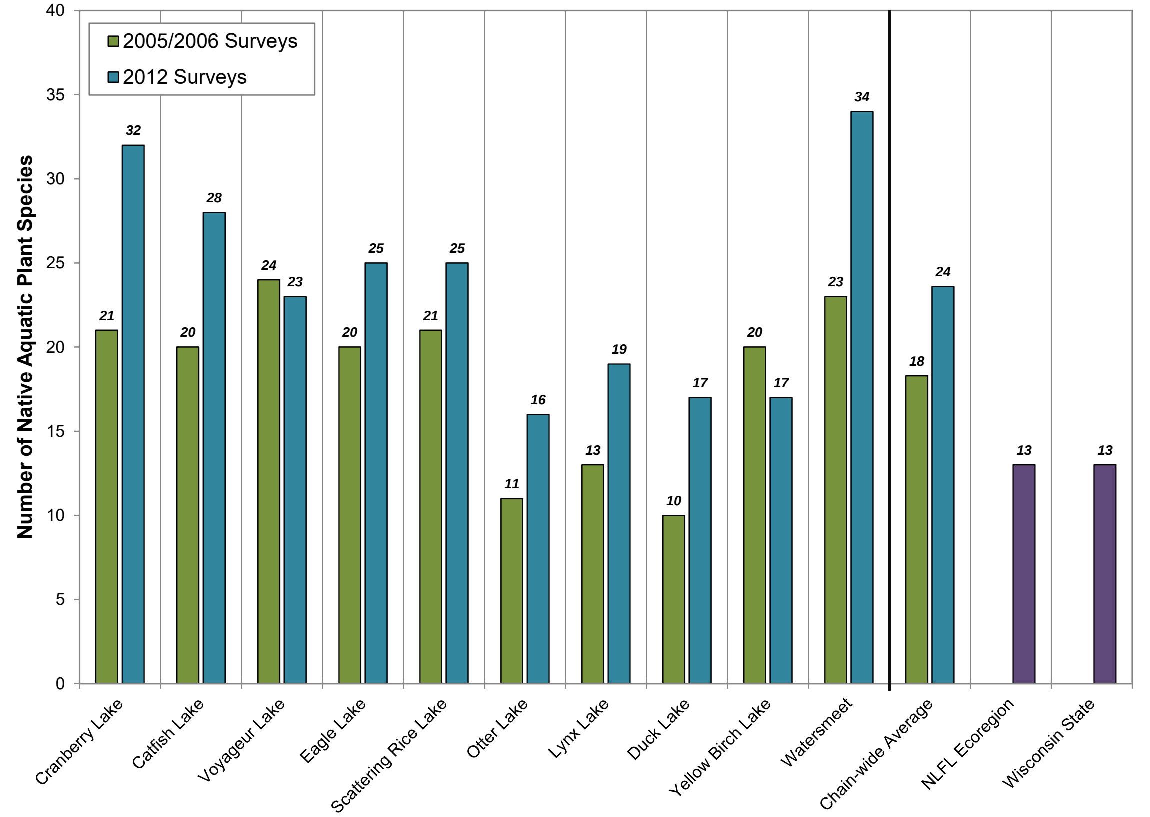


Figure 3.4-8. Lower Eagle River Chain of Lakes 2005/2006 and 2012 native species richness. Created using data from 2005/2006 and 2012 point-intercept surveys.

Studies have shown that the number of aquatic plant species within a lake increases as the lake's littoral area and its *shoreline complexity* increases (Vestergaard and Sand-Jensen 2000). Shoreline complexity is an index that relates the area of the lake to the perimeter of its shoreline. If a lake were a perfect circle, its shoreline complexity value would be 1.0. The farther a lake deviates from a perfect circle, the higher its shoreline complexity value is. Lakes with greater shoreline complexity harbor more areas that are sheltered from wind and wave action creating additional habitat types for aquatic plants.

Shoreline complexity values of the 10 lakes in the Lower Eagle River Chain of Lakes ranged from 1.3 in Duck Lake to 54.1 in Watersmeet (Table 3.4-4). Watersmeet and Cranberry Lake have the highest shoreline complexity values and were also found to have the highest aquatic plant species richness in 2012. However, shoreline complexity cannot be the sole attribute used to explain differences in species richness among these lakes. For example, Yellow Birch Lake has the third highest shoreline complexity value but the second-lowest species richness value. While Yellow Birch Lake has a relatively complex shoreline, it has a relatively small littoral area (75 acres) when compared to some of the other lakes like Catfish or Cranberry; most of Yellow Birch Lake is too deep to support aquatic plant growth. As another example, Eagle Lake is nearly five times the size of Voyageur Lake, yet they have approximately the same amount of littoral area and thus a similar number of aquatic plant species. As Table 3.4-4 shows, the lakes in the chain with higher littoral acreages and higher shoreline complexities tend to have higher species richness. The acreage of littoral area for each lake was calculated using the maximum depth of plant growth from the 2012 surveys.

Table 3.4-4. Lower Eagle River Chain of Lakes 2012 aquatic plant species richness compared to littoral area and shoreline complexity. Littoral acreage determined from maximum depth of plant growth during 2012 point-intercept surveys.

Lake	Species Richness (2012)	Lake Area (acres)	Littoral Area (acres)	Shoreline Complexity
Watersmeet	34	415	391	54.1
Cranberry	32	929	515	7.9
Catfish	28	977	699	6.8
Scattering Rice	25	266	124	3.5
Eagle	25	581	137	2.2
Voyageur	23	106	137	6.7
Lynx	19	30	16	1.7
Yellow Birch	17	238	75	7.3
Duck	17	109	82	1.3
Otter	16	195	68	4.3

As discussed in the primer section, all of the native aquatic plants that were located on the rake during the 2012 are used in calculating each lake's Floristic Quality Index (FQI). These calculations do not include species that were located "incidentally" during the 2012 surveys. The FQI for each lake is calculated using the native species richness and the average conservatism value (equation shown below).

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

Figure 3.4-9 displays the average conservatism value for each lake from 2005/2006 and 2012 point-intercept surveys and compares them to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion and to lakes throughout the State of Wisconsin. Average conservatism values in 2012 ranged from 7.0 in Cranberry Lake to 6.3 in Watersmeet. Three lakes exceeded the NLF Ecoregional median, while all of the lakes exceeded the median for lakes in Wisconsin. Higher average conservatism values indicate the lake contains a greater number of aquatic plant species that have higher coefficients of conservatism, or are less tolerant to environmental disturbance. The chain-wide average conservatism increased from 6.2 in the 2005/2006 surveys to 6.6 in 2012, falling just below the median value for lakes within the NLFL Ecoregion and exceeding the median for lakes statewide. All of the lakes in 2012, except for Catfish which remained the same, had higher conservatism values than in 2005/2006.

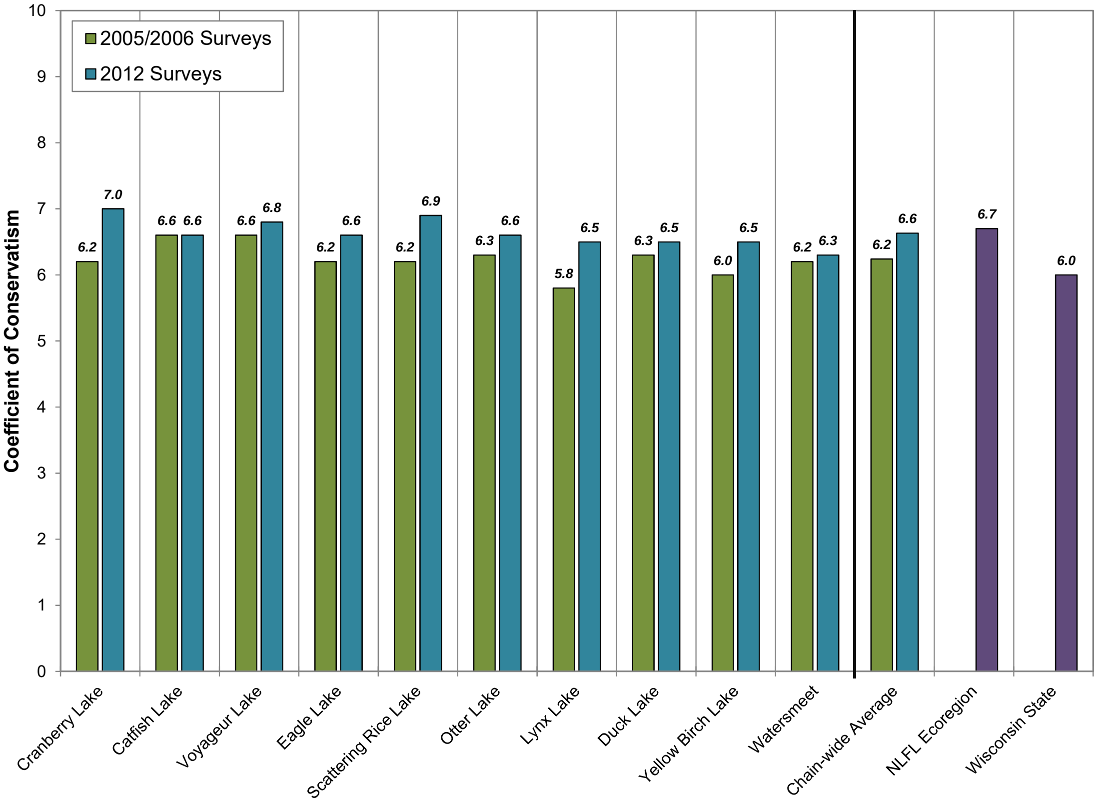


Figure 3.4-9. Lower Eagle River Chain of Lakes average coefficients of conservatism. Created using data from 2005/2006 and 2012 point-intercept surveys.

The average species richness and average conservatism values from the Lower Eagle River Chain of Lakes in 2005/2006 and 2012 were used to calculate their FQI values (Figure 3.4-10). The 2012 FQI values ranged from 39.6 in Cranberry Lake to 26.3 in Otter Lake, and all of the FQI values for all the lakes in 2012 exceeded the NLFL ecoregion and state medians. Each of the 10 lakes had higher FQI values in 2012 than in 2005/2006, and the chain-wide average FQI increased from 26.5 to 31.9. This indicates that the aquatic plant community of the Lower Eagle River Chain of Lakes is of higher quality than the majority of the lakes within the NLFL Ecoregion and lakes throughout Wisconsin.

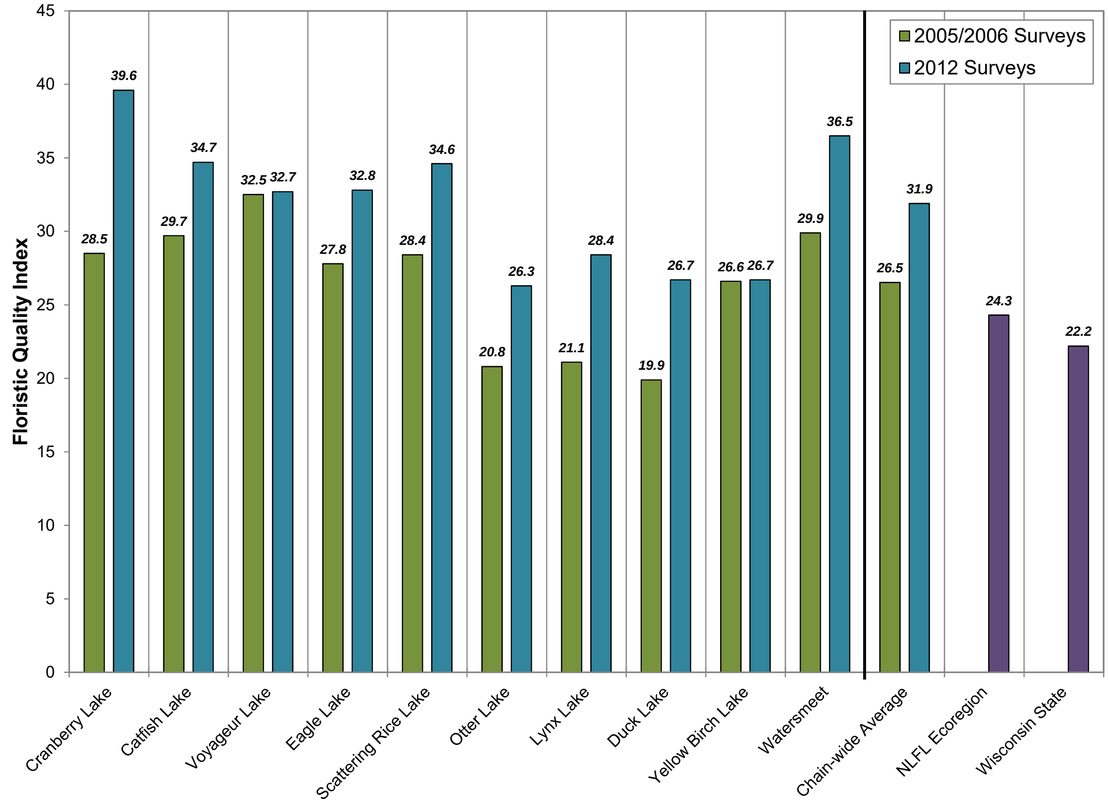


Figure 3.4-10. Lower Eagle River Chain of Lakes Floristic Quality Index values. Created using data from 2005/2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLF = Northern Lakes and Forests Ecoregion.

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 Lower Eagle River Chain of Lakes contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, as discussed, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how the chain's lakes' diversity values rank. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 3.4-11). Using the data collected from the 2005/2006 and 2012 point-intercept surveys, the diversity of each lake could be calculated. All 10 lakes exceeded the median value for lakes in the NLF Ecoregion in 2012, and eight exceeded the upper quartile. The chain-wide average diversity value increased from 0.89 in 2005/2006 to 0.91 in 2012, falling above the upper quartile for lakes in the NLF Ecoregion and indicating the aquatic plant community of the chain is exceptionally diverse. The loss of dominance of Eurasian watermilfoil throughout many areas within the chain may be one of the reasons why diversity was shown to have increased in 2012.

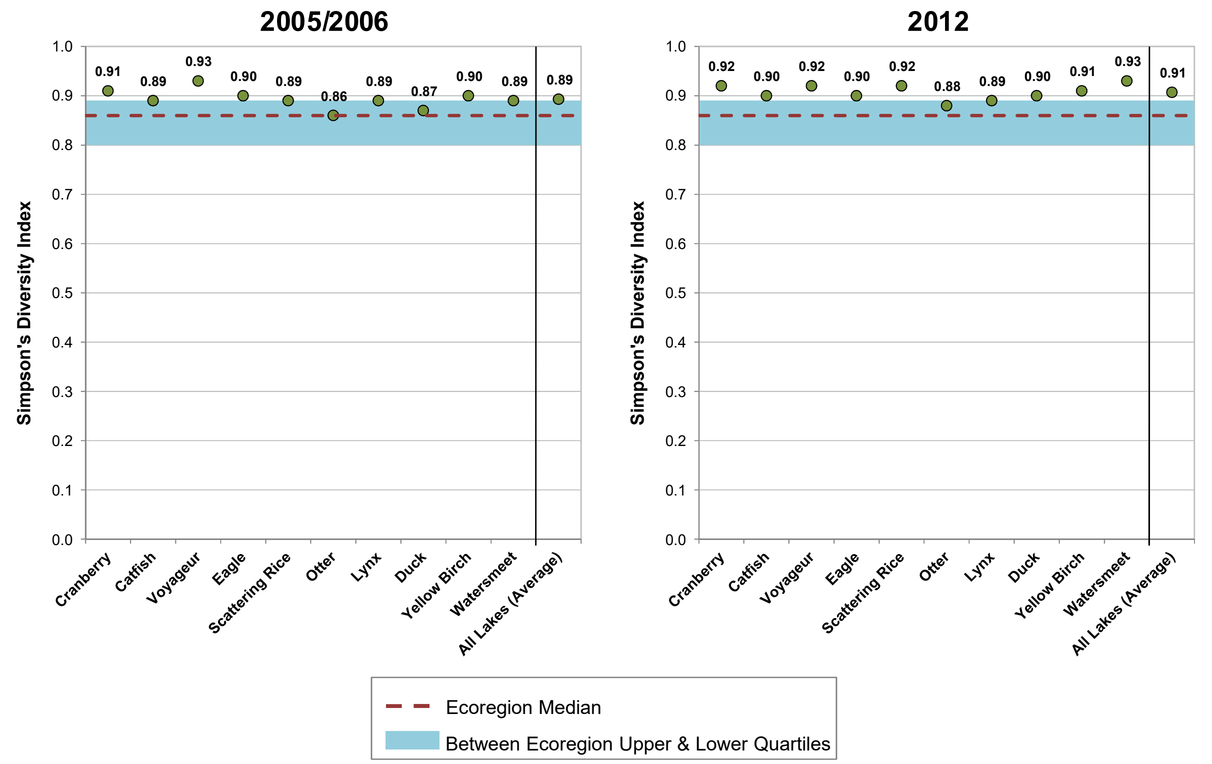


Figure 3.4-11. Lower Eagle River Chain of Lakes Simpson's Diversity Index. Created using data from 2005/2006 and 2012 point-intercept surveys.

An important component of a lake's aquatic plant community are the emergent and floating-leaf communities which provide valuable structural habitat and stabilize bottom and shoreland sediments. These communities are even more important during periods of lower water levels when coarse woody habitat becomes exposed above the lower water line. The mapping of emergent and floating-leaf aquatic plant communities in the Phase I, II, and III lakes found that the acreage of these communities range from 72 acres in Cranberry Lake to <1 acre in Duck Lake (Figure 3.4-12). A total of 33 emergent and floating-leaf aquatic plant species were located during these surveys on the Phase I, II, and III lakes (Table 3.4-2).

Figure 3.4-12 illustrates the composition of emergent and floating-leaf aquatic plant communities in the Lower Eagle River Chain of Lakes. The composition of these communities varied among lakes. Continuing the analogy that the community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the Lower Eagle River Chain project lakes. This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines.

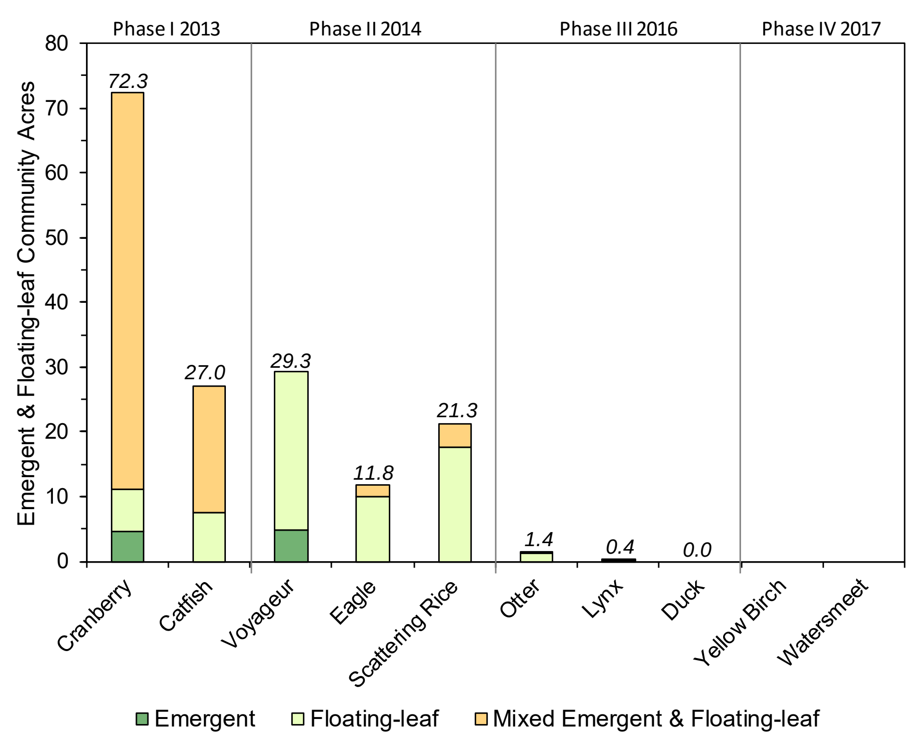


Figure 3.4-12. Lower Eagle River Chain of Lakes emergent and floating-leaf aquatic plant community composition. Locations of these aquatic plant communities are displayed on maps within the individual lake report sections.

Non-Native Aquatic Plants in the Eagle River Chain of Lakes

Eurasian watermilfoil

Eurasian watermilfoil (*Myriophyllum spicatum*; EWM) was first documented in the Lower Eagle River Chain of Lakes in 1992, and since 2001, various lake groups throughout the chain have recognized the negative impacts the EWM populations was impressing on the lakes. In 2005, the Town of Washington successfully applied for multiple WDNR Lake Management Planning Grants to fund the development of an aquatic plant management plan for each of the chain's lakes. Understanding that the degradation of the Lower Eagle River Chain of Lakes' ecology and recreation would be disastrous for the local and county economies, four municipalities including the Towns of Washington, Lincoln, and Cloverland, and the City of Eagle River partnered to fund the completion of the aquatic plant management plans. During the development of the aquatic plant management plans, it was realized that the Lower Eagle River Chain of Lakes must be viewed as one system if aquatic invasive species were to be effectively managed. In 2006, following public discussion, the parties involved agreed to form a public/private partnership out of which a joint powers agreement was made forming the Unified Lower Eagle River Chain of Lakes Commission (ULERCLC).

In 2007, Onterra ecologists completed an EWM peak-biomass survey of the entire Lower Eagle River Chain of Lakes and located approximately 278 acres of colonized Eurasian watermilfoil. In 2008, the ULERCLC successfully applied for a WDNR AIS Control Grant to initiate a multi-phased project with a goal of reducing the EWM population to more manageable levels and restore the ecological integrity of the chain. Following annual herbicide applications over areas of EWM, colonial Eurasian watermilfoil acreage has been reduced from the 278 acres in 2007 to approximately 12 acres in 2015 (Figure 3.4-13). In addition, the majority of EWM in 2007 was comprised of *dominant*, *highly dominant*, and *surface-matted* EWM, while the majority the acreage in 2015 is comprised of *scattered* and *highly scattered* EWM. The amount of EWM found in 2016 slightly increased from 2015 but the acreage is still much less than initially found in 2007.

It was evident from the 2006 plant surveys completed by Northern Environmental, Inc. that EWM comprised a significant portion of the chain's aquatic plant community. Another goal of the 2012 point-intercept surveys was to quantitatively determine if the EWM population within the chain had been reduced over the course of the 2008-2012 control project. As Figure 3.4-14 illustrates, seven of the 10 lakes saw a statistically valid reduction in the littoral occurrence of EWM from 2005/2006 to 2012 (Chi-square α = 0.05). No lakes saw an increase in EWM occurrence over this time period. Most notable were the reductions observed in Scattering Rice Lake and Watersmeet, which in 2006 had an EWM littoral occurrence of 17.6% and 23.3%, respectively. Even though Figure 3.4-13 indicates the littoral occurrences of EWM within Scattering Rice and Lynx Lakes to be 0.0, it is still present within these lakes. EWM was present in such a low frequency in these lakes in 2012 that it was not detectable with the point-intercept survey methodology. Overall, EWM within the Lower Eagle River Chain of Lakes has declined by a statistically valid 82% since 2005/2006.

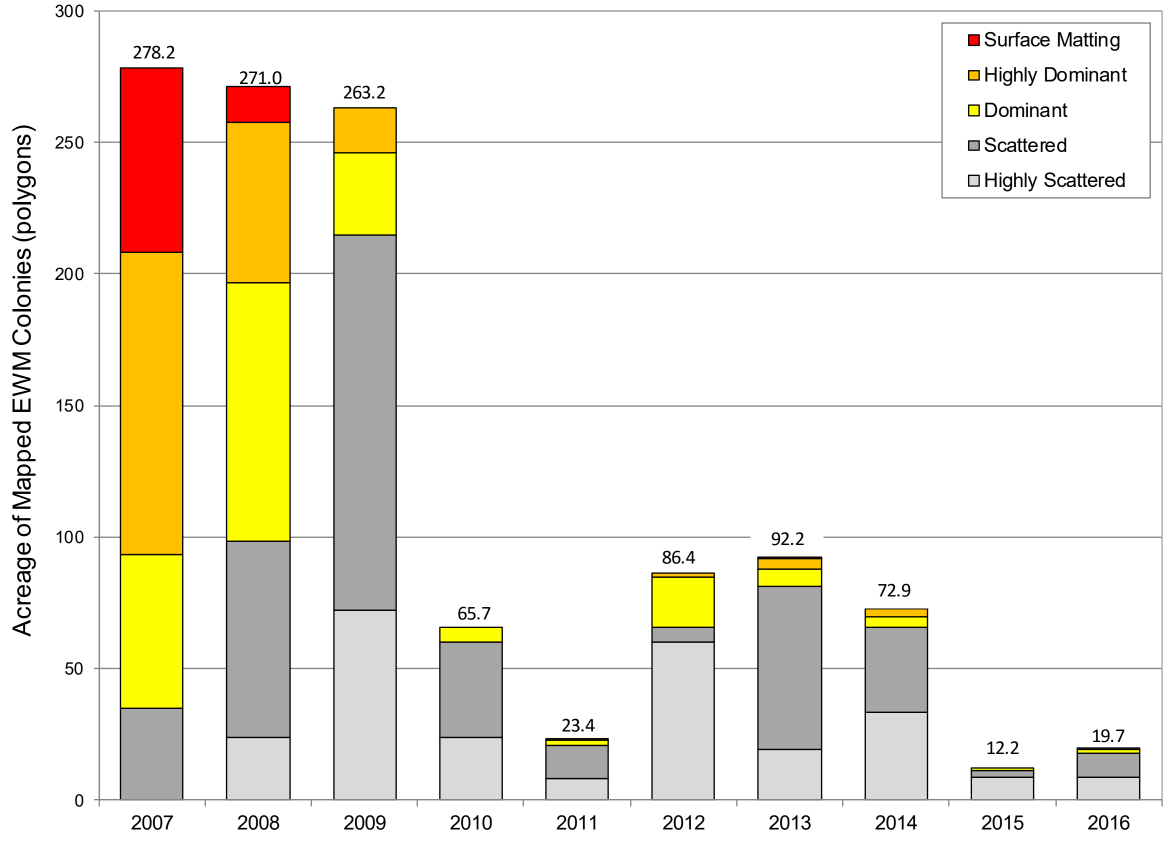


Figure 3.4-13. Acreage of mapped EWM colonies within the Lower Eagle River Chain of Lakes from 2007-2016.

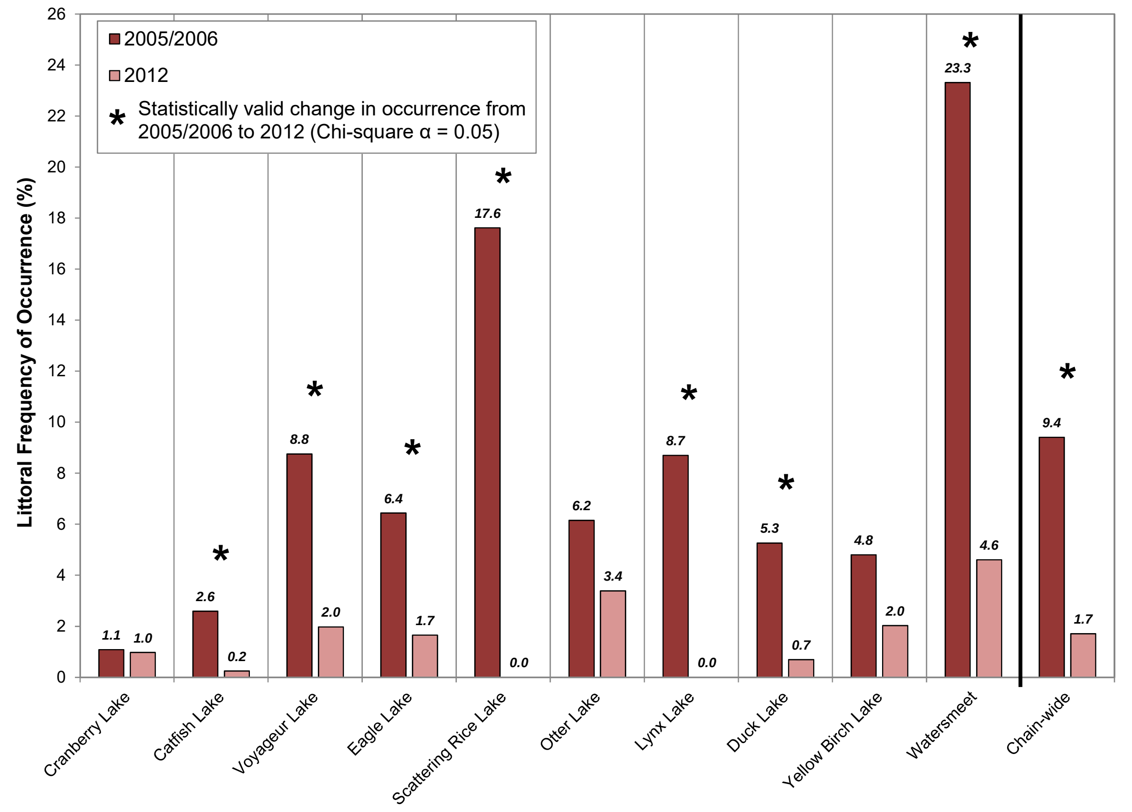


Figure 3.4-14. Lower Eagle River Chain of Lakes EWM littoral occurrence from 2005/2006 to 2012. Created using data from 2005/2006 and 2012 point-intercept surveys.

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 shoreline areas in Cranberry and Catfish Lakes in 2013 (Cranberry Lake – Map 4 and Catfish Lake – Map 4) and Voyageur and Scattering Rice Lakes in 2014 (Voyageur Lake – Map 4 and Scattering Rice 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. Control of purple loosestrife on the Eagle River Chain will be discussed in the Implementation Plan Section.

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 in shoreline areas of Cranberry and Catfish Lakes in 2013 (Cranberry Lake – Map 4 and Catfish Lake – Map 4) and Otter Lake in 2016 (Duck Lake – Map 4). Control of pale-yellow iris on the Eagle River Chain will be discussed in the Implementation Plan Section.

Garden yellow loosestrife

Like purple loosestrife, yellow garden loosestrife (*Lysimachia vulgaris*) is an escaped horticultural species that is potentially invasive in Wisconsin's wetland habitats. These plants can attain a height of greater than one meter, and produce a cluster of showy, yellow flowers at the top of the plant. This plant is now considered a restricted species in Wisconsin. In the Lower Eagle River Chain of Lakes, garden yellow loosestrife was located along shoreline areas in Cranberry Lake and Catfish Lake. Control of garden yellow loosestrife on the Eagle River Chain will be discussed in the Implementation Plan Section.

Stakeholder Survey Responses to Aquatic Vegetation within the Eagle River Chain

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lake and how it may have changed over the years. Figures 3.4-14 and 3.4-15 display the responses of members of the Eagle River Chain property owners to questions regarding aquatic plants, their impact on enjoyment of the lake and if aquatic plant control is needed. When asked how often aquatic plant growth, during the open water season, negatively impacts the enjoyment of the Eagle River Chain, half of the stakeholder survey respondents indicated *sometimes*, 23% indicated *rarely*, 17% indicated *often*, 8% indicated *always* and 2% indicated *always* (Figure 3.4-14).

When asked if they believe aquatic plant control is needed on the Eagle River Chain, 46% of respondents indicated *definitely yes*, 37% indicated *probably yes*, 12% indicated that they were *unsure*, and 4% indicated *probably no* or *definitely no* (Figure 3.4-15). The presence of AIS within the Eagle River Chain is well-known knowledge for the stakeholders so while aquatic plants do not generally impact user's enjoyment of the lake, stakeholders believe that control of AIS is needed. As is discussed in the Aquatic Plant Primer section, a number of management strategies are available for alleviating aquatic invasive species. The management strategy that will be taken to manage AIS in the Eagle River Chain is discussed within the Implementation Plan Section (Section 5.0).

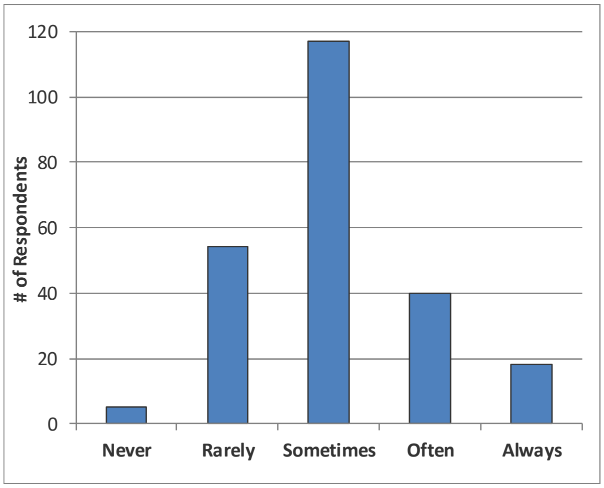


Figure 3.4-14. Stakeholder survey response Question #20. During open water season, how often does aquatic plant growth, including algae, negatively impact your enjoyment of the Eagle River Chain?

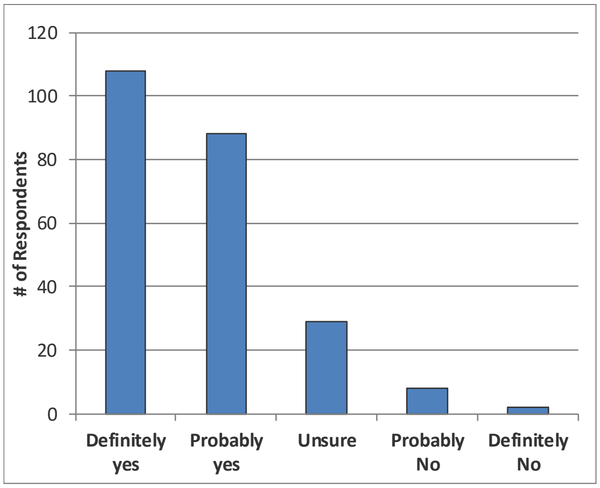


Figure 3.4-15. Stakeholder survey response Question #21. Do you believe aquatic plant control is needed on the Eagle River Chain?

3.5 Fisheries Data Integration

This section will be included in Phase IV, the final phase of the project.

4.0 SUMMARY AND CONCLUSIONS

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

1) Collect baseline data to increase the general understanding of the Lower Eagle River Chain of Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within each lake.
3) Collect sociological information from the Lower Eagle River Chain of Lakes stakeholders regarding their use of the chain and their thoughts pertaining to the past and current condition of the lake and its management.

Completing a comprehensive management plan for a large and diverse ecosystem such as the Lower Eagle River Chain of Lakes is a tremendous undertaking. By dividing the project into four phases, ERCLA, the WDNR, and Onterra ecologist were able to provide individualized attention to two to three lakes at a time and address specific issues that arose for each lake during this planning project. This is important because as we have progressed through the Phase I and II lakes thus far, while the lakes are all relatively similar in terms of their water quality and aquatic plant communities, individual lake challenges, such as internal phosphorus recycling on Scattering Rice Lake, were able to be addressed. Overall, the studies conducted thus far on the Phase I and Phase II lakes have found that overall, they are healthy. However, there are challenges that need to be addressed, such as aquatic invasive species and shoreland development, to enhance the Lower Eagle River Chain of Lakes ecosystem.

The watershed or drainage basin of the Lower Eagle River Chain is immense, encompassing approximately 531 square miles across five counties in Wisconsin and northern Michigan. The vast majority of the watershed is comprised of natural land cover types (forests and wetlands) which are the most beneficial in terms of maintaining healthy lakes as these land cover types export the least amount nutrients and sediment. However, while the land cover types within the chain's watershed export minimal amounts of nutrients, the cumulative amount of nutrients delivered from such a large watershed are sufficient to create productive, eutrophic lakes. These lakes are naturally eutrophic, and thus, have a tendency to experience periodic, perceptible algae blooms. These blooms typically occur in mid- to late-summer during calm weather when water temperatures are warm.

The water quality of the Phase I, II, and III lakes, with the exception of Scattering Rice Lake, is to be expected given the size and composition of their watersheds. Scattering Rice Lake's nutrient and algal levels were slightly higher than expected, and it is believed this is due to internal phosphorus recycling and higher than expected phosphorus output from wetlands within its watershed. A detailed discussion of Scattering Rice Lake's water quality can be found in the Scattering Rice Lake individual lake report section.

The chain's watershed is largely going to dictate the water quality within the chain's lakes. And the water quality in terms of water chemistry and light availability is largely going to influence the chain's aquatic plant community. As discussed within the Water Quality Section, the Phase I, II, and III lakes have relatively low water clarity. While this low clarity is driven in part by algae within the water, the dissolved organic compounds within the water (staining) also reduce clarity. This staining of the water is natural, and originates from decaying vegetation within the large forest and wetland complexes within the chain's watershed. The reduced light availability restricts aquatic plants to shallower areas of these lakes, and the overall occurrence of plants varies between lakes due to differences in lake morphology. The aquatic plant community of the chain was found to have high species richness and high species diversity, while the Floristic Quality Assessment indicated the quality of the chain's aquatic plant community is of higher quality than the majority of lakes within the region and the state.

The chain also contains a number of species that are relatively rare, including Vasey's pondweed (*Potamogeton vaseyi*), which is on the Wisconsin Natural Heritage Inventory list of special concern species. The aquatic plant studies conducted in 2012 have found that chain-wide EWM occurrence has been reduced significantly since the control program began in 2008 and that there were no detectable adverse impacts to the native aquatic plant community over this time period. In fact, more native aquatic plant species were located in 2012 than were located in 2005/2006. A reassessment of the chain's aquatic plant community was completed in 2017, and the results of these studies will be available in the final Phase IV report. Purple loosestrife, pale-yellow iris, and garden yellow loosestrife also inhabit wetland and shoreland areas around the chain. However, as outlined within the Implementation Plan, continued efforts focused on monitoring and control of current invasive species must continue along with monitoring for new infestations.

Along with the presence of aquatic invasive plants, another pressure on the Lower Eagle River Chain of Lakes ecosystem is the higher degree of shoreland development already revealed in the Phase I, II, and III lakes. Maintaining a natural shoreland serves as an important buffer area to intercept contaminants from upland yards, driveways, and roads before they enter the lake. Additionally, natural shorelands are an essential ecological component for maintaining healthy lakes because they provide habitat for many aquatic and terrestrial organisms as well as many organisms that have an aquatic and terrestrial life cycle. Natural shorelands also reduce shoreline erosion and reduce sediment resuspension. The Implementation Plan outlines management actions that ERCLA will undertake to restore developed shorelands and protect already natural ones. This will not only help to enhance the ecological integrity of the chain, but it will also improve the lakes' aesthetic appeal.

The Lower Eagle River Chain of Lakes is a unique and highly sought after resource that is utilized by recreationalists for varying uses. It is an exceptional water resource for relaxation, wildlife viewing, fishing, swimming, and more. With the knowledge that continues to be gained through this management planning process, ERCLA will now have a strategic plan in place to maximize the positive attributes of each lake, minimize negative attributes, and effectively and efficiently manage the Lower Eagle River Chain of Lakes as one ecosystem. The Chain-Wide Implementation Plan that follows is a result of the hard work of many Eagle River Chain stakeholders, and can be applied to each and every lake within the chain. Lakes with lake-specific challenges will have their own Individual Lake 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 ERCLA and ecologist/planners from Onterra. It represents the path ERCLA 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 Eagle River 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 lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders. While ERCLA is listed as the facilitator of the majority of management actions listed below, many of the actions may be better facilitated by a sub-committee (e.g. Education & Communication Committee, Water Quality Committee, and Invasive Species Committee). ERCLA will be responsible for deciding whether the formation of sub-committees is needed to achieve the various management goals.

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation and expansion of current effort.
Facilitator:	Suggested: Dave Mueller, Chair of the ERCLA Lakes and Shores Committee
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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). As of 2015, Cranberry, Eagle, Scattering Rice, Otter, Lynx, and Yellow Birch Lake have active volunteers collecting water quality data. Volunteers have not collected water quality data from Catfish,

Voyageur, Duck, and Watersmeet Lakes since 2010, 1997, 2010, and 2014, respectively. Cranberry Lake is currently in the advanced CLMN program, collecting total phosphorus and chlorophyll-*a* concentrations in addition to water clarity, while Eagle, Scattering Rice, Otter, Lynx, and Yellow Birch Lakes are currently collecting water clarity. While it would be ideal to have all the lakes in the chain be part of the advanced monitoring program, there is currently not enough funding to enroll all of the lakes. Given Cranberry Lake is the upstream-most lake in the chain, the collecting of total phosphorus and chlorophyll-*a* data are important. If funding becomes available to enroll additional lakes in the advanced monitoring program, Watersmeet and Scattering Rice Lake should be prioritized for this monitoring given Watersmeet's downstream-most position in the chain and Scattering Rice Lake's separate watershed (the Deerskin River).

A more realistic goal is to push for the remaining lakes that currently do not have an active volunteer to monitor Secchi disk transparency annually. 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. A list of the current (2015) CLMN volunteers can be found in the table below.

Lake	Current CLMN Volunteer
Cranberry Lake	Carole Linn
Catfish Lake	Jeff Boville & John Lansing
Voyageur Lake	David Tidmarsh
Eagle Lake	David Tidmarsh
Scattering Rice Lake	Dennis Burg
Otter Lake	Dave Mueller
Lynx Lake	Dave Mueller
Duck Lake	Marc Groth
Yellow Birch Lake	Dan Vladic
Watersmeet Lake	Jerome Plocinksi

Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee, currently coordinates CLMN volunteers on the 10 lakes within the chain. When a change in the collection volunteer occurs, Dave should 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 automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

Action Steps:

1. Dave Mueller continues to coordinate/recruit volunteers for CLMN water quality monitoring.
2. ERCLA appoints new Lakes and Shores Committee Chair/CLMN volunteer coordinator as needed.
3. Dave Mueller directs water quality monitoring program efforts.
4. Dave Mueller contacts Sandra Wickman (715.365.8951) when new volunteer training and/or sampling equipment are needed.
5. CLMN volunteers enter their sampling data into the WDNR SWIMS database.
6. ERCLA provides internet links (http://dnr.wi.gov/lakes/clmn/) on the association's website for members to view water quality data collected on their respective lake.

Management Action: Monitor for frequency of occurrence and location of water sheet flow over Chain O'Lakes road into Otter Lake and consider collection of water quality samples from drainage ditches draining to Otter and Lynx Lake from adjacent agricultural lands.

Timeframe: Initiate in 2018

Facilitator: Dave Mueller, current CLMN volunteer (suggested)

Description: During the 2017 planning meeting with the Phase III Planning Committee, concerns were raised regarding the potential impact agricultural fields north of Chain O'Lakes Road may be having on the water quality of Otter and Lynx lakes. Property owners from these lakes indicated that they have observed water flowing from these fields over Chain O'Lakes Road and into Otter Lake during rain events. In addition, they are also concerned about water draining from these fields through ditches which eventually flow into these lakes through culverts underneath Chain O'Lakes Road. The property owners have concerns about possible contamination from herbicides and/or pesticides originating from these fields.

Analyses using Geographic Information System (GIS) Spatial Analyst software found that all the portions of the agricultural fields which lie within Lynx Lake's watershed drain to a wetland on the lake's north side prior to flowing into the lake through a culvert under Chain O'Lakes road (Figure 5.0-1). The eastern portion of these fields drain to Otter Lake through another culvert beneath Chain O'Lakes Road (Figure 5.0-1).

Measured phosphorus concentrations in these lakes were not significantly higher when compared to upstream lakes, indicating these fields are likely not having a detectable impact on nutrient concentrations in these lakes. Given the large watersheds of these lakes, WiLMS predicted average water residence times of 5 days and

0.7 days for Otter and Lynx lakes, respectively. With the high rate of water flow through these systems, it is believed that in-lake sampling would likely not yield detectable levels of herbicides/pesticides from these agricultural fields.

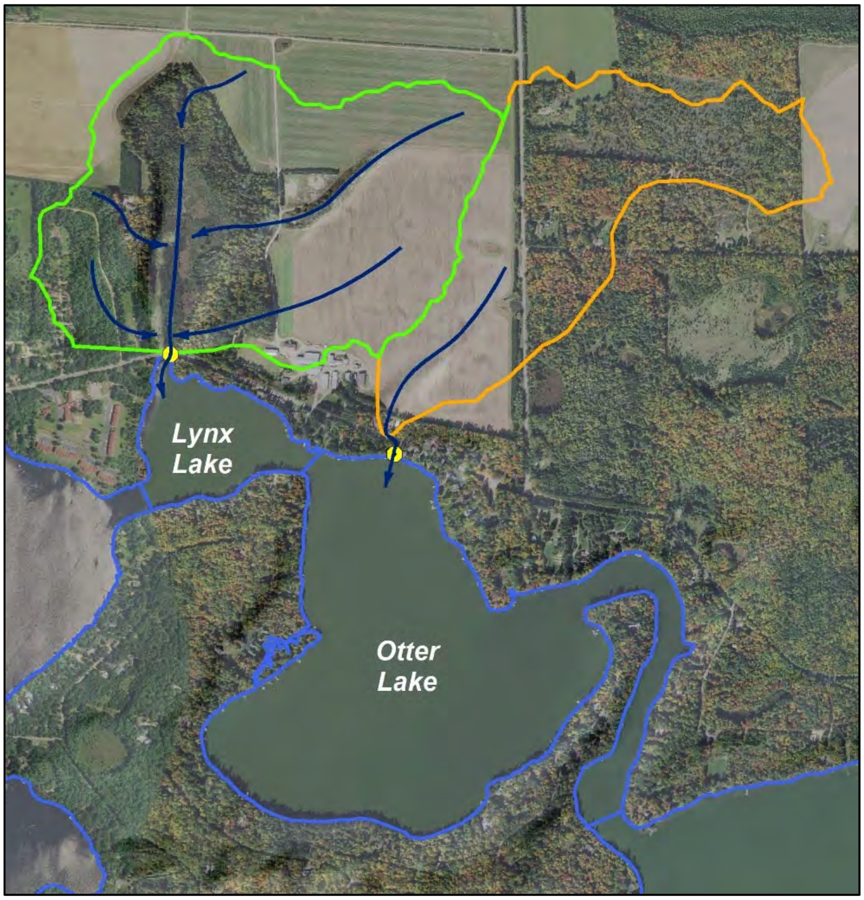


Figure 5.0-1. Drainage areas of concern in Otter and Lynx lakes. Area outlined in green drains through culvert in Lynx Lake and area outlined in orange drains through culvert to Otter Lake. Yellow circles indicate culvert location.

Given the concern regarding the observed flow of water over Chain O'Lakes Road, the property owners will keep a record of when and where they observe water flowing over the road and into Otter Lake in 2018. The frequency of occurrence and location of these flow events will aid in determining if samples of this water should be collected and analyzed for herbicides/pesticides.

The Lynx and Otter lake property owners also want to consider collecting water samples for analysis from the drainage ditches draining from these fields to Otter and Lynx lakes during rain events. Lake stakeholders were particular concerned about observed runoff from these fields during the spring when the ground was still frozen.

Onterra contacted the Wisconsin State Lab of Hygiene (WSLH) to inquire what types of herbicides and pesticides they are able to test for. Currently, the WSLH is only able to test for atrazine, a commonly-used broad-leaf herbicide. The WSLH recommended if any specific herbicides or pesticides apart from atrazine wanted to be tested, a private lab should be contacted. The sample results should be provided to and reviewed by local WDNR staff to determine if any detectable levels of herbicide/pesticide are within acceptable levels or not. This type of sampling and analysis would likely not be grant eligible given its small scope, and cost of analysis would have to be covered out of pocket.

Action Steps:

1. Lynx Lake volunteer, Dave Mueller, documents when and where water is observed flowing across Chain O'Lakes Road into Otter Lake in 2018.
2. If flow over the road is found to occur on a frequent basis, consider collecting samples during flow events to get tested for herbicides and/or pesticides.
3. Lynx and Otter lake property owners consider collecting water quality samples from drainage ditches draining agricultural fields north of Chain O'Lakes Road and draining through culverts into Lynx and Otter lakes.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action:	Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.
Timeframe:	Initiate 2016
Facilitator:	Suggested: ERCLA Shores Subcommittee
Description:	While the chain-wide management planning project has not yet been completed, shoreline assessments conducted on Cranberry, Catfish, Voyageur, Eagle, and Scattering Rice Lakes indicate that large proportions of the shorelines around these lakes are highly developed. 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. 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 partial funding and informational resources to restore quality shoreland habitat to their lakeside residence.

The shoreland areas on the chain delineated as Urbanized and Developed-Unnatural should be prioritized for restoration. ERCLA would acquire information from and work with appropriate entities such as Quita Sheehan (715.479.3721) from the Vilas County Land and Water Department to research grant programs, shoreland restoration techniques, and other pertinent information that will help ERCLA.

Because property owners may have little experience with or be uncertain about restoring a shoreland to its natural state, properties with restoration on their shorelands could serve as demonstration sites. Other lakeside property owners could have the opportunity to view a shoreland that has been restored to a more natural state, and learn about the maintenance, labor, and cost-sharing opportunities associated with these projects.

The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county and the WDNR Lake Protection Grant Program.

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per 350 ft^2 of native plantings (best practice cap)
- Implemented according to approved technical requirements (WDNR, County, Municipal, etc.) and complies with local shoreland zoning ordinances
- Must be at least 350 ft^2 of contiguous lakeshore; 10 feet wide by 35 feet deep
- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years
- Additional funding opportunities for water diversion projects and rain gardens (maximum of $1,000 per practice) also available

However, for a larger project that may include a number of properties, it may be more appropriate to seek funding through a WDNR Lake Protection Grant. While more funding can be provided through a Lake Protection Grant and there are no limits to where that funding utilized (e.g. technical, installation, etc.), the grant does require that the restored shorelines remain undeveloped in perpetuity.

Action Steps:

1. ERCLA Shores Subcommittee contacts Quita Sheehan (715.479.3721) from Vilas County Land and Water to gather information on initiating and conducting shoreland restoration projects. If able, Quita Sheehan would be asked to speak to ERCLA members about shoreland restoration at their annual meeting and/or at individual lake meetings.
2. ERCLA Shores Subcommittee would encourage property owners that have restored their shorelines to serve as demonstration sites.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Timeframe: Initiate 2016

Facilitator: Suggested: ERCLA Shores Subcommittee

Description: While the lakes that have had shoreline assessments conducted thus far (Cranberry, Catfish, Voyageur, Eagle, and Scattering Rice) contain higher proportions of developed shoreland areas, they also contain areas with little or no development. It is very important that owners of these properties become educated on the benefits their shoreland is providing to the Eagle River Chain, and that these shorelands remain in a natural state.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of.

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

- Wisconsin Lakes website: www.wisconsinlakes.org/shorelands)
- Conservation easements or land trusts: (www.northwoodslandtrust.org)
- Northeast Wisconsin Land Trust: (newlt.org)
- 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:

2. ERCLA Shores Subcommittee gathers appropriate information from sources described above.

Management Action:	Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.
Timeframe:	Initiate 2016
Facilitator:	Suggested: ERCLA Shores Subcommittee

Description: ERCLA stakeholders must realize the complexities and capabilities of the Eagle River Chain ecosystem with respect to the fishery it can produce. With this, an opportunity for education and habitat enhancement is present in order to help the ecosystem reach its maximum fishery potential. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish.

ERCLA will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with WDNR fisheries biologist.

The WDNR's Healthy Lakes Implementation Plan allows partial cost coverage for coarse woody habitat improvements (referred to as "fish sticks"). This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county.

- 75% state share grant with maximum award of $25,000; up to 10% state share for technical assistance
- Maximum of $1,000 per cluster of 3-5 trees (best practice cap)
- Implemented according to approved technical requirements (WDNR Fisheries Biologist) and complies with local shoreland zoning ordinances
- Buffer area (350 ft^2) at base of coarse woody habitat cluster must comply with local shoreland zoning or:
    - The landowner would need to commit to leaving the area un-mowed
    - The landowner would need to implement a native planting (also cost share thought this grant program available)
- Coarse woody habitat improvement projects require a general permit from the WDNR
- Landowner must sign Conservation Commitment pledge to leave project in place and provide continued maintenance for 10 years

Action Steps:

1. ERCLA Shores Subcommittee, Kevin Gauthier (WDNR Lakes Coordinator – 715.365.8937) and Steve Gilbert (WDNR Fisheries Biologist – 715.356.5211) to gather information on initiating and conducting coarse woody habitat projects.
2. ERCLA Shores Subcommittee would encourage property owners that have enhanced coarse woody habitat to serve as demonstration sites.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of the Eagle River Chain's Eurasian watermilfoil (EWM) population.

Timeframe: Continuation of current effort.

Facilitator: Suggested: Unified Lower Eagle River Chain of Lakes Commission

Description: While Eurasian watermilfoil has been greatly reduced in the Eagle River Chain of Lakes since 2008, continued monitoring of established aquatic invasive species over time is essential for effective management and lets resource managers know when the population has reached levels which require active management. Since 2008, the EWM population on the Eagle River Chain of Lakes has been monitored through a combination of professional- and volunteer-based surveys. One of the greatest successes of the Eagle River Chain of Lakes EWM management program has been the commitment by volunteers. In an effort to make the EWM management program more efficient and cost-effective, the combination of professional- and volunteer-based surveys has evolved since 2008.

While mapping of EWM is typically conducted later in the summer when it is at or near its peak growth, Early-Season AIS (ESAIS) Surveys conducted in June were initiated on the chain starting in 2013. These are professionally-conducted meander-based surveys that cover littoral areas throughout the entire chain and were designed to fulfill two primary goals: 1) locate any potential occurrences of the non-native curly-leaf pondweed which reaches its peak growth in June before naturally senescing (dying-back) by early July, and 2) to map locations of EWM and provide these locations to volunteer EWM surveyors. The former will be discussed under the management action pertaining to curly-leaf pondweed monitoring.

While EWM is typically not at its peak growth stage in early summer, it is usually taller than most of the native aquatic plants and water clarity is often clearer making it readily visible. The GPS data collected during the ESAIS Survey regarding the locations of EWM is provided to the volunteers and they are instructed to survey areas of the chain where EWM was not located during the ESAIS Survey. With this methodology, the volunteers can locate any EWM that was not visible during the ESAIS Survey and avoid duplicating search efforts over areas where EWM had already been located.

The volunteers then provide Onterra with their EWM data, and Onterra ecologists conduct the Late-Summer EWM Peak-Biomass Survey in late-August or early-September when EWM is at or near its peak growth. During this survey, all of the areas where EWM was located during the ESAIS Survey, the areas where volunteers located EWM, and any areas that were treated for EWM in the current year or the year before are reassessed. The data collected during the Late-Summer EWM Peak-Biomass Survey is used to develop the control strategies for the following spring.

The current WDNR AIS Established Population and Control (EPC) Grant received by the Unified Lower Eagle River Chain of Lakes Commission (ULERCLC) in 2013 has remaining funds to cover the costs of professional ESAIS and Late-Summer EWM Peak-Biomass Surveys through 2018. However, because the EWM population has been significantly reduced since 2008, it may become more difficult to receive state grant funds in the future to fund EWM management. A more sustainable management strategy may include volunteer-based ESAIS Surveys and a professionally-based Late-Summer EWM Peak-Biomass Survey.

Action Steps:

1. Retain qualified professional assistance to develop specific monitoring designs utilizing the methods described above.
2. ERCLA recruits and trains new volunteers as needed when current volunteers step down.
3. Volunteer monitors report findings to qualified professionals (Onterra).

Management Action: Enact Eurasian watermilfoil active management strategy and necessary management strategy assessments.

Timeframe: Continuation of current effort.

Facilitator: Suggested: Unified Lower Eagle River Chain of Lakes Commission

Description: The Eagle River Chain is involved in an EWM management project, and the annual EWM management and assessment reports should be the primary document to refer to regarding strategies for EWM management and monitoring. However, this document will be updated as necessary to reflect any changes in EWM management on the Eagle River Chain.

Aquatic invasive plants like Eurasian watermilfoil become problematic when they begin to form dense, monotypic stands which begin to affect the lake's ecology, recreation, and aesthetics. In 2008 at the beginning of the EWM control project, approximately 278 acres if the chain contained colonized EWM comprised of either *dominant*, *highly dominant*, or *surface matted* EWM. In the first years of the project, colonized areas of EWM containing EWM of *dominant* density rating or greater were targeted for herbicide control.

Following the successful control of the largest and densest (*dominant*, *highly dominant*, and *surface matting*) colonies of EWM in the Eagle River Chain since 2008, the majority of the approximately 73 acres of colonized EWM remaining in 2014 was comprised of *scattered* and *highly scattered* EWM. Following discussions between Onterra ecologists and the ULERCLC at the November 2014 AIS Meeting, the commission opted to take an aggressive approach to EWM management in 2015. This approach established a treatment threshold, or trigger that dictates which EWM colonies would be considered for herbicide control. The thresholds that would bring about the discussion include:

- Colonized EWM consisting of *scattered* density or greater
- Based upon past studies on the Eagle River Chain and on other lakes within Wisconsin, areas targeted of *scattered* density must have a high likelihood of success. EWM colonies that are determined to be *dominant* or higher would be targeted in all instances.
- Designed treatment sites will attempt to exceed 3.0 acres in size and no treatments would occur when at least a 1.5-acre treatment could not be logistically constructed.

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.

Two types of monitoring would be completed to determine treatment effectiveness: 1) quantitative monitoring using WDNR protocols, and, 2) qualitative monitoring using observations at individual treatment sites and on a treatment-wide basis. Results of both of these monitoring strategies would be used to create the subsequent treatment strategies. Comparing the monitoring results from the pretreatment and post treatment surveys would determine the effectiveness of the treatment on a site-by-site basis and on a treatment-wide basis. Qualitatively, a successful treatment on a particular site would include a reduction of

EWM density, as demonstrated by a decrease in density rating. Quantitatively, a successful treatment would include a significant reduction in EWM frequency following the treatments, as exhibited by at least a 50% decrease in exotic frequency from the pre- and post-treatment point-intercept sub-sampling.

To complete this objective efficiently, a cyclic series of steps is used to plan and implement the treatment strategies. The series includes:

1. *Mid- to Late-June:* A professional lake-wide assessment (ESAIS Survey) of the chain's EWM population. Data collected during this survey is relayed to volunteer surveyors.

2. *July-August:* Volunteers search areas of their respective lakes where EWM was not located during the ESAIS Survey. Volunteers report their EWM findings to professional ecologists.

3. *Late-August to Early-September:* Professional ecologists conduct Late-Summer EWM Peak-Biomass Survey to reassess areas of EWM located during ESAIS Survey, areas of EWM located by volunteers, and any areas treated with herbicides that spring or the spring prior. Quantitative post-treatment sub-sample point-intercept surveys are also conducted along with pre-treatment sub-sample point-intercept surveys for the next year's proposed treatments.

4. *Fall/Winter*: Treatment area delineation and control strategy determination developed based upon Late-Summer EWM Peak-Biomass Survey results.

5. *May/June:* Professional Pretreatment Confirmation and Refinement Survey is conducted to confirm the presence of EWM within the proposed treatment areas and refine the treatment area boundaries if necessary. Finalized treatment areas are submitted to the WDNR to serve as the final treatment permit, followed by the completion of an EWM herbicide treatment. Treatment occurs before water temperatures reach 60°F.

On much of the Eagle River Chain of Lakes, the EWM population has reached a point at which some of the herbicide application areas are too small to consistently predict if they will cause EWM mortality. As indicated earlier, it is difficult in small spot treatment scenarios to keep a sufficient herbicide concentration exposed to the target plants long enough to be effective. For that reason, almost all proposed 2015 treatment areas included an expanded buffer as well as the maximum liquid 2,4-D application rate of 4.00 ppm ae.

Given the high rate of water exchange within the Cranberry Lake channel, there is concern whether the herbicide exposure time would be sufficient to cause EWM mortality. A flow study was conducted in the spring of 2015 prior to the herbicide treatment. During this survey, 78 locations evenly spaced across the section of the channel planned for herbicide application were visited. At each location water velocity and direction of flow were collected using a solid-state flow meter (60% of water depth). With this information, water flow data was calculated (flow = velocity x cross-sectional area) that illustrated where higher and lower flows exist within this location. Upstream from the study location, a cross-sectional river flow measurement was also taken to relate to water flow at each sampling location.

Herbicide concentration monitoring samples were collected following the 2015 herbicide application on the Cranberry Lake channel. Water samples were collected by trained ULERCLC volunteers. The water samples were collected from four locations and seven time periods (1 hour after treatment [HAT], 2 HAT, 4 HAT, 6 HAT, 10 HAT, 14 HAT, and 24 HAT). The 28 samples were sent to the WI State Laboratory of Hygiene for analysis. Information collected from this effort was useful in analyzing treatment effectiveness and is aiding in strategy development for future herbicide applications should they occur. These data are also valuable because they demonstrate to lake stakeholders when the herbicide dissipated below detectable levels.

For the proposed 2015 treatment on Watersmeet Lake, previous herbicide concentration monitoring in the area of the proposed treatment indicates that herbicide dissipation rates were expected to be at a level such that adequate herbicide exposure time was likely to be attained to achieve successful EWM control.

Since 2015, no herbicide applications have occurred on the Lower Eagle River Chain of Lakes. In 2016-18, experimental traditional and mechanical (diver-assisted suction harvesting) hand-harvesting was implemented in a few lakes in an effort to control isolated colonies of EWM. Results of these hand-harvesting efforts have been promising thus far, and hand-harvesting is proposed to be implemented again on the Eagle River Chain in 2019. For more detailed information on the most current EWM control strategy, please see the *latest EWM Monitoring & Control Strategy Assessment Report* created each winter for ERCLA

Lake-Wide Aquatic Plant Community Monitoring

To determine if the multi-year EWM control program has had detectable effects on the chain's aquatic plant communities at the lake-wide level, WDNR guidance requires that whole-lake point-intercept surveys be conducted every three to five years during the course of the control program. Whole-lake point-intercept surveys were conducted on the Eagle River Chain in 2012 and again in 2017 to inventory each lake's aquatic plant community. The data collected in 2012 and 2017 will be compared to assess the chain's native aquatic plant community and the effectiveness of the EWM control program. Comparison of the 2005/06, 2012, and 2017 datasets will be available in the Phase IV report that will likely be finalized in late-2018 or early-2019.

Action Steps:

1. Retain qualified professional assistance to develop a specific project design utilizing the methods discussed above.
2. Initiate control plan.
3. Revisit control plan in fall/winter of 2018/19.
4. Update management plan to reflect changes in control needs and those of the lake ecosystem.

Management Action: Continue annual early-season AIS monitoring to detect potential occurrences of curly-leaf pondweed (CLP).

Timeframe: Continuation of current effort.

Facilitator: Suggested: Unified Lower Eagle River Chain of Lakes Commission

Description: As discussed in the previous management action, the non-native plant curly-leaf pondweed (CLP) reaches its growth in early summer (June) and typically dies back by early July. While CLP has not yet been documented within the Eagle River Chain, observations from similar systems with CLP, like the Manitowish Chain, indicate that this species will likely do well in the Eagle River Chain. Given the chain's high recreational use and proximity to nearby waterbodies with CLP (Little Saint Germain Lake, Rainbow Flowage, and Kentuck Lake), there is a higher probability that CLP will be introduced somewhere in the chain.

Early detection of new introductions commonly leads to successful control, and in cases of very small infestations, possibly even eradication. As mentioned previously, one of the primary goals of initiating professional Early-Season AIS (ESAIS) Surveys in 2013 on the Eagle River Chain was to detect any potential occurrences of CLP. The current WDNR AIS-EPC Grant contains funding to conduct professional ESAIS Surveys through 2018; however, as state funding sources become more difficult to acquire, the ULERCLC may want to consider enlisting volunteers to conduct early-season surveys to search for potential occurrences of CLP.

Action Steps:

1. Retain qualified professional to conduct ESAIS Surveys through 2018.

2. Research additional sources of funding to continue professional ESAIS Surveys after 2018, or utilize volunteers to conduct early-season monitoring.

Management Action: Continue monitoring and control of the shoreline/wetland invasive plants purple loosestrife, garden yellow loosestrife, and pale-yellow iris on the Eagle River Chain of Lakes.

Timeframe: Continuation of current effort

Facilitator: Suggested: ERCLA Shores Subcommittee

Description: *Purple Loosestrife*

In 2012, the ERCLA together with the then Vilas County Invasive Species Coordinator initiated a purple loosestrife control program in areas along the Eagle River Chain. This program was a community-based effort where partnerships were formed with the Eagle River Chain of Lakes Association (ERCLA), Northland Pines High School students, and the Vilas County Land and Water Conservation, Mapping, Forestry, and Highway Departments.

In 2011, ERCLA volunteers searched the shoreline of the Eagle River Chain for blooming purple loosestrife plants. In the spring of 2012, Northland Pines High School students dug up a number of purple loosestrife plants and then they were cultured into mature plants on the grounds of the Vilas County Forestry/Highway Departments. Approximately 500 *Galerucella* beetles, which eat and complete their lifecycle on purple loosestrife, were collected from a nearby bio-control project. The beetles were raised on the planted purple loosestrife plants where they quickly multiplied, and then they were released onto purple loosestrife plants on the shoreland areas of the chain. Beetles were also released in 2013.

Garden Yellow Loosestrife

In 2013, Cranberry Lake riparians noted plant with yellow flowers growing within the small bog islands located on the northeast side of the big island. The plants were identified as the non-native garden yellow loosestrife (GYL) by the Vilas County Lake Conservation Specialist, Quita Sheehan. A close relative of purple loosestrife, GYL is an invasive wetland plant. Surveys by ERCLA volunteers have located GYL along portions of the shorelines in Cranberry Lake and Catfish Lake.

Because little is known of how quickly GYL spreads and how aggressive its behavior is towards native species, ERCLA and Quita Sheehan have developed an ongoing monitoring project. One part of the project involved volunteers from Cranberry Lake marking and tracking the growth of GYL plants on the bog island. These volunteers will continue to monitor these plants and track how their growth progresses over the years. The second part of the project involved establishing test plots that contained GYL on a Cranberry Lake volunteer's shoreline property. Using set transects within these plots, Quita identified all of the plant species present and their percent coverage. She will replicate this survey again in 2019 to see how much GYL has spread and if it has displaced native plant species.

Pale-Yellow Iris

Like purple loosestrife and garden yellow loosestrife, pale-yellow iris is a non-native, invasive wetland plant. ERCLA volunteers surveying for invasive species found that the largest population of pale-yellow iris occurs in Cranberry Lake. ERCLA is currently developing a program to manage pale-yellow iris in the chain, and early indications suggest that cutting the plants below the water is an effective form of control.

Action Steps:

1. ERCLA to continue working with Vilas County AIS Coordinator Catherine Higley (715.479.3738) to coordinate annual monitoring and development of control strategies for purple loosestrife, garden yellow loosestrife, and pale-yellow iris on the Eagle River Chain of Lakes.
2. Continue garden yellow loosestrife monitoring study with Quita Sheehan.

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

Timeframe: Initiate upon invasive species discovery

Facilitator: Suggested: ERCLA Board of Directors with professional help as needed

Description: While the Eagle River Chain of Lakes already contains populations of the invasive species Eurasian watermilfoil, purple loosestrife, yellow garden loosestrife, pale-yellow iris, rusty crayfish, banded mystery snail, and the Chinese mystery snail, nearby lakes harbor aquatic invasive species like curly-leaf pondweed and zebra mussels that are not yet present in the Eagle River Chain. While the Eagle River Chain is believed to have low susceptibility to zebra mussel establishment, curly-leaf pondweed will likely be able to establish a population if introduced into the chain. For this reason, lake users should also familiarize themselves with curly-leaf pondweed in the event they encounter it within the lake.

If lake users do encounter a new non-native species within the lake, it should be reported to resource managers immediately. Identification of an early infestation can aid in rapid control and possibly even eradication.

Action Steps:

1. See description above.

Management Action:	Continue and expand Clean Boats Clean Waters watercraft inspections at Eagle River Chain of Lakes public access locations.
Timeframe:	Continuation and expansion of current effort.
Facilitator:	Suggested: ERCLA Board of Directors

Description: Since 2010, ERCLA has aided in funding paid watercraft inspectors (UW summer interns) to monitor high-use public access locations on the Eagle River Chain. These paid inspectors have been received training provided by the Clean Boats Clean Waters program. These inspectors check watercraft entering and leaving the chain for invasive species and provide educational materials to boaters. These paid inspectors have been funded by both direct funds from ERCLA and from grants awarded to ERCLA from the WDNR.

The Eagle River Chain is an extremely popular destination for recreationalists and anglers, making it vulnerable to new infestations of exotic species as well as invasive species already present being transported from the chain. The intent of these watercraft inspections would not only be to prevent additional invasive species from entering the chain through its public access points, but also to prevent the infestation of other waterways with invasive species that originated in the chain. The goal is to cover the landings during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of their spread. In 2014 and 2015, paid water inspectors spent approximately 200 hours each at the Yellow Birch Lake, Eagle Lake, and Catfish Lake public boat landings during the busy summer months. Of these 600 hours, 200 hours were funded by ERCLA while 400 were funded by the United Lower Eagle River Chain of Lakes Commission (ULERCLC).

While the paid watercraft inspectors cover the busiest public access points within the chain, ERCLA would like to expand the watercraft inspections to cover time periods following the departure of paid inspectors later in the season as well as to additional boat landings on the chain. The ERCLA Lakes and Shores Committee will recruit volunteer watercraft inspectors to cover these landings during high-use periods later in the season when the paid-inspectors are no longer available. These may include holiday weekends or during professional fishing tournaments. ERCLA would also like to expand inspections to include the Chain O'Lakes Campground, which is a high-use private landing. Private boat landings are applicable for WDNR grant funding, and ERCLA should seek CBCW funding through an AIS-Education, Planning and Prevention (EPP) Grant to aid in funding paid inspectors at the Chain O'Lakes Campground boat landing.

Action Steps:

1. ERLCA to continue annual funding of 200 paid watercraft inspector hours and to work with the ULERCLC to continue to fund additional 400 paid watercraft inspector hours to monitor the Yellow Birch, Eagle Lake, and Catfish Lake public access locations.
2. ERCLA Lakes and Shores committee contacts and works with Chain O'Lakes Campground owner for permission to conduct watercraft inspections at their landing.
3. ERCLA to include Chain O'Lakes Campground boat landing in CBCW AIS-EPP Grant application to aid in funding paid watercraft inspections at this private boat landing.
4. ERCLA Lakes and Shores Committee to recruit volunteers to conduct watercraft inspections at Yellow Birch Lake, Eagle Lake, and Catfish Lake public access locations and the Chain O'Lakes Campground landing after paid inspectors have left for the season.

Management Action: Continue ERCLA Pink Bucket Program.

Timeframe: Continuation of current effort

Facilitator: Suggested: ERCLA Board of Directors

Description: In an effort to prevent the spread of the invasive plant EWM throughout the Eagle River Chain of Lakes, ERCLA instituted the Pink Bucket Program. This ERCLA-funded program places pink buckets along with AIS informational materials at nine public access points throughout the chain. The intent of this program is to provide fishermen and other lake users an opportunity to dispose of EWM fragments that are brought out of the water and into their boats through fishing lines, anchors, etc. as well as to educate lake users about the spread of AIS. Rather than throwing the fragments back into the water, lake users can take a pink bucket with them while on the water and place EWM fragments in the bucket. Upon returning the landing, lake users can empty the plant fragments (and other boat trash) into a waste container that is provided. ERCLA has developed a relationship with Eagle River Waste and Recycling, Inc., and they have agreed to pick up the waste at these public landings free of charge.

Action Steps:

1. Maintain relationship with Eagle River Waste and Recycling, Inc. (715.477.0077) to continue pick up of plant and boat trash at Pink Bucket Program Eagle River Chain designated public access locations.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action:	ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.
Timeframe:	Continuation of Current Effort
Facilitator:	Suggested: ERCLA Education Committee

Description: Education represents an effective tool to address lake issues like shoreline development, invasive species, water quality, lawn fertilizers, as well as other concerns such as community involvement and boating safety. Currently, ERCLA supports an Education Committee for marketing and public relations, community outreach, and public safety. ERCLA regularly publishes and distributes a newsletter, maintains website that provides association-related information including current projects and updates, meeting times, volunteer opportunities, and educational topics, and uses Constant Contact email marketing. Both of these mediums are an excellent source for communication and education to both association and non-association members.

While 85% of respondents indicated that ERCLA keeps them either *fairly well informed* or *highly informed* regarding issues with the Eagle River Chain and its management (Appendix B, Question #27), ERCLA would like to increase its capacity to reach out to and educate association and non-association members regarding the Eagle River Chain and its preservation. In addition to creating a newsletter, a variety of educational efforts will be initiated by the Education Committee. These include educational materials such as a tri-fold brochure containing information and results from the current lake management planning project. The Education Committee can also organize workshops and speakers surrounding lake-related topics.

Education of lake stakeholders on all matters is important. During the Phase I planning meeting, the list below of educational topics was developed. These topics can be included within the association's newsletter and/or website or distributed as separate educational materials. In addition, ERCLA can invite professionals who work within these topics to come and speak at the association's annual/and or individual lake meetings or hold workshops if available.

Example Educational Topics

- Shoreline restoration and protection
- Boating regulations and safety
- Light pollution

- Lake user/neighbor etiquette
- Riparian property management
- Septic system maintenance
- Importance of maintaining course woody habitat
- Aquatic invasive species (AIS) prevention and updates for AIS in the Eagle River Chain
- Water quality monitoring updates from the Eagle River Chain

Action Steps:

1. See description above.

Management Action: Increase ERCLA membership and participation.

Timeframe: Continuation of current effort

Facilitator: Suggested: ERCLA Membership Committee

Description: Even through lake associations consist of individuals who are passionate about the lake they reside upon, it is often difficult to recruit new members and volunteers to complete the tasks that are necessary to protect that lake. Many lake association members are elderly and retired, often making labor intensive volunteer jobs are difficult to perform. Other residents may only visit the lake several times during the year, often on weekends to "get away" from the pressures of the work-week back home. Some have cut back on volunteering because of recent economic downturns or concerns over the time commitment involved with various volunteer tasks, while others may simply have not been asked to lend their services.

Those that have volunteered in the past and have had a poor experience may be hesitant to volunteer again. Without good management, volunteers may become underutilized. Some may have been turned off by an impersonal, tense or cold atmosphere. Volunteers want to feel good about themselves for helping out, so every effort must be made by volunteer managers to see to it that the volunteer crews enjoy their tasks and their co-volunteers.

ERCLA is proud of their active role in preserving and enhancing the Eagle River Chain for all stakeholders; however, they are in need of new members and volunteers to continue this high level of commitment. To increase ERCLA membership and participation, a Membership Committee has been created. The Membership Committee will work closely with the Education Committee to distribute ERCLA informational materials to current members as well as non-members in an effort to increase membership and participation.

Action Steps:

1. ERCLA to appoint chair of Membership Committee and recruit volunteers.

2. Membership Committee works with Education Committee to distribute ERCLA informational materials to lake stakeholders.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the Eagle River 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**
Dissolved Phosphorus	●	●			●	●					●	●
Total Phosphorus	●	●	●	●	●	●	●	●	●	●	●	●
Total Kjeldahl Nitrogen	●	●			●	●					●	●
Nitrate-Nitrite Nitrogen	●	●			●	●					●	●
Ammonia Nitrogen	●	●			●	●					●	●
Chlorophyll-*a*	●		●		●		●		●			
True Color	●				●							
Hardness	●				●							
Total Suspended Solids	●	●			●	●			●	●		
Laboratory Conductivity	●	●			●	●						
Laboratory pH	●	●			●	●						
Total Alkalinity	●	●			●	●						
Calcium	●				●							

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

Watershed Analysis

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

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on the Eagle River 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 all of the lakes within the Eagle River Chain of Lakes by Onterra on July 31 and August 1, 2, 3, and 6, 2012 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	**Lake**	**Point-Intercept Resolution (meters)**	**Number of Sampling Locations**
Phase I	Cranberry	80	588
	Catfish	80	616
Phase II	Voyageur	50	232
	Eagle	70	476
	Scattering Rice	60	287
Phase III	Otter	60	195
	Lynx	30	137
	Duck	50	168
Phase IV	Yellow Birch	45	416
	Watersmeet	50	554

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. These surveys were conducted on each lake during their respective years (see table below). 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.

Phase	**Lake**	**Community Mapping Survey Date**
Phase I	Cranberry	August 15, 2013
	Catfish	August 14-15, 2013
Phase II	Voyageur	July 30, 2014
	Eagle	July 30, 2014
	Scattering Rice	July 30, 2014
Phase III	Otter	Scheduled for 2016
	Lynx	Scheduled for 2016
	Duck	Scheduled for 2016
Phase IV	Yellow Birch	Scheduled for 2017
	Watersmeet	Scheduled for 2017

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

8.1 Cranberry Lake

An Introduction to Cranberry Lake

Cranberry Lake, Oneida and Vilas County, is a shallow, lowland drainage lake with a maximum depth of 23 feet, a mean depth of 9 feet, and a surface area of approximately 929 acres. It is the upstream-most lake in the Lower Eagle River Chain, and is fed and drained via the Eagle River. The lake is currently in a eutrophic state, and has a surficial watershed that encompasses approximately 97,792 acres. In 2012, 52 native aquatic plant species were located in the lake, of which slender naiad (*Najas flexilis*) was the most common. Four non-native plants, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and yellow garden loosestrife were observed growing in the lake or along the shoreline in 2012.

Field Survey Notes

Cranberry Lake is a productive lake with a diverse aquatic plant community, particularly within the upstream channel. Two relatively rare aquatic plant species, apline pondweed and spiny hornwort, were located in this area. Vasey's pondweed, a state-listed special concern species, is relatively abundant throughout littoral areas of the lake.

Photo 8.1 Cranberry Lake, Oneida and Vilas Counties

Lake at a Glance* – Cranberry Lake

Morphology	
Acreage	929
Maximum Depth (ft)	23
Mean Depth (ft)	9
Volume (acre-feet)	8,361
Shoreline Complexity	7.9
Vegetation	
Curly-leaf Survey Date	July 11, 2013
Comprehensive Survey Date	July 31, 2012
Number of Native Species	52
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil; Purple loosestrife; Pale-yellow iris; Garden yellow loosestrife
Simpson's Diversity	0.92
Average Conservatism	7.0
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	106:1

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

8.1.1 Cranberry Lake Water Quality

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

A fair amount of data exists for two water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations. In 2013, average summer phosphorus concentrations (35.4 µg/L) were only slightly higher than the median value (33.0 µg/L) for other shallow, 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 *Good* for a shallow, lowland drainage lake.

Total phosphorus surface values from 2013-2014 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 June, July and August of 2013, 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 Eagle River Chain-wide document. While this process may be contributing some phosphorus to Cranberry Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Cranberry Lake's surface water total phosphorus values are about the same as the median value for comparable lakes in Wisconsin.

2013 summer average chlorophyll-*a* concentrations (25.7 µg/L) were roughly 2.5 times the median value (9.4 µg/L) for chlorophyll-*a* in other lakes of this type (Figure 8.1.1-3). The 2013 value is almost five times higher than the median for all lakes in the Northern Lakes and Forests ecoregion. A weighted value over all years is considerably higher than these two comparables as well. Despite the higher chlorophyll-*a* reading, the highest of average values in the dataset remain in the lower portion of the *Fair* category for shallow, lowland drainage lakes.

Overall, total phosphorus and chlorophyll-*a* weighted summer averages rank within a TSI category of *Good to Fair*, indicating the lake has enough nutrients for production of aquatic plants, algae, and other organisms but not so much that a water quality issue is present. During 2013 visits to the lake, Onterra ecologists recorded field notes describing good water conditions, though slightly stained water. As explained below, the stained water is not due to nutrients or another form of pollution.

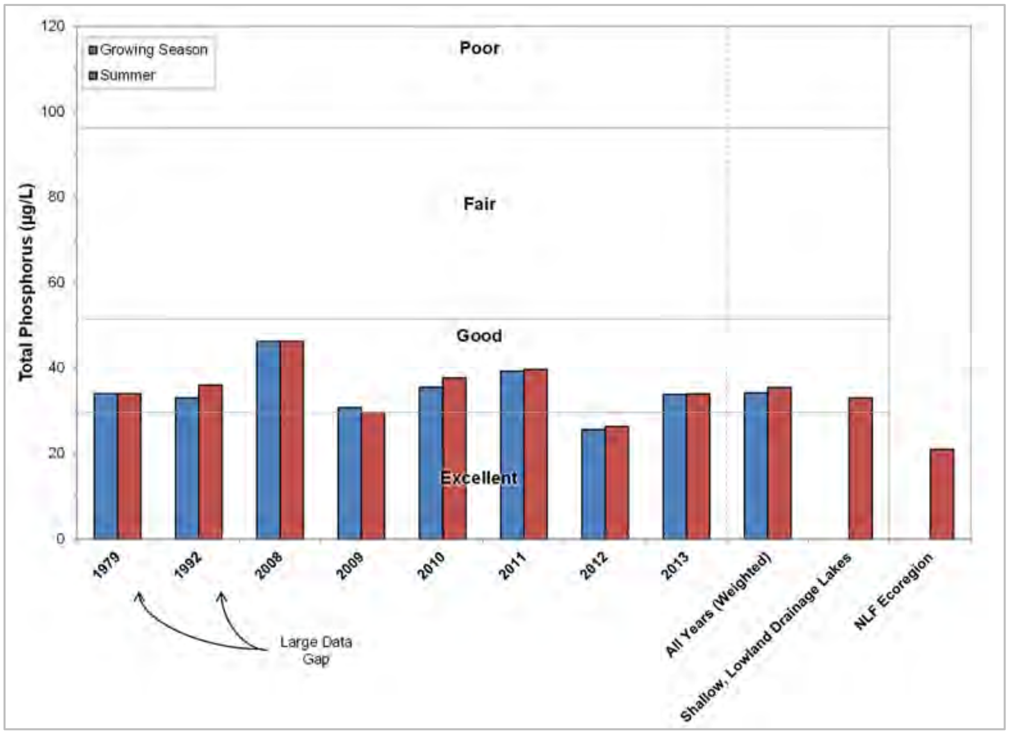


Figure 8.1.1-1. Cranberry Lake, statewide shallow, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

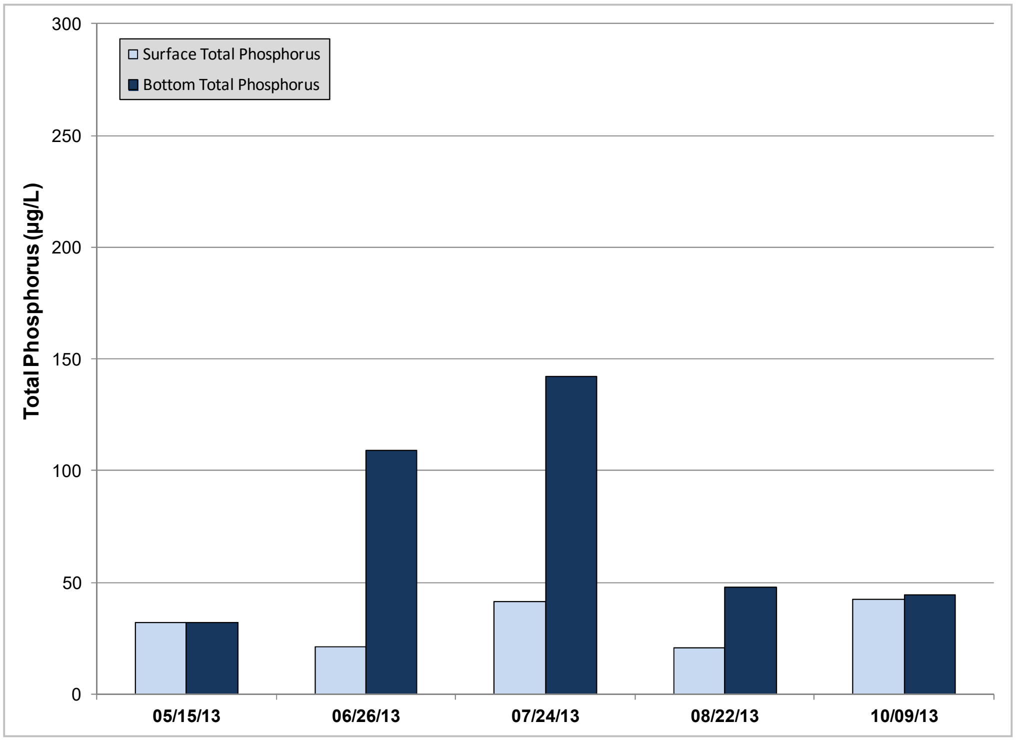


Figure 8.1.1-2. Cranberry Lake surface and bottom total phosphorus values, 2013. Anoxia was observed in the hypolimnion of the lake during summer sampling visits.

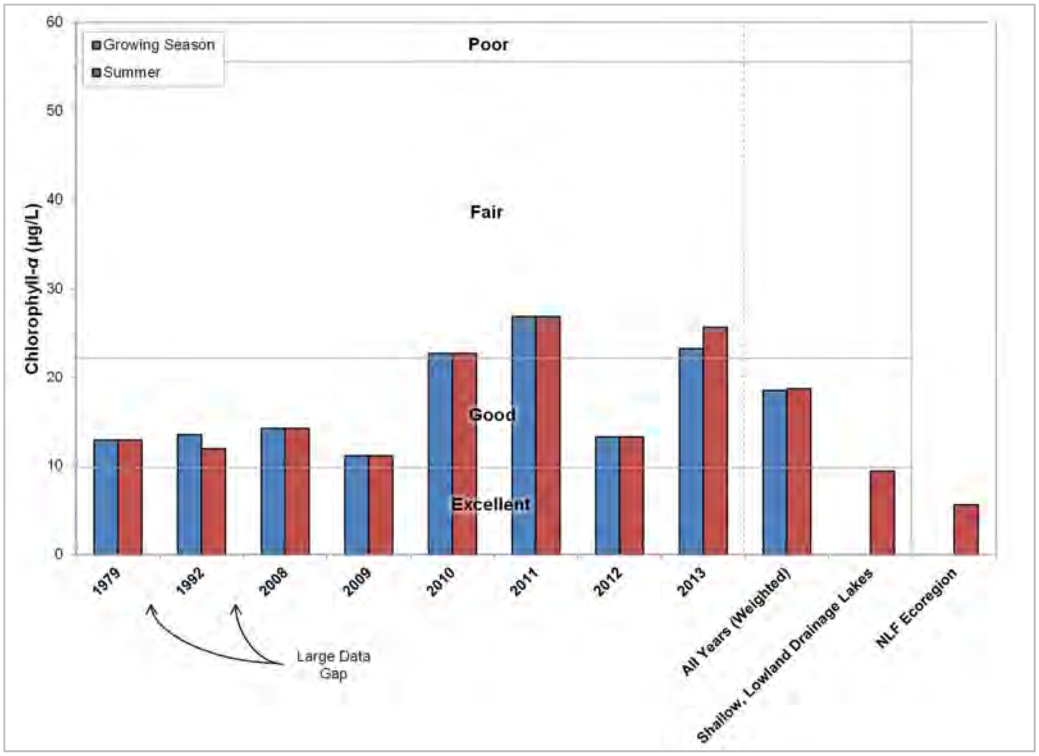


Figure 8.1.1-3. Cranberry Lake, statewide shallow, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of nearly three decades worth of intermittent Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Cranberry Lake's water can be described as between *Good* and *Excellent* in most years (Figure 8.1.1-4). A weighted average over this timeframe is about the same than the median value for other shallow, lowland drainage lakes in the state but lower than the median value for lakes within the ecoregion. Secondly, there is no apparent trend in the clarity of the water in Cranberry 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 Cranberry Lake as well as the other lakes in the Eagle River Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Cranberry 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 2013 were measured for this parameter, and were found to be at 50 and 40 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.

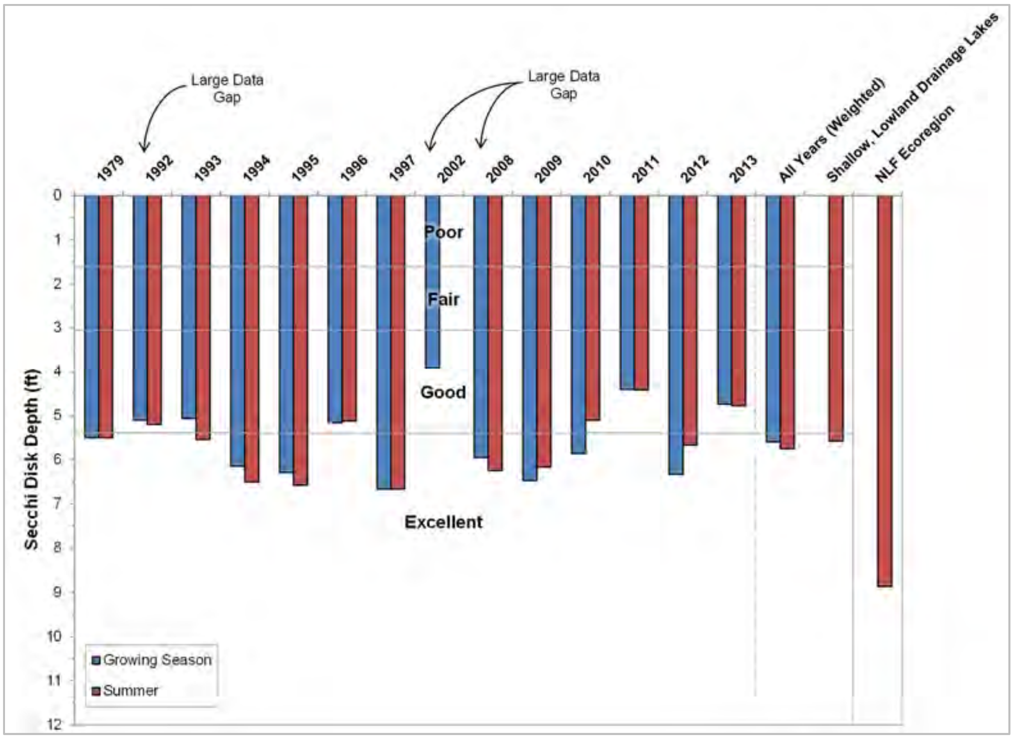


Figure 8.1.1-4. Cranberry Lake, statewide shallow, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Cranberry Lake Trophic State

The TSI values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning the eutrophic category (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 Cranberry Lake is in a eutrophic state.

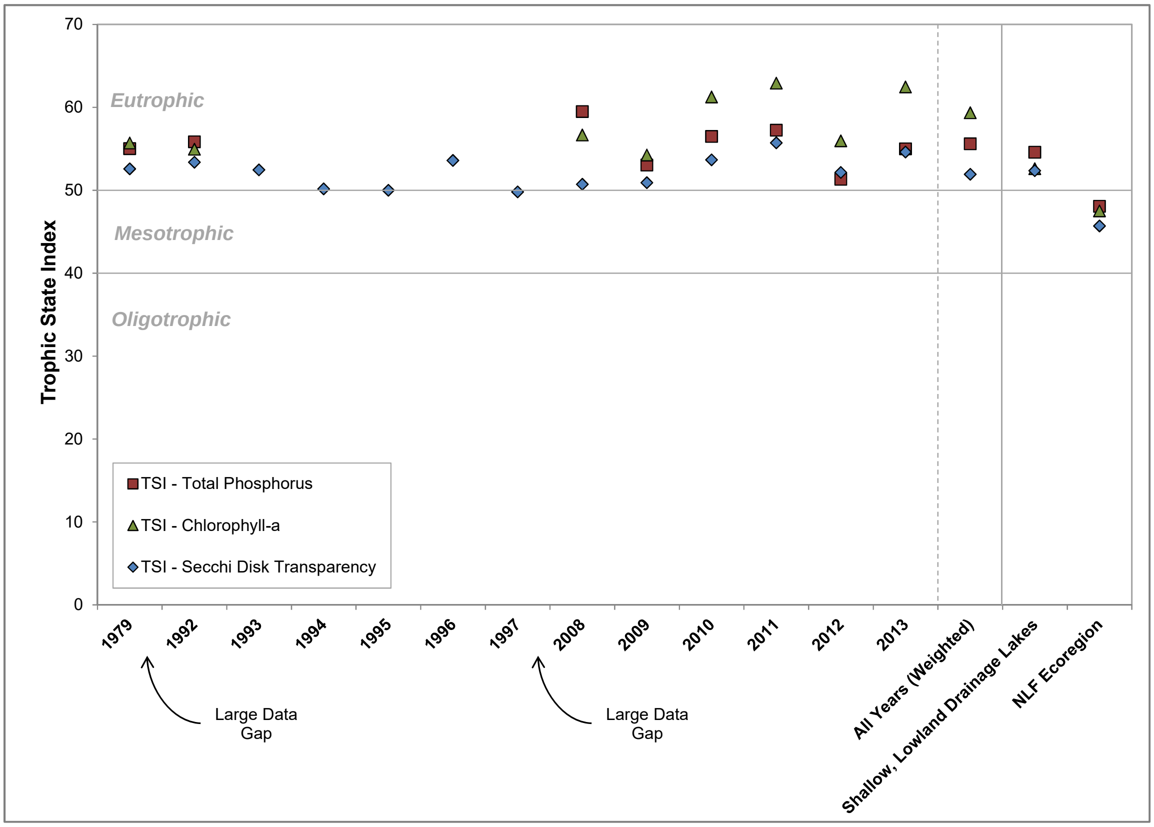


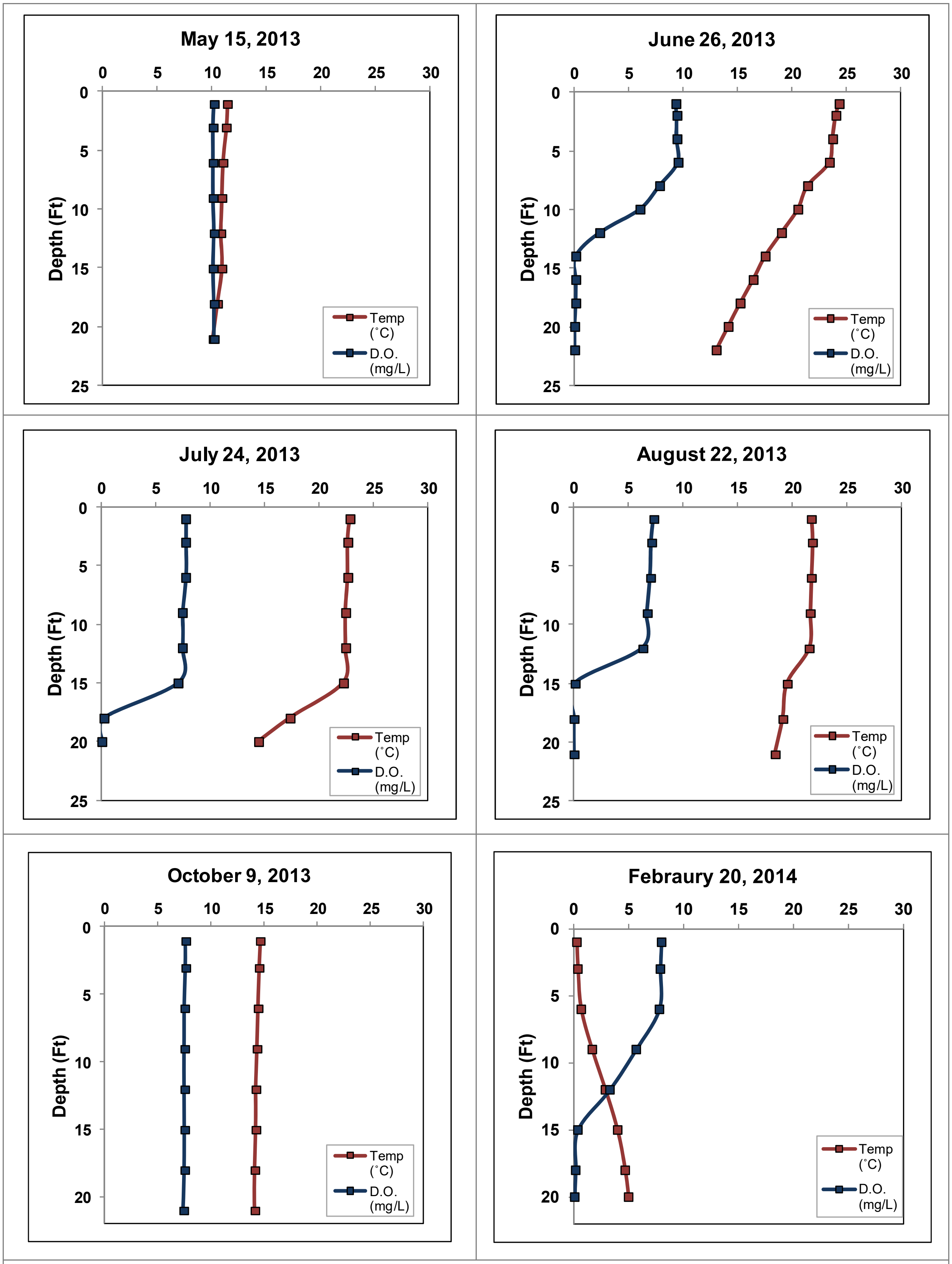
Figure 8.1.1-5. Cranberry Lake, statewide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Cranberry Lake

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

Cranberry 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 deeper 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. In a relatively large and shallow lake such as Cranberry Lake, this thermal barrier may break during the summer months, re-oxygenating the hypolimnion and potentially releasing some nutrients to surface waters.

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 2014, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.


May 15, 2013

June 26, 2013

July 24, 2013

August 22, 2013

October 9, 2013

Febraury 20, 2014

Figure 8.1.1-6. Cranberry Lake 2013/2014 dissolved oxygen and temperature profiles.

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

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. Cranberry Lake's surface water pH was measured at roughly 6.9 during May and 8.1 during July of 2013. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter adds 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 Cranberry Lake was measured at 27.0 mg/L as $CaCO_3$ in April and 30.7 in July of 2013. This indicates that the lake has a substantial capacity to resist fluctuations in pH and is not sensitive to acid rain.

Samples of calcium were also collected from Cranberry Lake during 2013. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Cranberry Lake's pH of 6.9 – 8.1 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 Cranberry Lake was found to be 7.16 mg/L in June and 8.25 mg/L in August of 2013, which is below the lower range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. The results were negative for the presence of zebra mussel veligers.

True color is a measure of water clarity once suspended material (i.e. algae, sediments) has been removed is called true color. True color measures the amount of light scattered and absorbed by organic materials dissolved within the water. Many lakes in the northern region of Wisconsin have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These give the water a tea-like color and decrease water clarity. Cranberry Lake had an average true color value of 45.0 SU (standard units), indicating the water is most often tea-colored. Lakes with large areas of forests and wetlands within their watersheds tend to have tea-colored or stained water, as these dissolved organic materials within the lake's water originate from decaying vegetation within the watershed.

8.1.2 Cranberry Lake Watershed Assessment

Cranberry Lake's watershed is approximately 97,792 acres in size. Compared to its surface area of 929 acres, this makes for a large watershed to lake area ratio of 106:1.

Exact land cover calculation and modeling of nutrient input to Cranberry Lake will be completed towards the end of this project (in 2016-2017). 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 Cranberry 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 2013, Cranberry Lake's immediate shoreline was assessed in terms of its development. Cranberry Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 7.3 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.2.3-1). This constitutes about 50% of Cranberry 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, 3.3 miles of urbanized and developed–unnatural shoreline (22%) was observed. If restoration of the Cranberry 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. Cranberry Lake - Map 1 displays the location of these shoreline lengths around the entire lake.

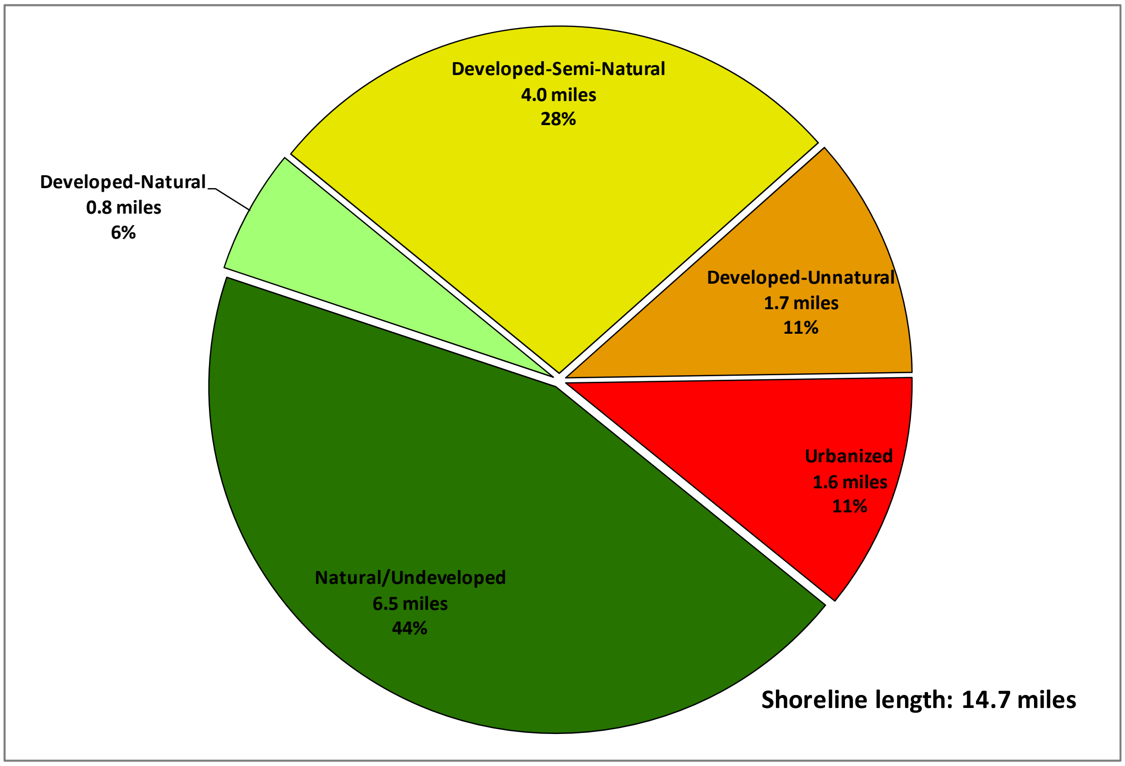


Figure 8.1.3-1. Cranberry Lake shoreland categories and total lengths. Based upon a late summer 2013 survey. Locations of these categorized shorelands can be found on Cranberry Lake - Map 1.

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 Eagle River 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, 233 total pieces of coarse woody habitat were observed along 14.7 miles of shoreline, which gives Cranberry Lake a coarse woody habitat to shoreline mile ratio of 16:1. Locations of coarse woody habitat are displayed on Cranberry 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).

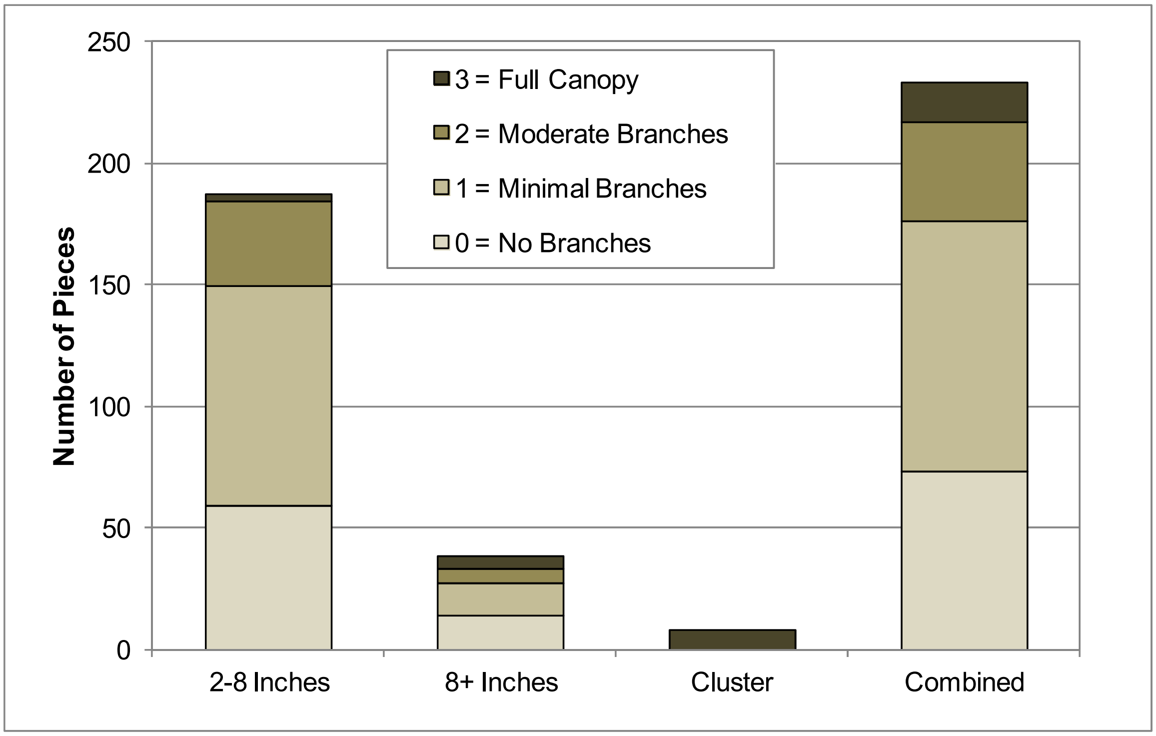


Figure 8.1.3-2. Cranberry Lake coarse woody habitat survey results. Based upon a late summer 2013 survey. Locations of Cranberry Lake coarse woody habitat can be found on Cranberry Lake - Map 2.

8.1.4 Cranberry Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Cranberry Lake on July 11, 2013. 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.

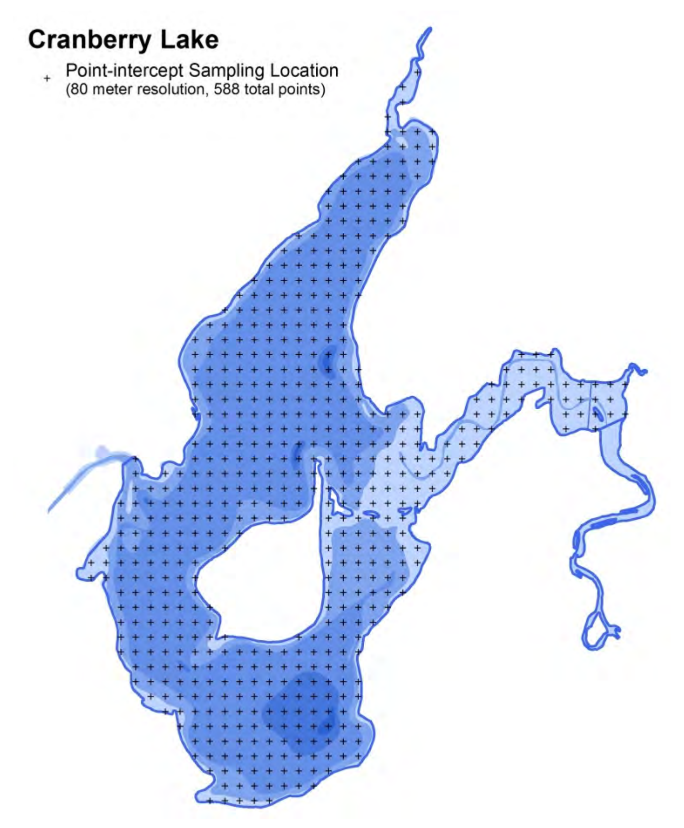


Figure 8.1.4-1. Point-intercept locations on Cranberry Lake.

The whole-lake aquatic plant point-intercept survey was conducted on Cranberry Lake by Onterra on July 31, 2012 (Figure 8.1.4-1), while the aquatic plant community mapping survey was conducted on August 14 and 15, 2013. During these surveys, a total of 56 aquatic plant species were located, four of which is considered to be a non-native, invasive species: Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and yellow garden loosestrife (Table 8.1.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 57% of the point-intercept locations within littoral areas contained fine, organic sediments (muck), 39% contained sand, and 4% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 12 feet, the same as in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.1.4-1. Aquatic plant species located in Cranberry Lake during 2006 and 2012/2013 aquatic plant surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2013 (Onterra)
E	*Calla palustris*	Water arum	9		I
	Carex comosa	Bristly sedge	5		I
	Carex crinita	Fringed sedge	6		I
	Carex utriculata	Common yellow lake sedge	7		I
	Decodon verticillatus	Water-willow	7		I
	Dulichium arundinaceum	Three-way sedge	9		I
	Eleocharis palustris	Creeping spikerush	6		I
	Equisetum fluviatile	Water horsetail	7		I
	Iris pseudacorus	Pale-yellow iris	Exotic		I
	Iris versicolor	Northern blue flag	5		I
	Lysimachia vulgaris	Yellow garden loosestrife	Exotic		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Pontederia cordata	Pickerelweed	9		X
	Sagittaria latifolia	Common arrowhead	3		I
	Sagittaria rigida	Stiff arrowhead	8		I
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A		I
	Schoenoplectus acutus	Hardstem bulrush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Typha spp.	Cattail spp.	1		I
FL	*Brasenia schreberi*	Watershield	7		X
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium americanum*	Eastern bur-reed	8		I
	Sparganium androcladum	Shining bur-reed	8		X
	Sparganium angustifolium	Narrow-leaf bur-reed	9		X
	Sparganium emersum	Short-stemmed bur-reed	8		I
	Sparganium eurycarpum	Common bur-reed	5		I
	Sparganium fluctuans	Floating-leaf bur-reed	10		X
Submergent	*Bidens beckii*	Water marigold	8		X
	Ceratophyllum demersum	Coontail	3	X	X
	Ceratophyllum echinatum	Spiny hornwort	10		X
	Chara spp.	Muskgrasses	7	X	
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton alpinus	Apline pondweed	9		I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton hybrid	Hybrid pondweed	N/A		X
	Potamogeton natans	Floating-leaf pondweed	5	X	I
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton robbinsii	Fern pondweed	8	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
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A		X
	Sparganium sp.	Bur-reed sp.	N/A	X	
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X
FF	*Lemna trisulca*	Forked duckweed	6		X

E = Emergent, 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*

Of the 309 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 55% contained aquatic vegetation. This is higher than what was found in the 2006 survey where approximately 39% of the littoral sampling locations contained aquatic vegetation. Cranberry Lake – Map 3 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore and in the western portion of the lake up into the channel. Twenty-four percent of the point-intercept locations had a total rake fullness (TRF) rating of 2, 17% had a total rake fullness rating of 1, and 14% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.1.4-1 displays the aquatic plant species located in Cranberry Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the plants that surveyors had located in 2006 where re-recorded in 2012. An additional 13 native aquatic plant species were located in 2012 that had not been recorded in 2006, including two relatively rare, sensitive species: spiny hornwort and alpine pondweed. This increase in the number of species recorded in 2012 is likely due to differences in the aquatic plant identification abilities of the surveyors.

Of the 33 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, spiral-fruited pondweed, wild celery, and Vasey’s pondweed were the four-most frequently encountered (Figure 8.1.4-2). Slender naiad, the most abundant aquatic plant in Cranberry Lake in 2012 with a littoral occurrence of nearly 30%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad’s small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Spiral-fruited pondweed was the second-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 19%. As its name indicates, this plant produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water (Photo 8.1.4-1). The submersed leaves are long and narrow, and are usually curved. Like slender naiad, spiral-fruited pondweed is food and habitat source for wildlife.

Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

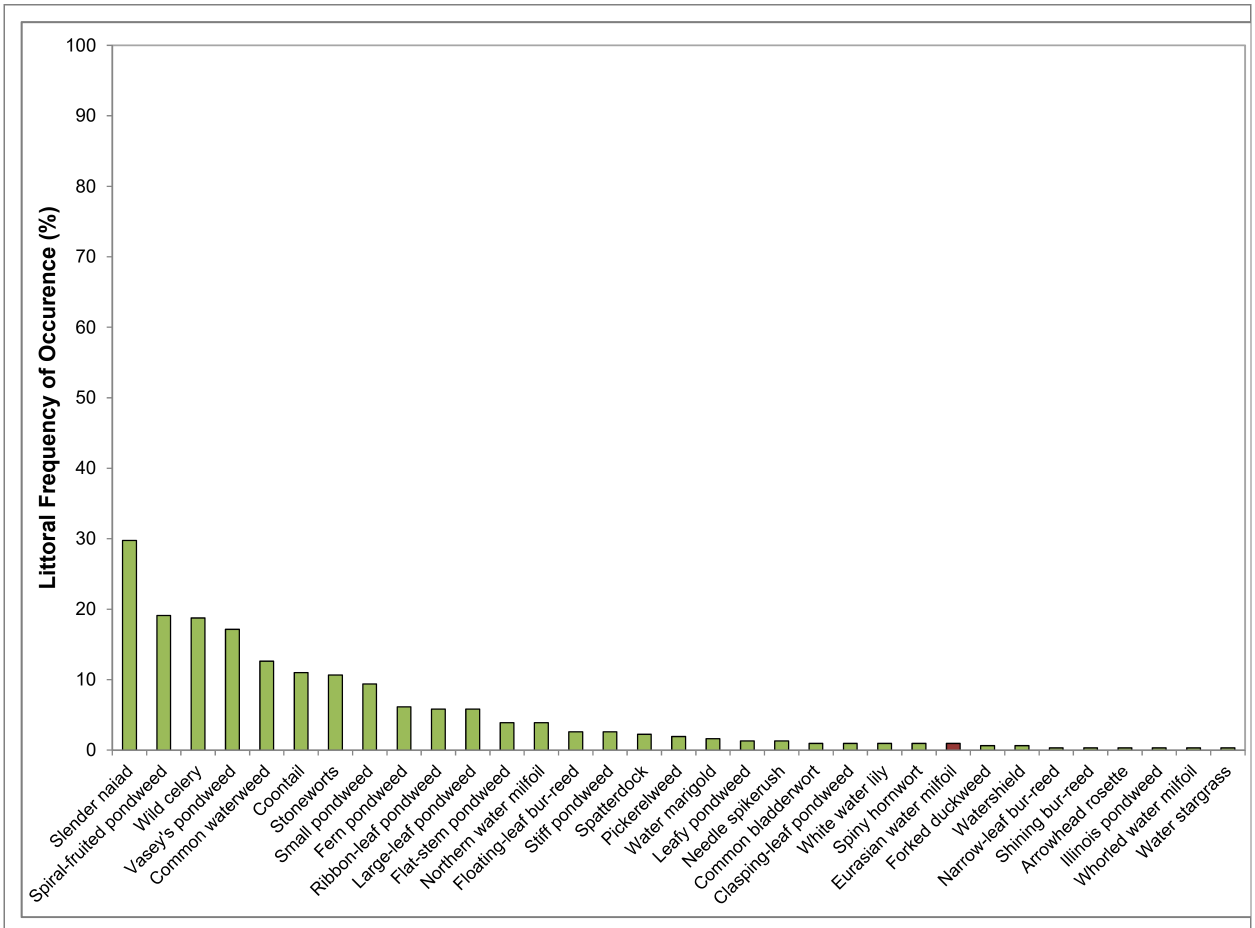


Figure 8.1.4-2. Cranberry Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Vasey's pondweed was the fourth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like spiral-fruited pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer than spiral-fruited pondweed. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Cranberry Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian watermilfoil control project on Cranberry Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.1.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Cranberry Lake.

As illustrated, the occurrence of Eurasian watermilfoil in Cranberry Lake was found to be not statistically different from 2006 to 2012, and had a littoral occurrence of around 1% in both surveys. However, from the annual Eurasian watermilfoil mapping surveys, it is clear that Eurasian watermilfoil within Cranberry Lake did increase since 2006. Had point-intercept surveys been conducted on an annual basis, this likely would have been captured. It is believed that the herbicide treatments have been effective at reducing and maintaining a low population of Eurasian watermilfoil in Cranberry Lake. Five of the native aquatic plant species that had an occurrence of at least 5% in 2006 or 2012 saw statistically valid increases in their littoral occurrence, while the other five did not have statistically different occurrences from 2006 to 2012 (Figure 8.1.4-3). From these data, it appears that the Eurasian watermilfoil control program has not had any detectable adverse effects on any of the aquatic plant species' populations in Cranberry Lake.

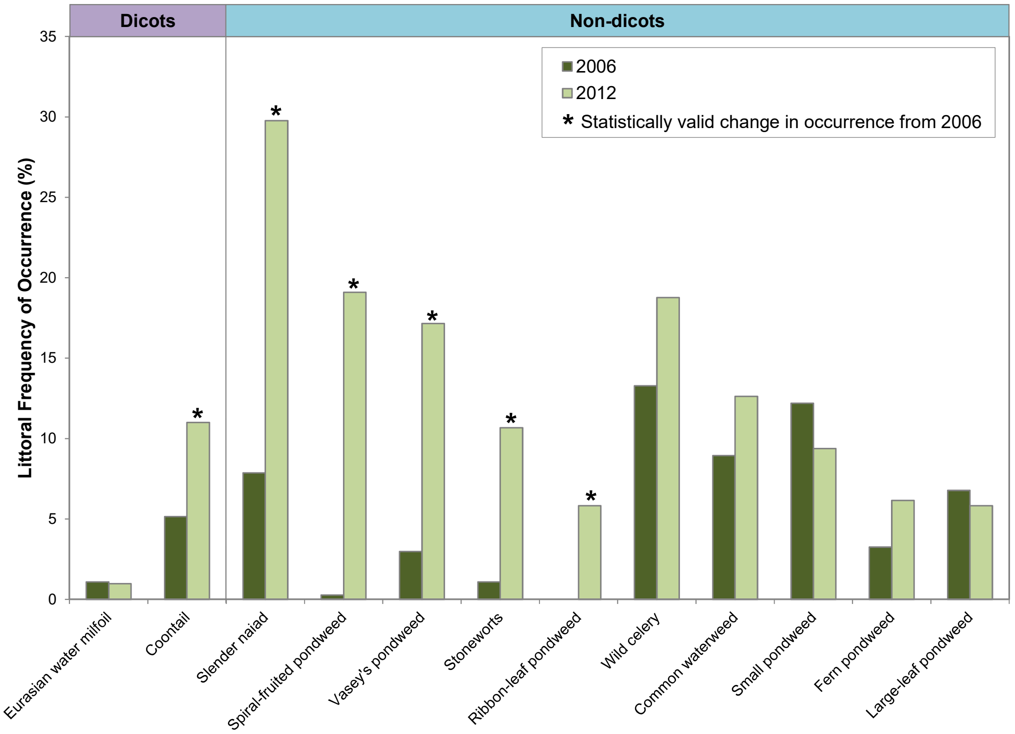


Figure 8.1.4-3. Cranberry Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total 34 native aquatic plant species were located in Cranberry Lake during the 2012 survey, 32 were encountered on the rake and two were incidentally located. These 32 native species and their conservatism values were used to calculate the FQI of Cranberry Lake's aquatic plant community in 2012 (equation on next page). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.1.4-4 compares the FQI components of Cranberry Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL)

Ecoregion as well as the entire State of Wisconsin. In 2012, Cranberry Lake's native species richness (32) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (7.0) is also exceeds the ecoregional and state medians. Combining Cranberry Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 39.6, which greatly exceeds the ecoregional and state median values (Figure 8.1.4-4). The FQI values from 2012 are also much higher than those calculated from point-intercept survey in 2006, indicating that the quality of Cranberry Lake's aquatic plant community has not been diminished by the Eurasian watermilfoil control project. This analysis indicates that Cranberry Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

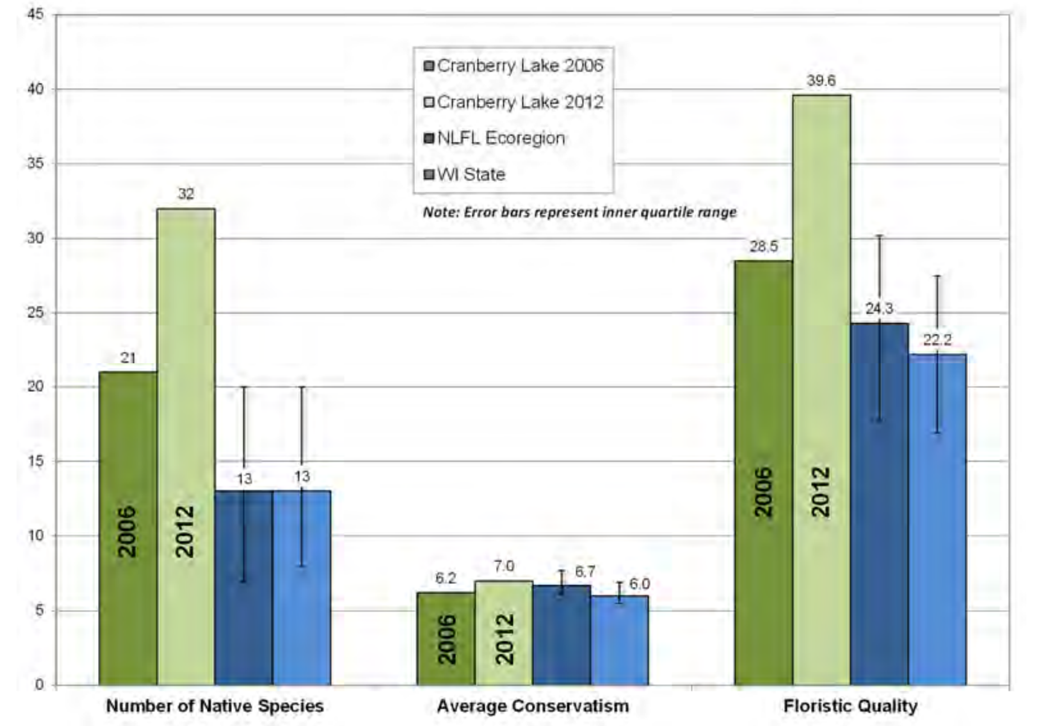


Figure 8.1.4-4. Cranberry Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Cranberry Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.1.4-5). Using the data collected form the 2012 point-intercept survey, Cranberry Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.92, falling above the upper quartile value for lakes in both the ecoregion and the state. Cranberry Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.91).

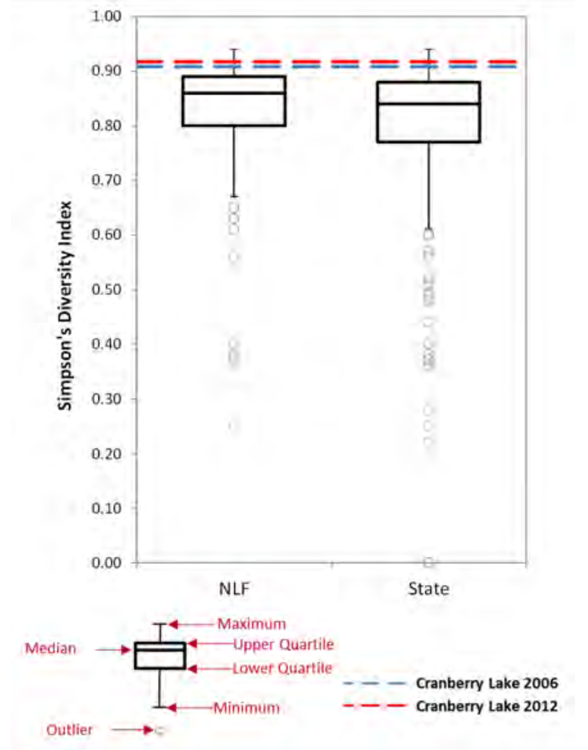


Figure 8.1.4-5. Cranberry Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 8.1.4-6 displays the relative frequency of occurrence of aquatic plant species in Cranberry Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

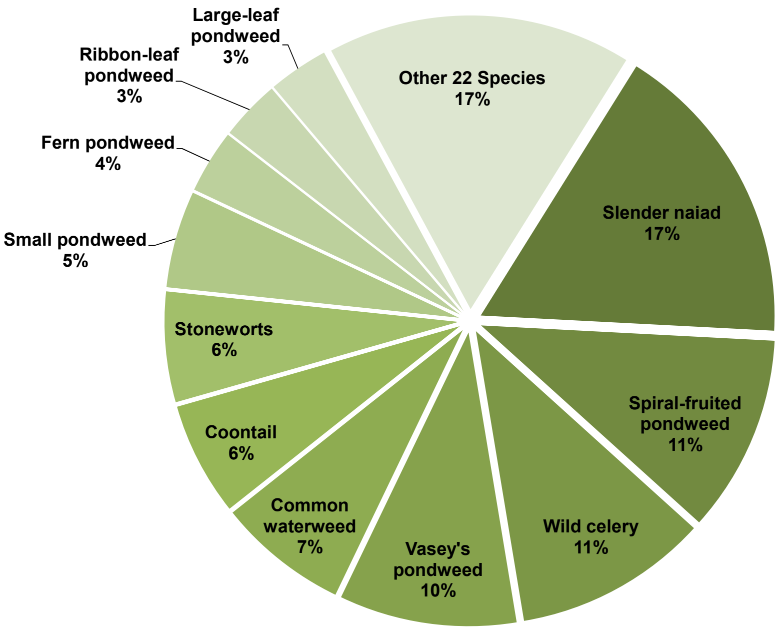


Figure 8.1.4-6. Cranberry Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Overall, the 2012 point-intercept survey on Cranberry Lake indicated that there have been no detectable adverse lake-wide impacts to any of the lake's native aquatic plant species and to the entire community over the course of the five-year Eurasian watermilfoil control project. The native species richness, average conservatism, Floristic Quality, and species diversity all increased from 2006 to 2012. A Eurasian watermilfoil treatment did occur in 2012 and information regarding this treatment can be found in the Lower Eagle River Chain 2012 Treatment Report (January 2013).

The 2013 aquatic plant community mapping survey revealed that Cranberry Lake contains approximately 72.3 acres of emergent and floating-leaf aquatic plant communities (Table 8.1.4-2, Cranberry Lake – Map 4 and 5). Twenty-six emergent and floating-leaf aquatic plant species were located in the lake in 2012 (Table 8.1.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Cranberry Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.1.4-2. Acres of emergent and floating-leaf aquatic plant communities in Cranberry Lake. Created using data from 2013 aquatic plant community mapping survey.

Plant Community	**2013 Acres**
Emergent	4.7
Floating-Leaf	6.5
Mixed Emergent & Floating-Leaf	61.1
Total	**72.3**

8.1.5 Cranberry Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Cranberry Lake's Implementation Plan illustrates how Cranberry Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Cranberry Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue advanced water quality monitoring of Cranberry Lake's through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Carole Linn, current Cranberry Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Cranberry Lake have been collecting water quality data since 1992. The lake is currently enrolled in the advanced monitoring program and has an active volunteer (Carole Linn) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis. Cranberry Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Carole Linn, the current CLMN volunteer, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. Carole Linn, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. Carole Linn, current CLMN volunteer, notifies Dave Mueller or current Lakes and Shores Committee chair when a new Cranberry Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Cranberry Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 22% (3.3 miles) of the shoreline are in an urbanized or developed-unnatural state, 28% (4.0 miles) is in a developed-semi-natural state, and 50% (7.3 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 22% of Cranberry Lake's shoreline is in a highly-developed state, approximately 50% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Cranberry Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Cranberry Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Cranberry Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Cranberry Lake shoreland assessment, approximately 16 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Cranberry Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.

Description: Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Cranberry Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Cranberry Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA.

Cranberry Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Cranberry Lake Association and ERCLA meetings. Cranberry Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Cranberry Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Cranberry Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action: ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.

Description: Cranberry Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Cranberry Lake and its stakeholders.

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

8.2 Catfish Lake

An Introduction to Catfish Lake

Catfish Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 30 feet, a mean depth of 12 feet, and a surface area of approximately 977 acres. The lake is fed via the Eagle River from upstream Cranberry Lake and drains into downstream Voyageur Lake, and has a surficial watershed that encompasses approximately 99,991 acres. In a study conducted by Onterra in 2012, 39 native aquatic plant species were located in the lake, of which slender naiad (*Najas flexilis*) was the most common. Two non-native plants, Eurasian watermilfoil and purple loosestrife were observed growing in or along the shorelines of Catfish Lake in 2012.

Field Survey Notes

Catfish Lake contains a relatively small littoral zone with the majority of the lake being too deep to support aquatic plant growth. However, the lake's aquatic plant community was found to be species-rich and contains a number of high-quality native species including Vasey's pondweed, a species listed as special concern in Wisconsin.

Photo 8.2 Catfish Lake, Vilas County

Lake at a Glance* – Catfish Lake

Morphology	
Acreage	977
Maximum Depth (ft)	30
Mean Depth (ft)	12
Volume (acre-feet)	11,724
Shoreline Complexity	6.8
Vegetation	
Curly-leaf Survey Date	July 11, 2013
Comprehensive Survey Date	August 1, 2013
Number of Native Species	39
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil; Purple loosestrife
Simpson's Diversity	0.90
Average Conservatism	6.6
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	101:1

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

8.2.1 Catfish Lake Water Quality

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

Unfortunately, somewhat limited data exists for three water quality parameters of interest – total phosphorus and chlorophyll-*a* concentrations and Secchi disk depths. In 2013, average summer phosphorus concentrations (22.4 µg/L) were less than the median value (33.0 µg/L) for other shallow, lowland drainage lakes in the state (Figure 8.2.1-1). The value is a little more than 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 shallow, lowland drainage lake.

Total phosphorus surface values from 2013 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 of 2013, 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 Eagle River Chain-wide document. While this process may be contributing some phosphorus to Catfish Lake's water column, the impacts of nutrient loading are not apparent in the lake's overall water quality; as previously mentioned, Catfish Lake's surface water total phosphorus values are less than the median value for comparable lakes in Wisconsin.

Summer average chlorophyll-*a* concentrations (17 µg/L) were higher than the median value (9.4 µg/L) for other shallow, lowland drainage lakes (Figure 8.2.1-3). 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 2013 visits to the lake, Onterra ecologists recorded field notes describing good water conditions.

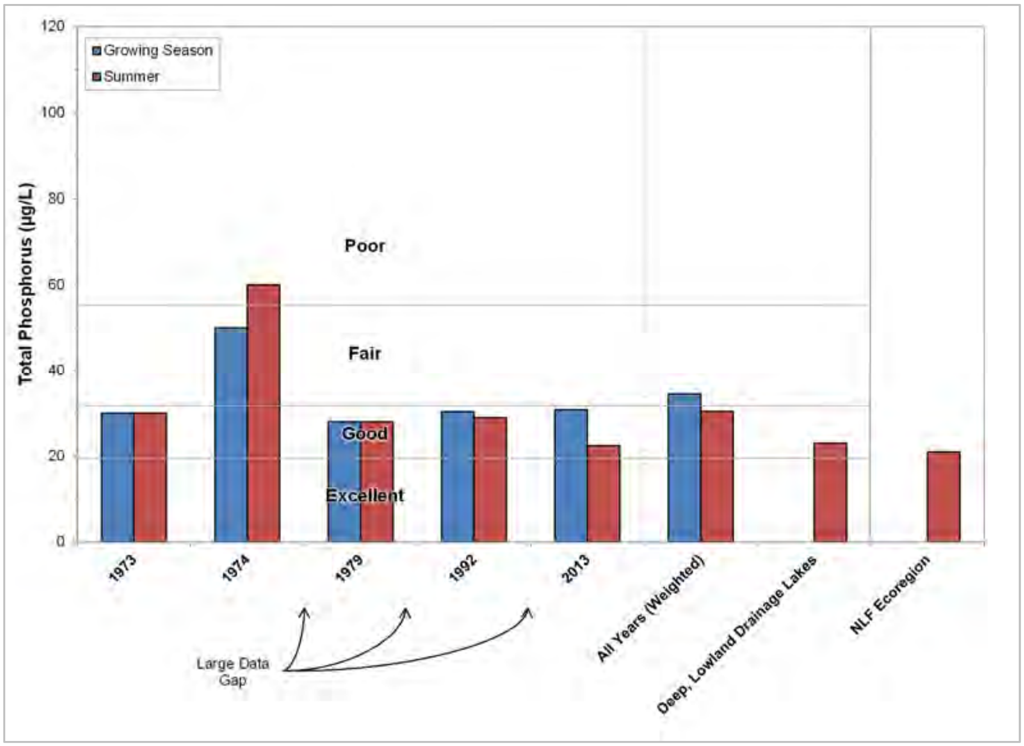


Figure 8.2.1-1. Catfish Lake, statewide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

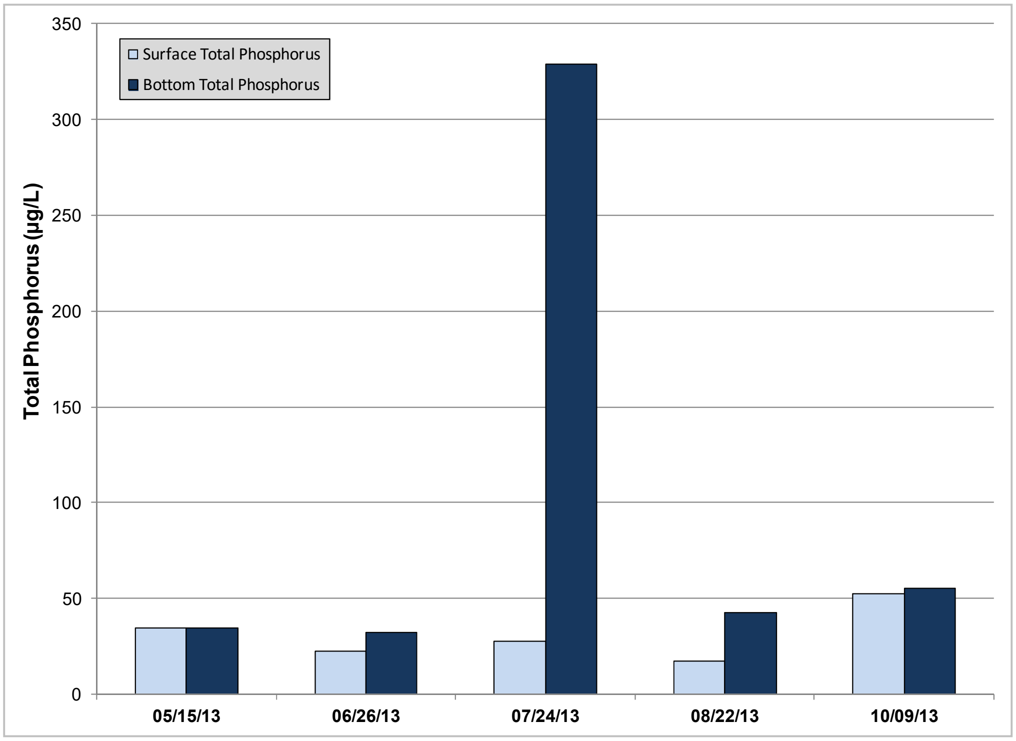


Figure 8.2.1-2. Catfish Lake surface and bottom total phosphorus values, 1973-2013. Anoxia was observed in the hypolimnion of the lake during August sampling visits.

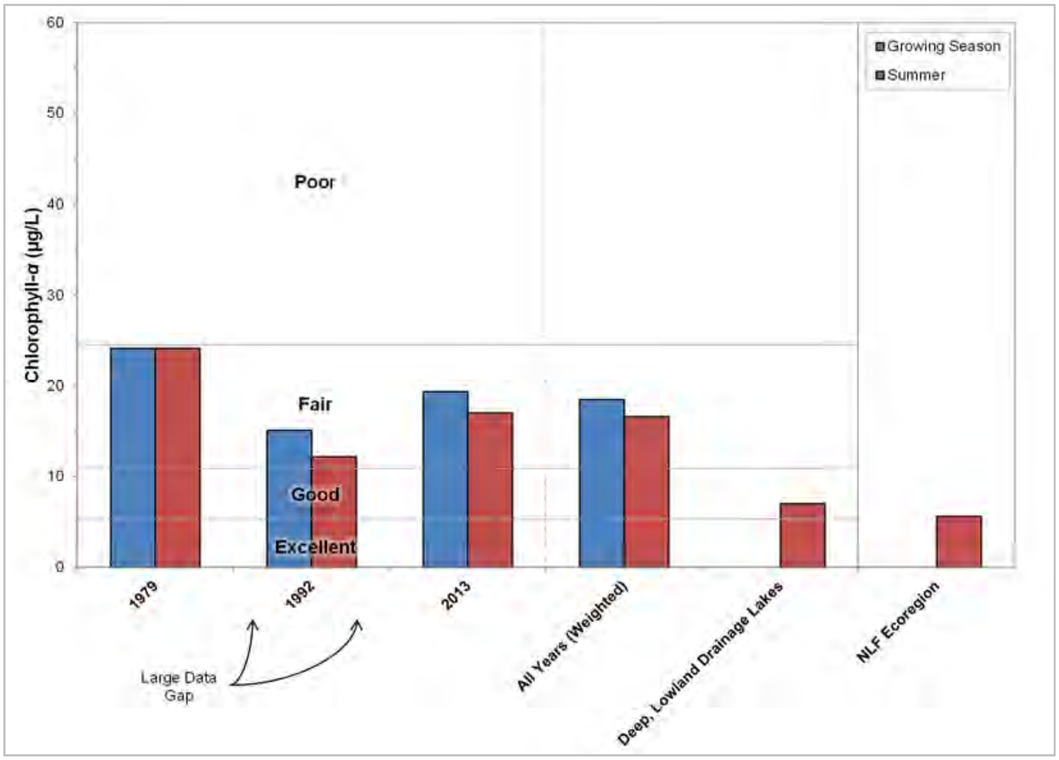


Figure 8.2.1-3. Catfish Lake, statewide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

From the examination of nearly two decades worth of Secchi disk clarity data, several conclusions can be drawn. First, the clarity of Catfish Lake's water can be described as *Good* to *Excellent* (Figure 8.1.1-4). A weighted average over this timeframe is less than the median value for other shallow, lowland drainage lakes in the state. Secondly, there is no apparent trend in the clarity of the water in Catfish 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 Catfish Lake as well as the other lakes in the Eagle River Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Catfish 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 May and July of 2013 were measured for this parameter, and were found to be 30 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.

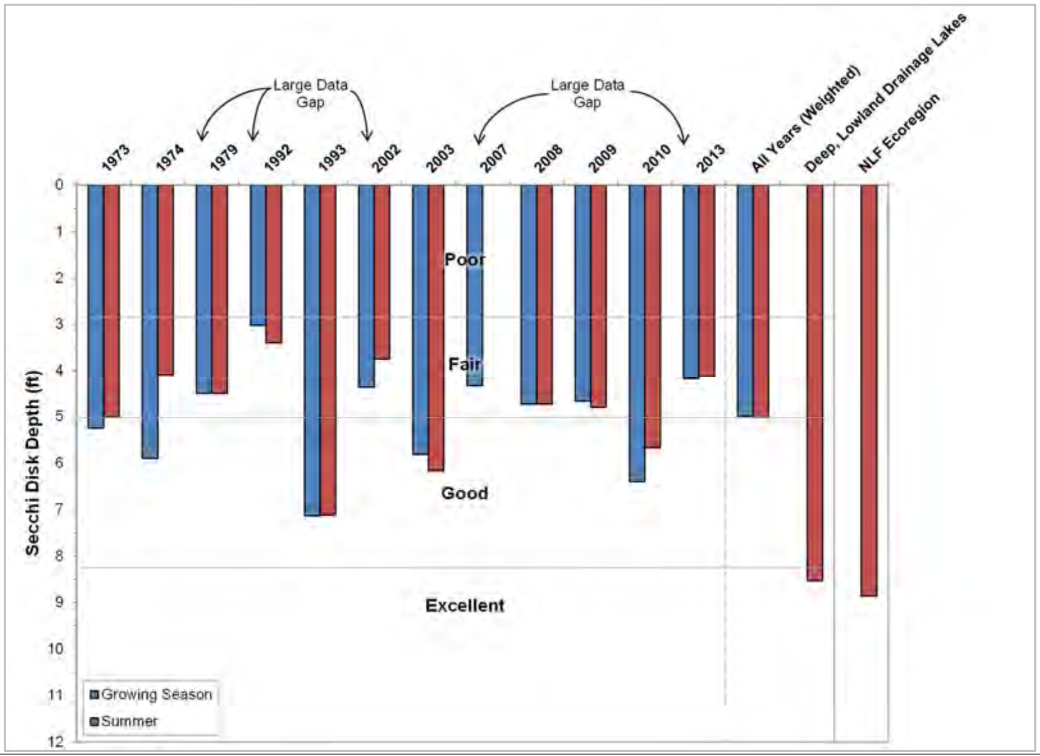


Figure 8.2.1-4. Catfish Lake, statewide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Catfish 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 Catfish Lake is in a eutrophic state.

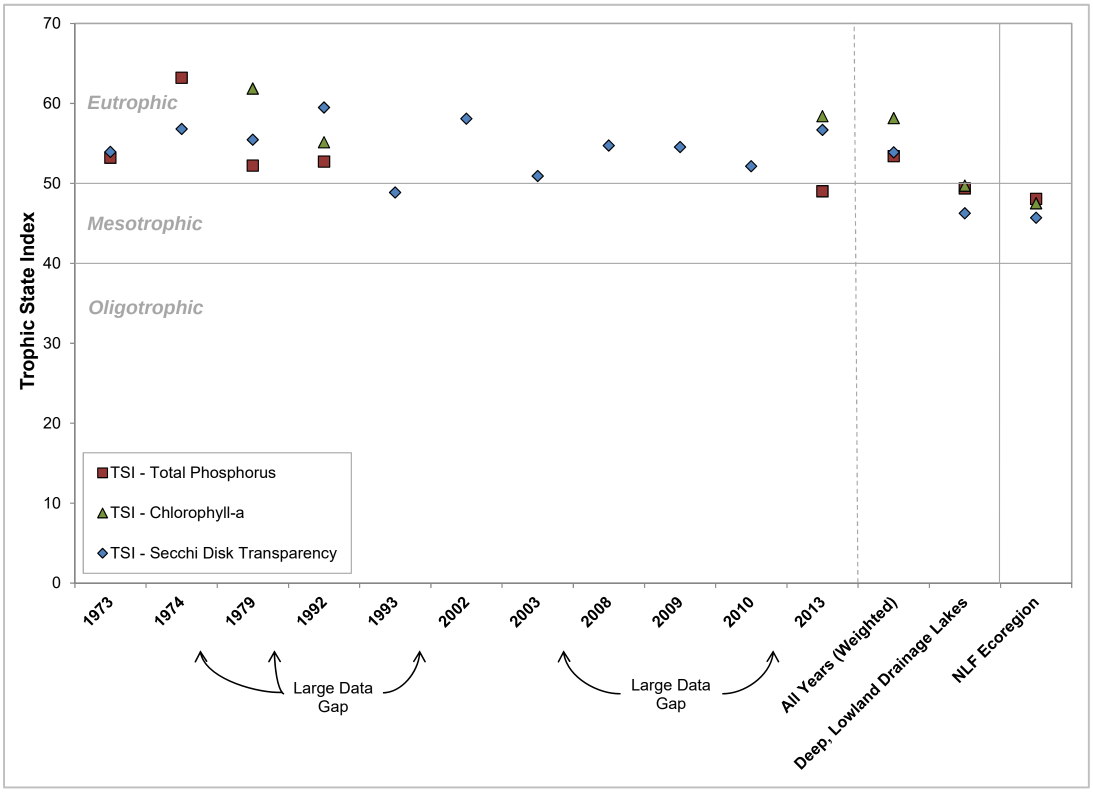


Figure 8.2.1-5. Catfish Lake, statewide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Catfish Lake

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

Catfish 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 2014, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

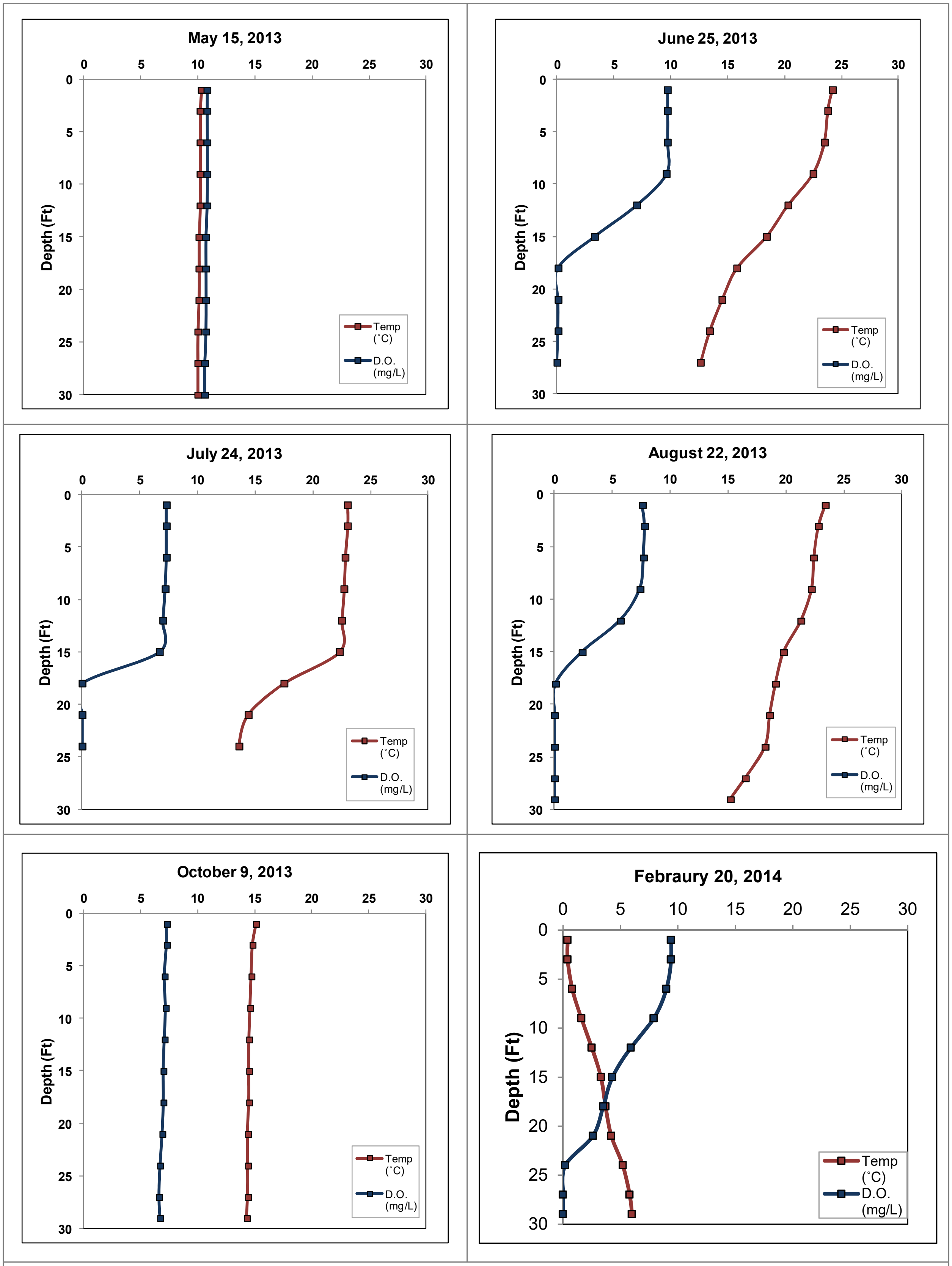


Figure 8.2.1-6. Catfish Lake 2013/2014 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Catfish 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 Catfish 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. Catfish Lake's surface water pH was measured at roughly 7.1 during May and 7.8 during July of 2013. These values are near or slightly above neutral and fall within the normal range for Wisconsin lakes. Fluctuations in pH with respect to seasonality is common; in-lake processes such as photosynthesis by plants act to reduce acidity by carbon dioxide removal while decomposition of organic matter add carbon dioxide to water, thereby increasing acidity.

A lake's pH is primarily determined by the amount of alkalinity that is held within the water. Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. Lakes with low alkalinity have higher amounts of the bicarbonate compound (HCO_3^-) while lakes with a higher alkalinity have more of the carbonate compound of alkalinity ($CO_3^=$). The carbonate form is better at buffering acidity, so lakes with higher alkalinity are less sensitive to acid rain than those with lower alkalinity. The alkalinity in Catfish Lake was measured at 30 and 32 mg/L as $CaCO_3$ in May and July of 2013. 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 Catfish Lake during 2013. Calcium is commonly examined because invasive and native mussels use the element for shell building and in reproduction. Invasive mussels typically require higher calcium concentrations than native mussels. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Catfish Lake's pH of 7.1 – 7.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Catfish Lake was found to be 7.52 mg/L in June and 8.74 mg/L in August of 2013, which is below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2013 and these samples were processed by the WDNR for larval zebra mussels. Their results were negative for the presence of zebra mussel veligers.

True color is a measure of water clarity once suspended material (i.e. algae, sediments) has been removed is called true color. True color measures the amount of light scattered and absorbed by organic materials dissolved within the water. Many lakes in the northern region of Wisconsin have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These give the water a tea-like color and decrease water clarity. Catfish Lake had an average true color value of 30.0 SU (standard units), indicating the water is most often lightly tea-colored. Lakes with large areas of forests and wetlands within their watersheds tend to have tea-colored or stained water, as these dissolved organic materials within the lake's water originate from decaying vegetation within the watershed.

8.2.2 Catfish Lake Watershed Assessment

Catfish Lake's watershed is approximately 99,991 acres in size. Compared to its surface area of 977 acres, this makes for a large watershed to lake area ratio of 101:1.

Exact land cover calculation and modeling of nutrient input to Catfish Lake will be completed towards the end of this project (in 2016-2017). 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 Catfish 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 2013, Catfish Lake's immediate shoreline was assessed in terms of its development. Catfish Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.6 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.1.3-1). This constitutes about 23% of Catfish 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, 4.7 miles of urbanized and developed–unnatural shoreline (60%) was observed. If restoration of the Catfish 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. Catfish Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

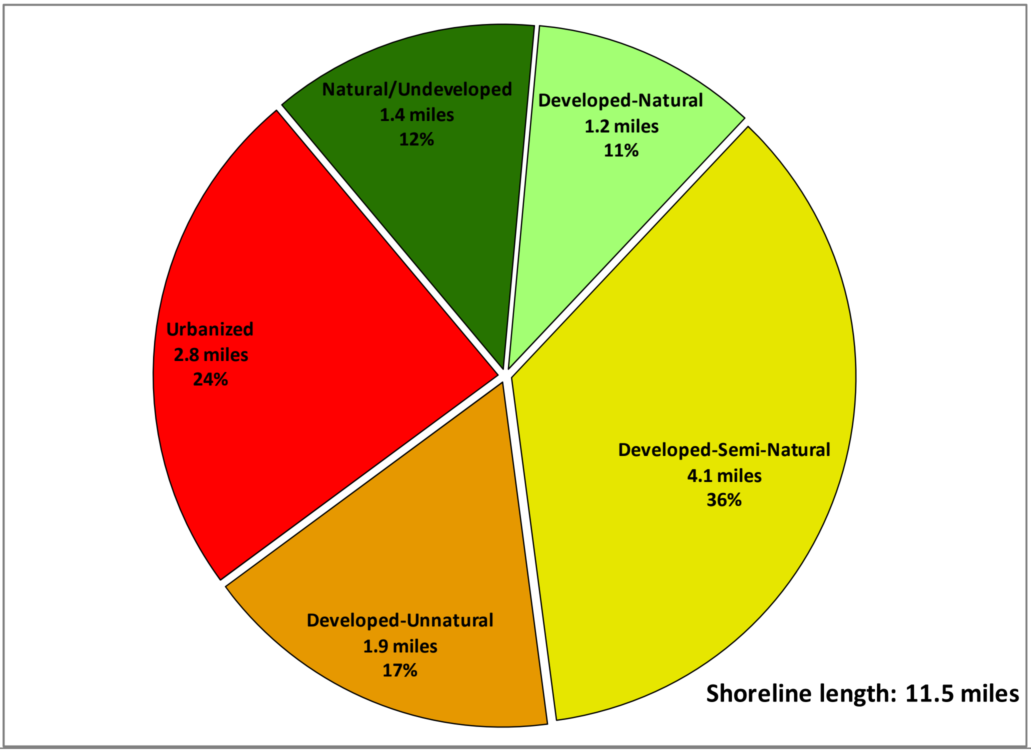


Figure 8.2.3-1. Catfish Lake shoreland categories and total lengths. Based upon a late summer 2013 survey. Locations of these categorized shorelands can be found on Catfish Lake – Map 1.

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 Eagle River 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, 196 total pieces of coarse woody habitat were observed along 11.5 miles of shoreline, which gives Catfish Lake a coarse woody habitat to shoreline mile ratio of 17:1 (Figure 8.1.3-2). Locations of coarse woody habitat are displayed on Catfish 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).

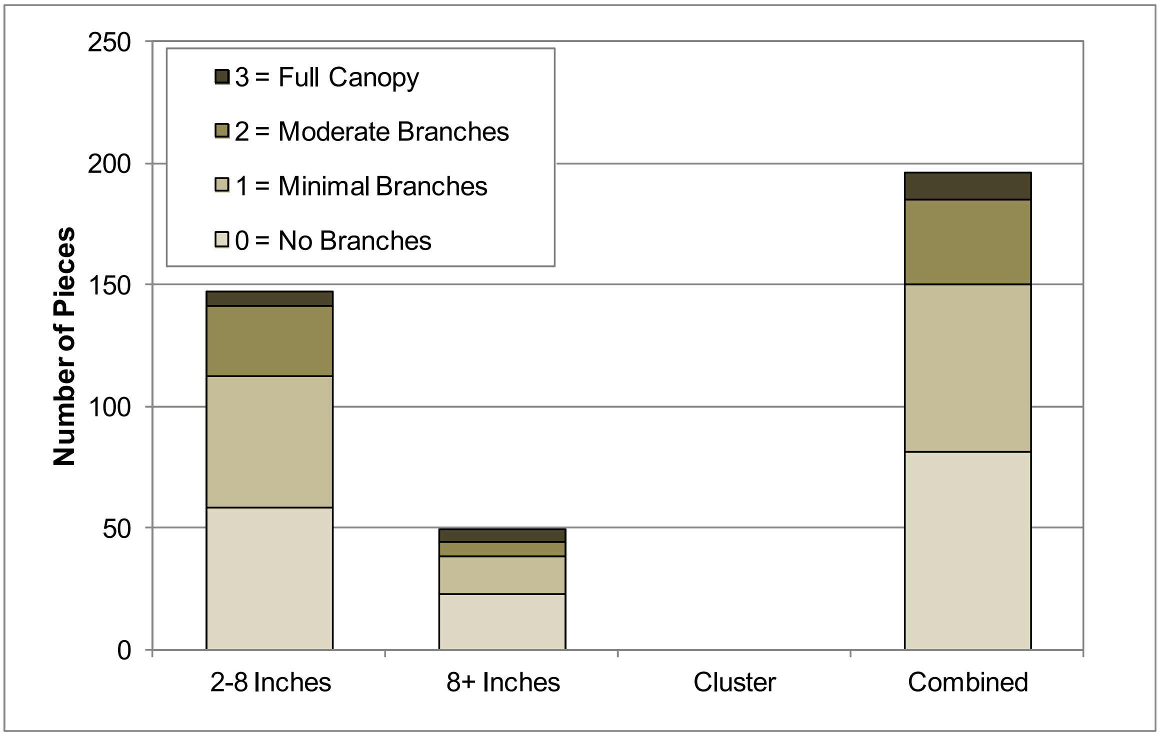


Figure 8.2.3-2. Catfish Lake coarse woody habitat survey results. Based upon a late summer 2013 survey. Locations of Catfish Lake coarse woody habitat can be found on Catfish Lake – Map 2.

8.2.4 Catfish Lake Aquatic Vegetation

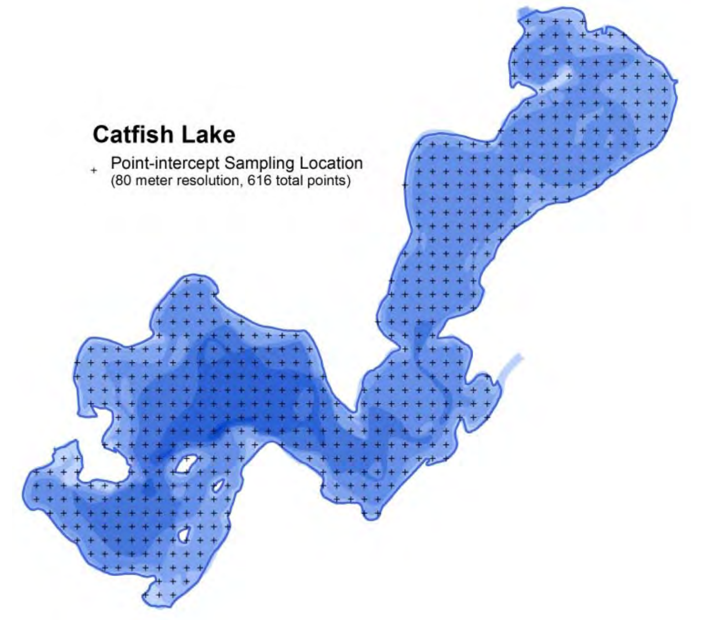


Figure 8.2.4-1. Point-intercept locations on Catfish Lake.

An early season aquatic invasive species survey was conducted on Catfish Lake on July 11, 2013. 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.

The whole-lake aquatic plant point-intercept survey was conducted on Catfish Lake by Onterra on July 31 and August 1, 2012 (Figure 8.2.4-1), while the aquatic plant community mapping survey was conducted on August 14 and 15, 2013. During these surveys, a total of 30 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian watermilfoil (Table 4.2-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 48% of the point-intercept locations within littoral areas contained sand, 46% contained fine, organic sediments (muck), and 6% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 14 feet, similar to 15 feet observed in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.2.4-1. Aquatic plant species located in Catfish Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2013 (Onterra)
E	*Carex utriculata*	Common yellow lake sedge	7		I
	Equisetum fluviatile	Water horsetail	7		I
	Iris pseudacorus	Pale-yellow iris	Exotic		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Pontederia cordata	Pickerelweed	9		I
	Sagittaria rigida	Stiff arrowhead	8		I
	Schoenoplectus acutus	Hardstem bulrush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	X
	Typha spp.	Cattail spp.	1		I
FL	*Brasenia schreberi*	Watershield	7		I
	Nuphar variegata	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6		X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		X
	Sparganium eurycarpum	Common bur-reed	5		I
	Sparganium fluctuans	Floating-leaf bur-reed	10		I
	Sparganium sp.	Bur-reed sp.	N/A	X	
Submergent	*Bidens beckii*	Water marigold	8	X	I
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		X
	Isoetes spp.	Quillwort species	8	X	X
	Lobelia dortmanna	Water lobelia	10	X	
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton praelongus	White-stem pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	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
	Sagitaria sp. (rosette)	Arrowhead rosette	N/A		X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	5		X
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

E = Emergent, 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*

Of the 407 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 35% contained aquatic vegetation. This is the same frequency that was recorded during the 2006 survey. Catfish Lake – Map 3 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore throughout the lake. Fifteen percent of the point-intercept locations had a total rake fullness rating of 1, 13% had a total rake fullness rating of 2, and 13% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.2.4-1 displays the aquatic plant species located in Catfish Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except water lobelia, were recorded in 2012. Water lobelia is a small, inconspicuous species that was only located at one sampling location in 2006; it is not believed to have disappeared from the lake, but rather exists at a low occurrence and was not detected in 2012. An additional 10 native aquatic plant species were located in 2012 that had not been recorded in 2006 (Table 8.2.4-1).

Of the 28 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, wild celery, small pondweed, and spiral-fruited pondweed were the four-most frequently encountered (Figure 8.2.4-2). Slender naiad, the most abundant aquatic plant in Catfish Lake in 2012 with a littoral occurrence of nearly 27%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad’s small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Small pondweed was the third-most abundant aquatic plant encountered in Catfish Lake in 2012, with a littoral occurrence of approximately 17%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Catfish Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms. Unlike two other narrow-leaved pondweed species located in Catfish Lake, spiral-fruited and Vasey’s pondweeds, small pondweed does not produce floating-leaves.

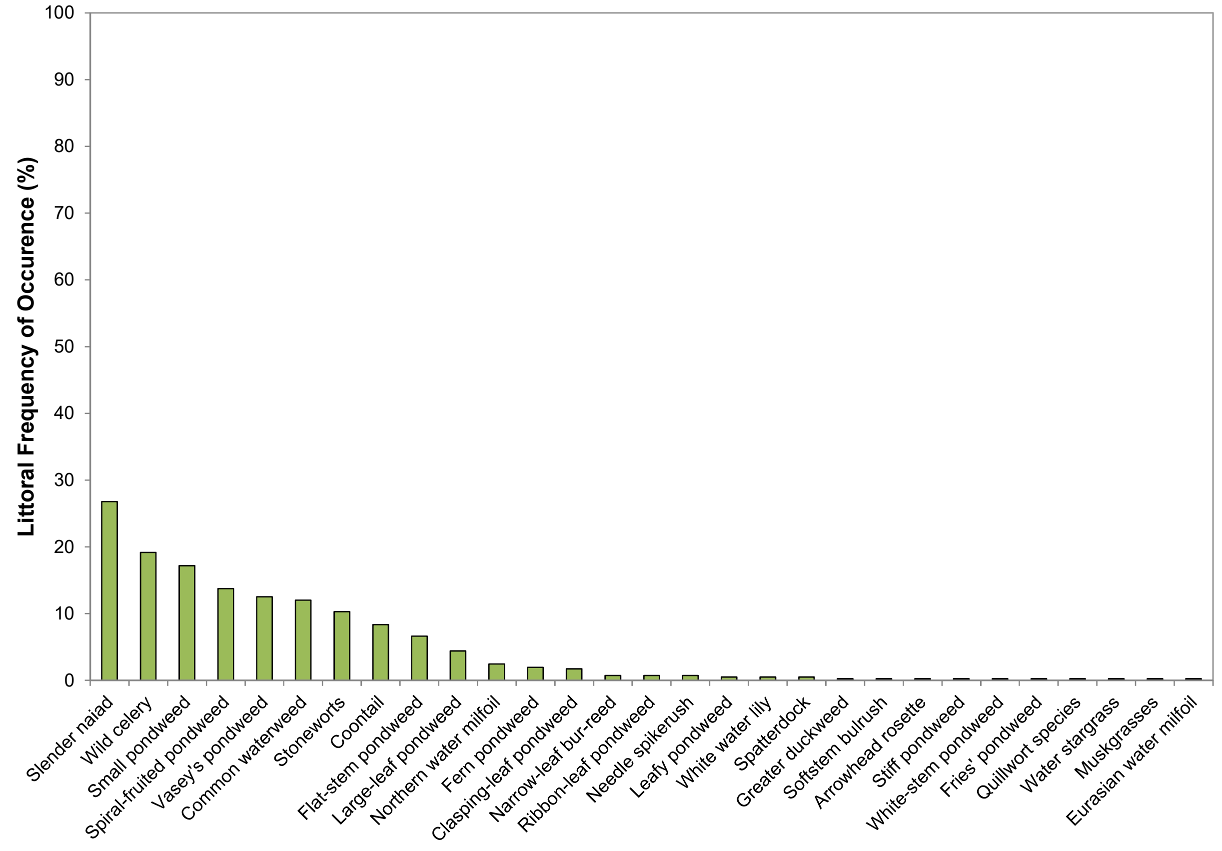


Figure 8.2.4-2. Catfish Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Spiral-fruited pondweed was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 17%. As its name indicates, produces fruit with a distinct coiled embryo and like small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Spiral-fruited pondweed is a provider of food and habitat for wildlife.

Vasey's pondweed was the fifth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like spiral-fruited pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer than spiral-fruited pondweed. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Catfish Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian watermilfoil control project on Catfish Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.2.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5%

in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Catfish Lake.

As illustrated, the occurrence of Eurasian watermilfoil in Catfish Lake was reduced by a statistically valid 91%, from an occurrence of 2.6% in 2006 to 0.2% in 2012. Three native aquatic plant species, northern watermilfoil, small pondweed, and large-leaf pondweed exhibited statistically valid reductions in their occurrence from 2006 to 2012. Like Eurasian watermilfoil, northern watermilfoil is a dicot and is sensitive to the 2,4-D applications that have occurred on Catfish Lake. Unlike Eurasian watermilfoil, small pondweed and large-leaf pondweed are monocots, and were historically not thought to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research conducted by the WDNR and US Army Corps of Engineers (USACE) is indicating that some of these species may be prone to decline following these types of treatments. It is possible that the declines observed in the small pondweed and large-leaf pondweed populations in Catfish Lake are a result of the Eurasian watermilfoil spatially targeted spot-treatments that have been occurring since 2008. Four native aquatic plant species displayed statistically valid increases in their occurrence from 2006 to 2012, some of them very large gains like slender naiad and spiral-fruited pondweed. The occurrences of the remaining four native aquatic plant species, including one dicot (coontail), were not statistically different from 2006 to 2012.

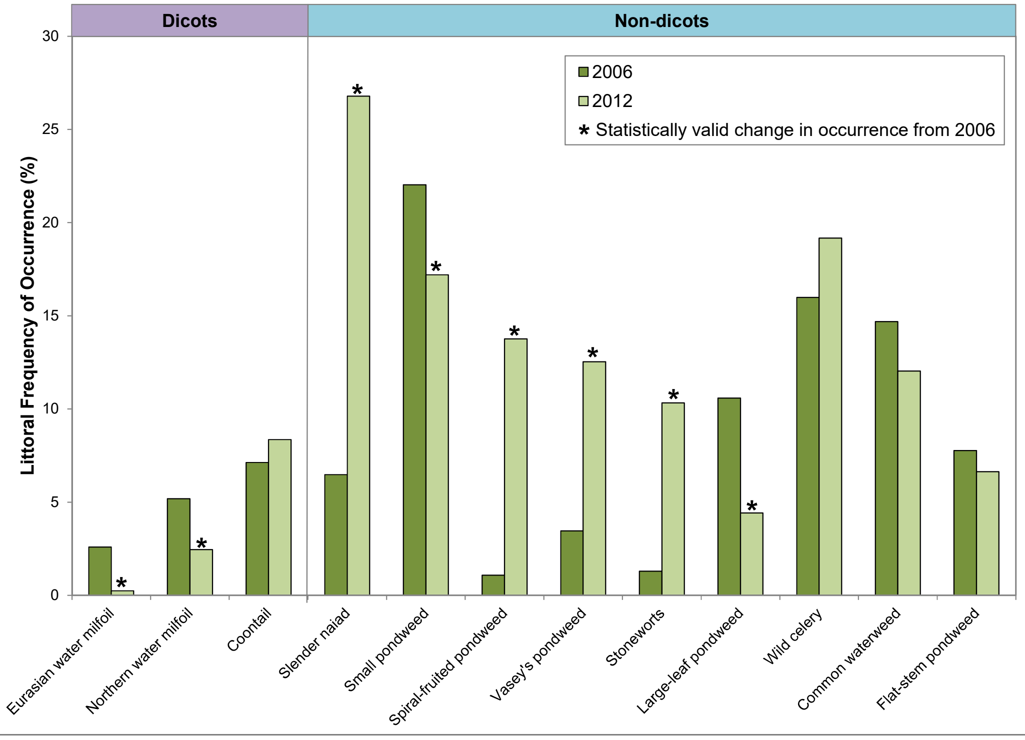


Figure 8.2.4-3. Catfish Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total 30 native aquatic plant species were located in Catfish Lake during the 2012 survey, 28 were encountered on the rake and two were incidentally located. These 28 native species and their conservatism values were used to calculate the FQI of Catfish Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.2.4-4 compares the FQI components of Catfish Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Catfish Lake's native species richness (28) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.6) is slightly lower than the ecoregional median but above the state median. Combining Catfish Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 34.7, which greatly exceeds the ecoregional and state median values (Figure 8.2.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Catfish Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Catfish Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

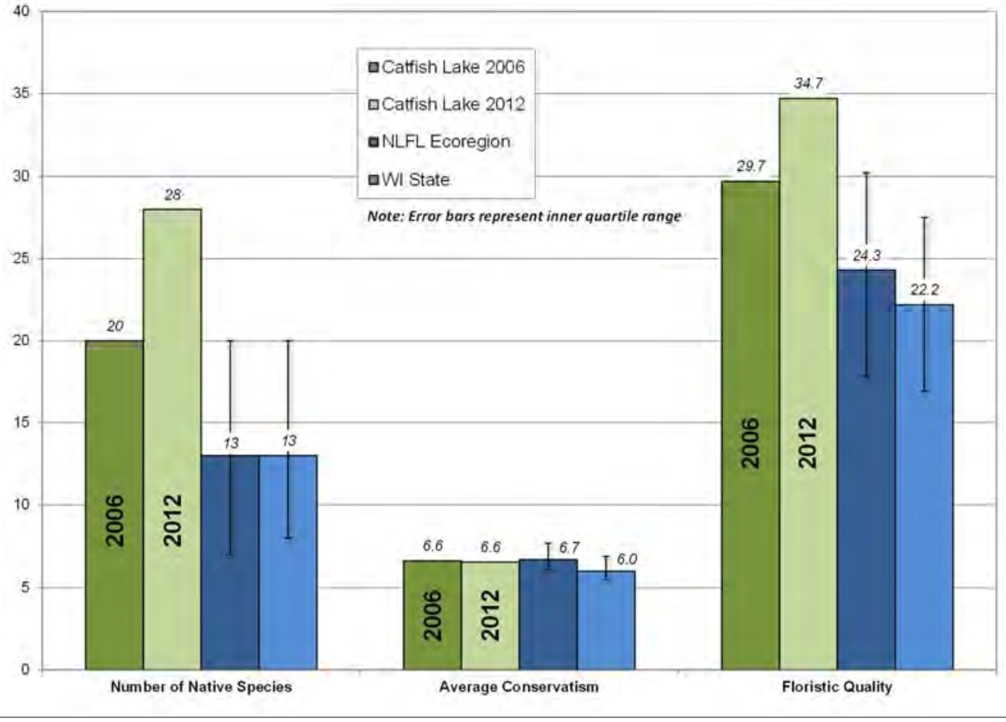


Figure 8.2.4-4. Catfish Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants.

In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Catfish Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Catfish Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.2.4-5). Using the data collected form the 2012 point-intercept survey, Catfish Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.90, falling above the upper quartile value for lakes in both the ecoregion and the state. Catfish Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.89).

Figure 8.2.4-6 displays the relative frequency of occurrence of aquatic plant species in Catfish Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

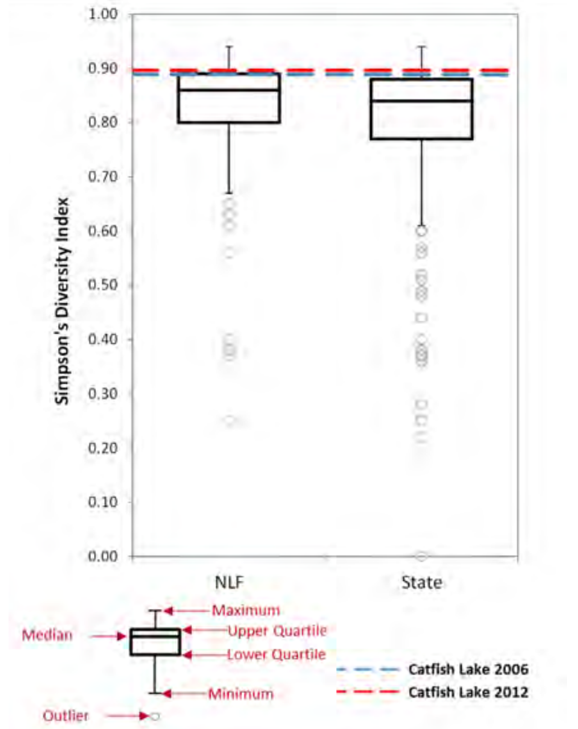


Figure 8.2.4-5. Catfish Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

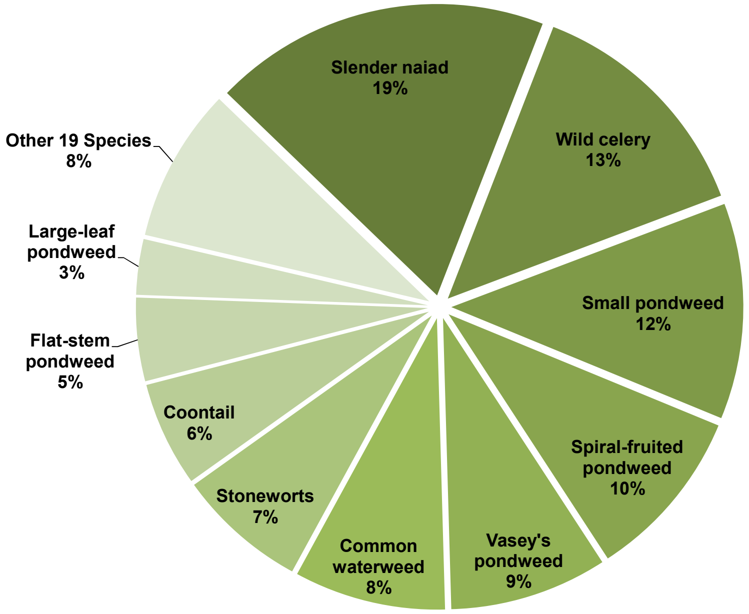


Figure 8.2.4-6. Catfish Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Overall, the 2012 point-intercept survey on Catfish Lake indicated that the Eurasian watermilfoil control project may have had an adverse impact to populations of small pondweed and large-leaf pondweed, as indicated by statistically valid reductions in their occurrence from the 2006 to 2012 surveys. However, Catfish Lake still contains healthy populations of these two species, and four other native species saw large, statistically valid increases in their occurrence. In addition, average conservatism remained the same from 2006 to 2012, while native species richness, Floristic Quality, and species diversity increased, indicating there were no significant impacts to the overall quality of Catfish Lake’s aquatic plant community.

The 2013 aquatic plant community mapping survey revealed that Catfish Lake contains approximately 27.0 acres of emergent and floating-leaf aquatic plant communities (Table 8.2.4-2, Catfish Lake – Map 4). Twenty-six emergent and floating-leaf aquatic plant species were located in the lake in 2012 (Table 8.2.4-1). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a ‘snapshot’ of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Catfish Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.2.4-2. Acres of emergent and floating-leaf aquatic plant communities in Catfish Lake. Created using data from 2013 aquatic plant community mapping survey.

Plant Community	2013 Acres
Emergent	0.0
Floating-Leaf	7.5
Mixed Emergent & Floating-Leaf	19.5
Total	**27.0**

8.2.4 Catfish Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Catfish Lake's Implementation Plan illustrates how Catfish Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Catfish Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Catfish Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Jeff Boville and John Lansing, current Catfish Lake CLMN volunteers
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Catfish Lake have been collecting water quality data intermittently since 1992. Catfish Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Catfish Lake currently has active volunteers (Jeff Boville and John Lansing) who collect and enter water quality data into the WDNR's SWIMS database on an annual basis. Catfish Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Jeff Boville and John Lansing, the current CLMN volunteers, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. Jeff Boville and/or John Lansing, current CLMN volunteers, continue to collect water quality data and enter data into WDNR SWIMS database.
2. Jeff Boville and/or John Lansing, current CLMN volunteer, notify Dave Mueller or current Lakes and Shores Committee chair when a new Catfish Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action:	Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.
Description:	As part of the planning project, the entire shoreline of Catfish Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 41% (4.7 miles) of the shoreline are in an urbanized or developed-unnatural state, 36% (4.1 miles) is in a developed-semi-natural state, and 23% (2.6 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA’s Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 41% of Catfish Lake’s shoreline is in a highly-developed state, approximately 23% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake’s overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Catfish Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain’s shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Catfish Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Catfish Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Catfish Lake shoreland assessment, approximately 17 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Catfish Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action:	Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.
Description:	Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Catfish Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Catfish Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA. Catfish Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Catfish Lake Association and ERCLA meetings. Catfish Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Catfish Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Catfish Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action:	ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.
Description:	Catfish Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Catfish Lake and its stakeholders.

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

8.3 Voyageur Lake

An Introduction to Voyageur Lake

Voyageur Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 13 feet, a mean depth of 6.5 feet, and a surface area of approximately 143 acres. The lake is fed via the Eagle River from upstream Catfish Lake and drains into downstream Eagle Lake, and has a surficial watershed that encompasses approximately 102,751 acres. In a study conducted by Onterra in 2012, 22 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. Two non-native plants, Eurasian watermilfoil and purple loosestrife, were recorded within the lake.

Field Survey Notes

Like many of the lakes within the Eagle River Chain, Voyageur Lake contains stained water which restricts aquatic plant growth to the shallower fringes of the lake. For its relatively small size, Voyageur Lake contains a relatively high number of aquatic plant species. The lake contains a large floating-leaf/emergent plant wetland along its northeast side which is comprised of white water lily, pickerelweed, and many other beneficial native plants.

Photo 8.3 Voyageur Lake, Vilas County

Lake at a Glance* – Voyageur Lake

Morphology	
Acreage	143
Maximum Depth (ft)	13
Mean Depth (ft)	6.5
Volume (acre-feet)	923
Shoreline Complexity	9.9
Vegetation	
Curly-leaf Survey Date	July 8, 2014
Comprehensive Survey Date	August 1, 2012
Number of Native Species	22
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil; Purple loosestrife
Simpson's Diversity	0.92
Average Conservatism	6.8
Water Quality	
Wisconsin Lake Classification	Shallow (Mixed), Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	738:1

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

8.3.1 Voyageur Lake Water Quality

Water quality data was collected from Voyageur Lake on six occasions in 2014/2015. 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 2014/2015, any historical data was researched and are included within this report as available.

Unfortunately, somewhat limited data exists for three water quality parameters of interest – total phosphorus, chlorophyll-*a*, and Secchi disk depths. In 2014, average summer phosphorus concentrations (30.4 µg/L) were less than the median value (33.0 µg/L) for other shallow, lowland drainage lakes in the state. The value is a little more than the median value (21.0 µg/L) for all lakes within the Northern Lakes and Forests ecoregion. A weighted value from all available data ranks as *good* to *excellent* for a shallow, lowland drainage lake.

Near-surface total phosphorus concentrations from 2014 are compared with near-bottom total phosphorus concentrations collected during this same time frame in Figure 8.3.1-1. As displayed in this figure, on all occasions surface and bottom total phosphorus concentrations were similar. Voyageur Lake is relatively shallow and oxygenated water near the surface is able to be mixed down throughout the water column. This indicates that internal nutrient loading from bottom sediments in Voyageur Lake is not a concern.

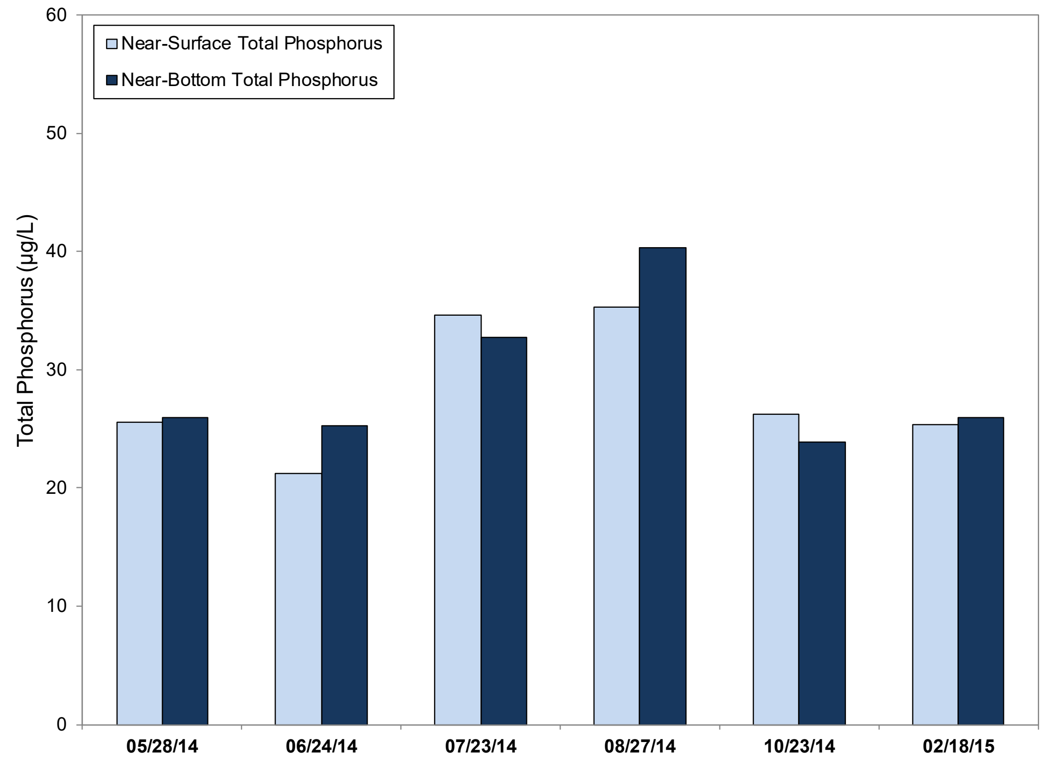


Figure 8.3.1-1. Voyageur Lake growing season 2014 and winter 2015 near-surface and near-bottom total phosphorus concentrations.

Growing season and summer chlorophyll-*a* concentrations fell within the *good* category for shallow, lowland drainage lakes in Wisconsin, with values of 12.4 µg/L and 15.7 µg/L, respectively. The summer value was slightly higher than the median value for shallow, lowland drainage lakes statewide (9.4 µg/L) and the median value for all lake types within the Northern Lakes and Forests ecoregion (5.6 µg/L). Historical chlorophyll-*a* data prior to 2014 are not available for Voyageur Lake.

Secchi disk transparency data are available from Voyageur Lake from 1993-1997 and 2014 (Figure 8.3.1-2). Over the time period for which data are available, average summer Secchi disk transparency has ranged from the *good* to *excellent* categories for shallow, lowland drainage lakes. Secchi disk transparency in 1993-1995 and 2014 fall in line with clarity values in upstream Catfish Lake and downstream Eagle Lake. However, clarity values from 1996 and 1997 are significantly higher than the other years for which data are available. No other lakes within the chain, including downstream Eagle Lake, exhibited detectable increases in water clarity in 1996 and 1997. Given the stained nature of the water within the lakes, the validity of these higher water clarity values in Voyageur Lake in 1996 and 1997 are suspect. Unfortunately, no chlorophyll-*a* or total phosphorus data are available from these years. If the data from 1996 and 1997 are removed, the weighted average summer Secchi disk transparency value for Voyageur Lake falls within the *good* category and is comparable to the median value for other shallow, lowland drainage lakes in Wisconsin.

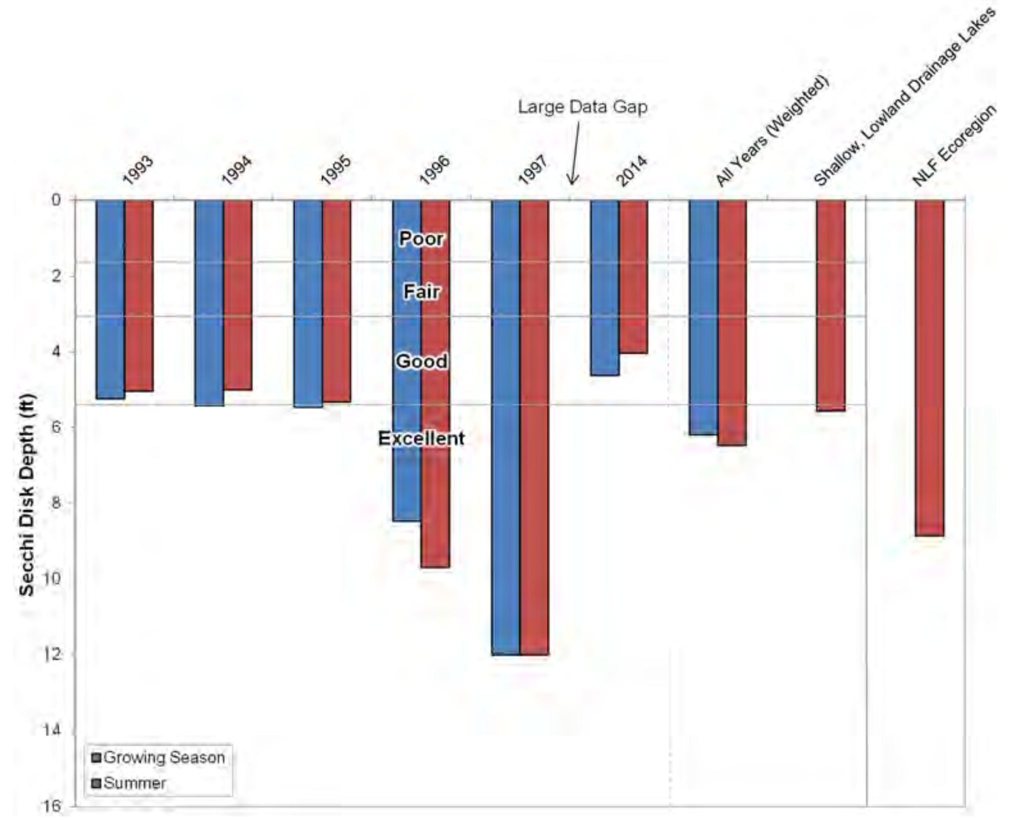


Figure 8.3.1-2. Voyageur Lake average annual Secchi disk transparency and median values for statewide shallow, lowland drainage lakes and Northern Lakes and Forests (NLF) ecoregion lakes. Water quality index values adapted from WDNR PUB WT-913.

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 Voyageur Lake as well as the other lakes in the Eagle River Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Voyageur Lake contain naturally occurring organic acids that are washed into the lake from wetlands and forests within the watershed. 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 May and July of 2014 were measured for this parameter, and were found to be 40 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. This value indicates that Voyageur Lake's water has a tea-colored appearance.

Voyageur 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 8.3.1-3). 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 Voyageur Lake is in a eutrophic state.

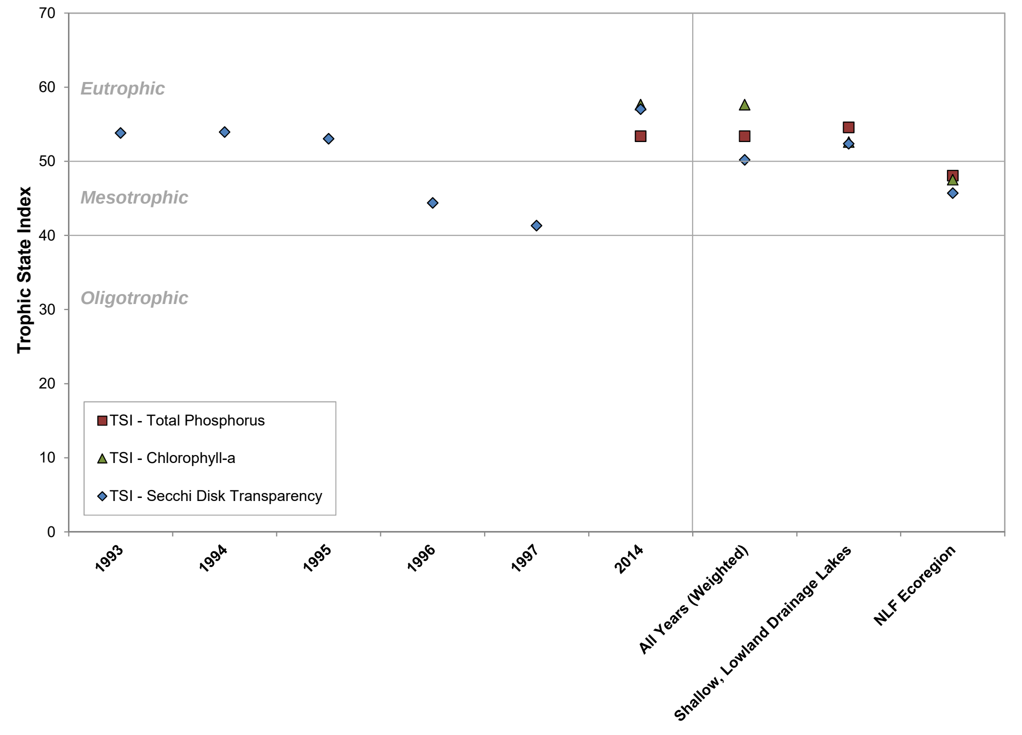


Figure 8.3.1-3. Voyageur Lake, statewide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Voyageur Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Voyageur Lake by Onterra staff. Graphs of those data are displayed in Figure 8.3.1-4 for all sampling events. Voyageur Lake is relatively shallow, and because of this, the lake does not strongly stratify during the summer months and the entire water column remains oxygenated. 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.

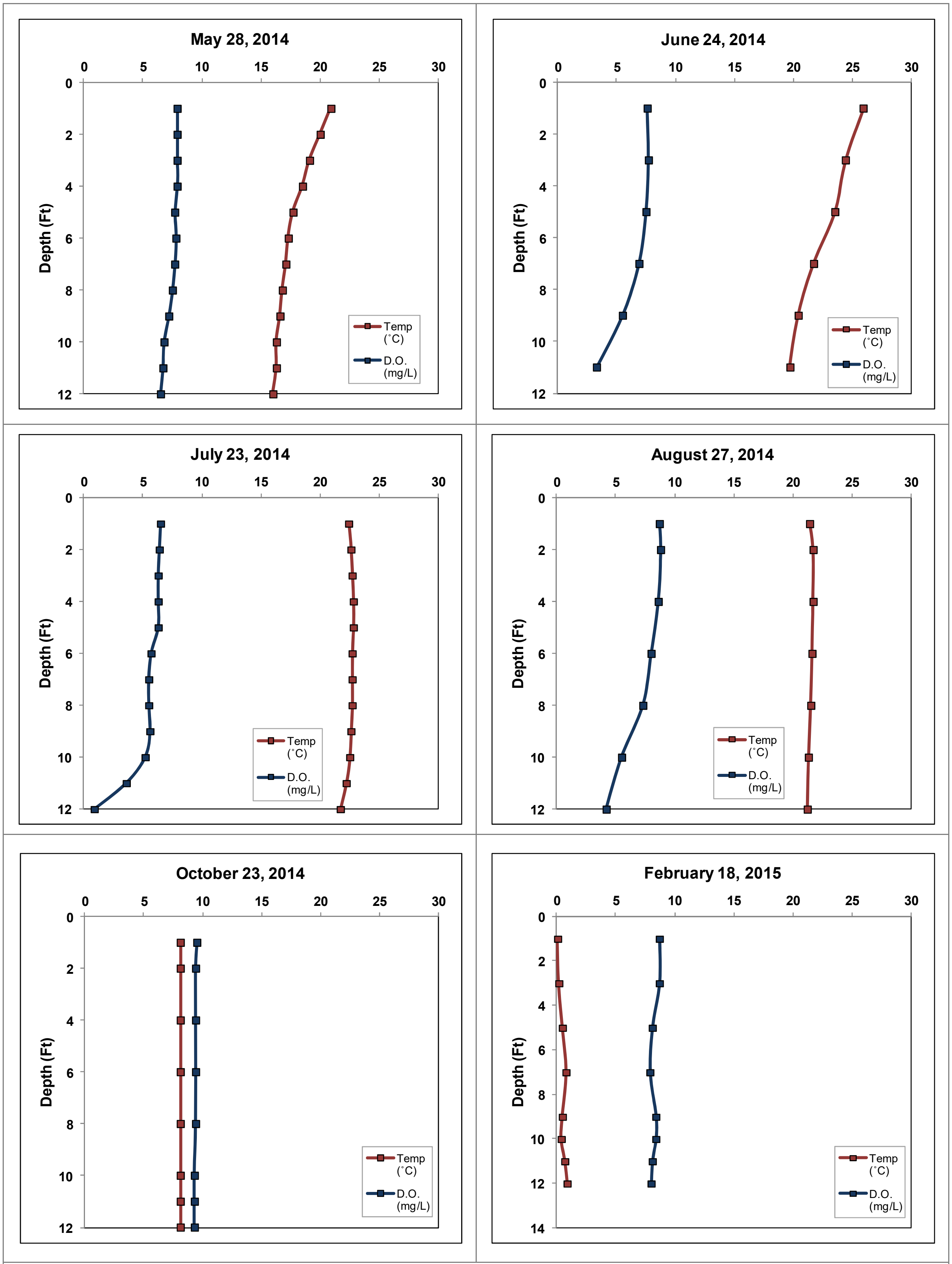


Figure 8.3.1-4. Voyageur Lake 2014/2015 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Voyageur 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 Voyageur 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. Voyageur Lake's surface water pH was measured at 7.3 in May and July of 2014. 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 Voyageur Lake was measured at 26.6 and 27.7 mg/L as $CaCO_3$ in May and July of 2014, 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 Voyageur Lake during 2014. 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 Voyageur Lake's pH of 7.3 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 Voyageur Lake was found to be 7.14 mg/L in May and 7.32 mg/L in July of 2014, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. Their results were negative for the presence of zebra mussel veligers.

8.3.2 Voyageur Lake Watershed Assessment

Voyageur Lake's watershed is approximately 102,751 acres in size. Compared to its surface area of 139 acres, this makes for a large watershed to lake area ratio of 738:1.

Exact land cover calculation and modeling of nutrient input to Voyageur Lake will be completed towards the end of this project (in 2017-2018). 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 Voyageur 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 2014, Voyageur Lake's immediate shoreline was assessed in terms of its development. Voyageur Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.7 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.3.3-1). This constitutes about 47% of Voyageur 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, 0.9 miles of urbanized and developed–unnatural shoreline (25%) was observed. If restoration of the Voyageur 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. Voyageur Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

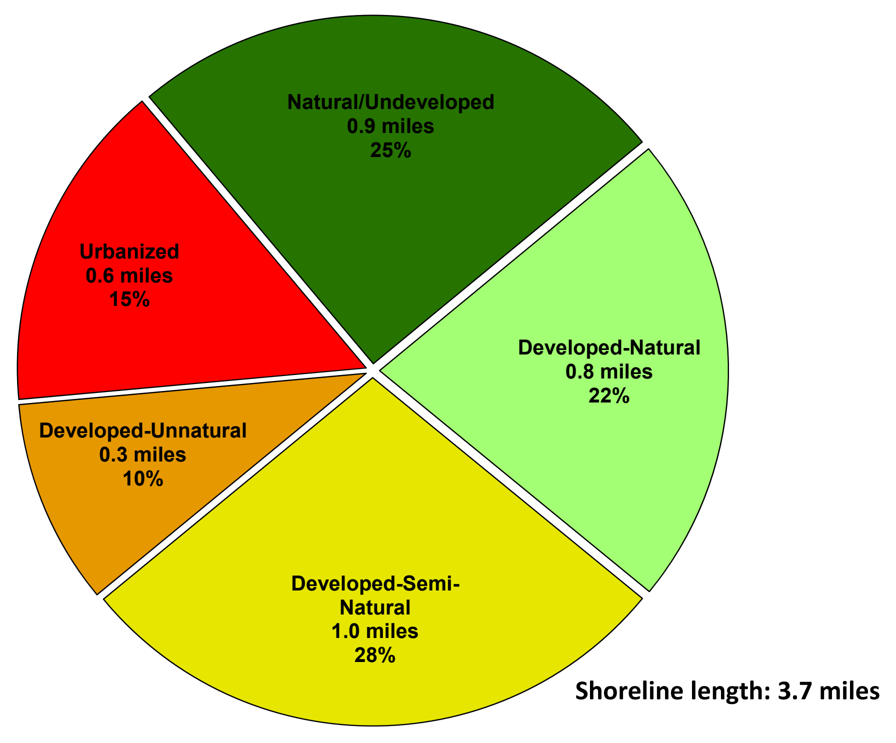


Figure 8.3.3-1. Voyageur Lake shoreland categories and total lengths. Based upon a late-summer 2014 survey. Locations of these categorized shorelands can be found on Voyageur Lake – Map 1.

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 Eagle River 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, 64 total pieces of coarse woody habitat were observed along 3.7 miles of shoreline, which gives Voyageur Lake a coarse woody habitat to shoreline mile ratio of 17:1 (Figure 8.3.3-2). Locations of coarse woody habitat are displayed on Voyageur 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).

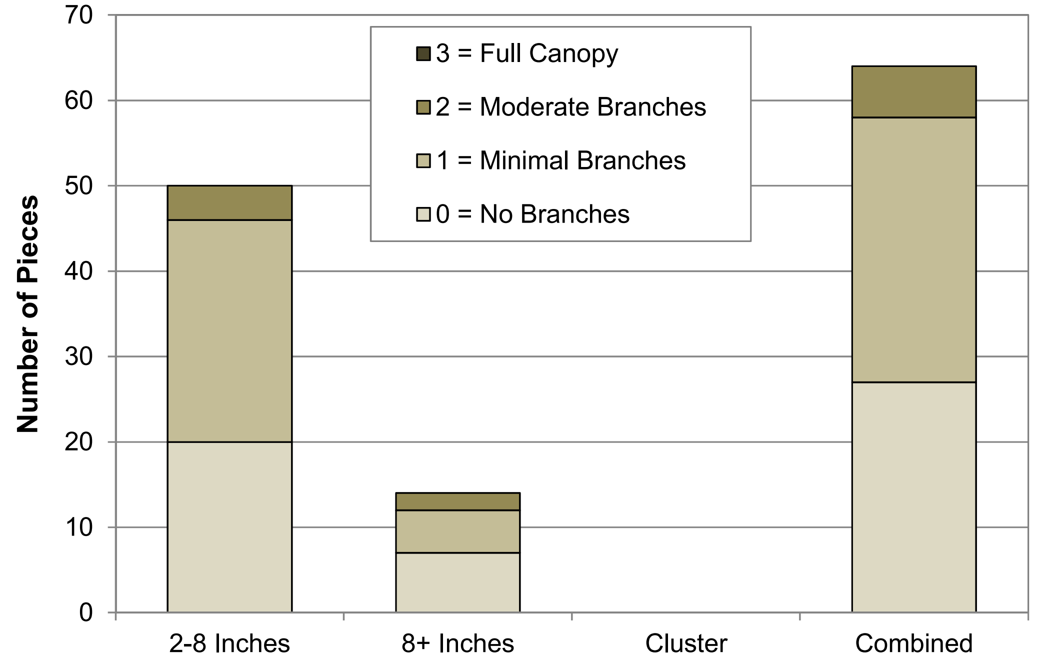


Figure 8.3.3-2. Voyageur Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of Voyageur Lake coarse woody habitat can be found on Voyageur Lake – Map 2.

8.3.4 Voyageur Lake Aquatic Vegetation

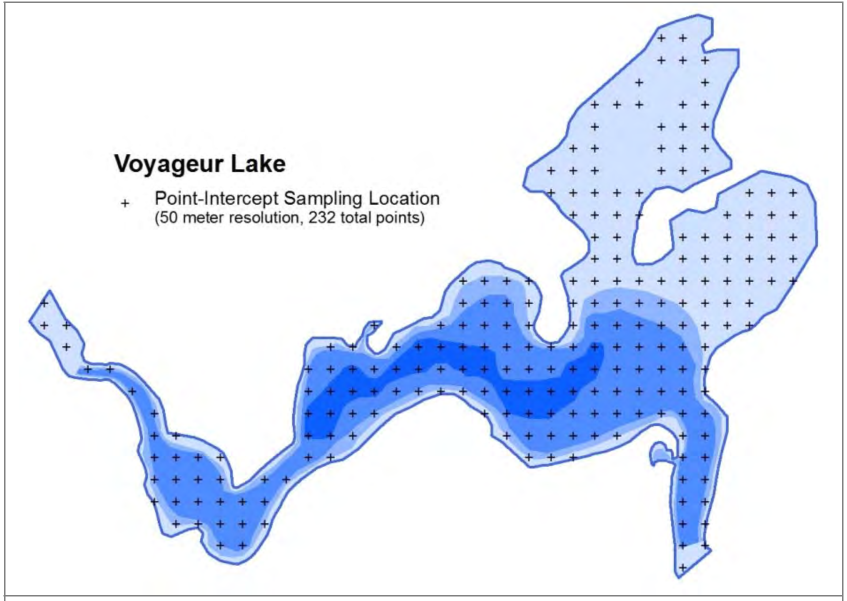


Figure 8.3.4-1. Point-intercept locations on Voyageur Lake.

An early season aquatic invasive species survey was conducted on Voyageur Lake on July 7, 2014. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate potential occurrences of 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 in Voyageur Lake.

The whole-lake aquatic plant point-intercept survey was conducted on Voyageur Lake by Onterra on July 31 and August 1, 2012 (Figure 8.2.4-1), while the aquatic plant community mapping survey was conducted on July 30, 2014. During these surveys, a total of 39 aquatic plant species were located, two of which are considered to be a non-native, invasive species: Eurasian watermilfoil and purple loosestrife (Table 8.3.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 44% of the point-intercept locations within littoral areas contained sand, 51% contained fine, organic sediments (muck), and 5% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 12 feet, similar to 11 feet observed in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.3.4-1. Aquatic plant species located in Voyageur Lake during 2006, 2012, and 2014 aquatic plant surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2014 (Onterra)
Emergent	*Calla palustris*	Water arum	9		I
	Carex utriculata	Common yellow lake sedge	7		I
	Juncus effusus	Soft rush	4		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Pontederia cordata	Pickerelweed	9	X	I
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	I
	Sparganium eurycarpum	Common bur-reed	5		I
	Typha spp.	Cattail spp.	1		I
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		X
	Sparganium sp.	Bur-reed sp.	N/A	X	
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7		X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Myriophyllum verticillatum	Whorled water milfoil	8	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7		X
	Potamogeton alpinus	Apline pondweed	9		I
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton natans	Floating-leaf pondweed	5	X	I
	Potamogeton praelongus	White-stem pondweed	8	X	
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton robbinsii	Fern pondweed	8	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
	Ranunculus aquatilis	White-water crowfoot	8	X	
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria sp. (rosette)*	Arrowhead sp. (rosette)	N/A	X	

FL = Floating Leaf; FL/E = Floating Leaf and Emergent; S/E = Submergent and Emergent
X = Located on rake during point-intercept survey; I = Incidentally located
** = Species listed as 'special concern' in Wisconsin*

Of the 152 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 61% contained aquatic vegetation. This is the similar frequency of occurrence that was recorded during the 2006 survey of 60%. Voyageur Lake – Map 3 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore throughout the lake. Twenty-two percent of the point-intercept locations had a total rake fullness rating of 1, 16% had a total rake fullness rating of 2, and 22% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.3.4-1 displays the aquatic plant species located in Voyageur Lake during the Onterra 2012 point-intercept survey. All of the species recorded in 2006, with the exception of white-stem pondweed and white-water crowfoot, were relocated again in 2012. An additional four aquatic plant species were located in 2012 that were not located in 2006.

Of the 23 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, flat-stem pondweed, slender naiad, and coontail were the four-most frequently encountered (Figure 8.3.4-2). Wild celery, the most abundant aquatic plant in Voyageur Lake in 2012 with a littoral occurrence of nearly 35%, has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Flat-stem pondweed was the second-most abundant aquatic plant encountered in Voyageur Lake in 2012, with a littoral occurrence of approximately 21%. As its name indicates, flat-stem pondweed possesses a compressed or flattened stem which bears long, narrow, linear leaves. Often forming denser colonies, flat-stem pondweed provides valuable structural habitat and its fruit provides food sources of aquatic organisms.

Slender naiad was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 21%. Slender naiad is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Coontail was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 18%. Coontail is a free-floating submersed species that obtains the majority of its nutrients directly from the water. It is arguably the most common aquatic plant in Wisconsin, able to grow in a wide variety of conditions. Coontail produces whorls of stiff leaves and has the capacity to grow in very dense colonies. Its leaves and dense network of branches provide excellent structural habitat for aquatic organisms, and the fact it obtains most of its nutrients directly from the water aids in reducing nutrients that would otherwise be available to free-floating algae.

Vasey's pondweed was the sixth-most frequently encountered aquatic plant species in 2012 in Voyageur Lake. As discussed in the Chain-Wide Section, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Vasey's pondweed is a narrow-leaf pondweed with very fine linear leaves. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Voyageur Lake is an indicator of a high-quality environment.

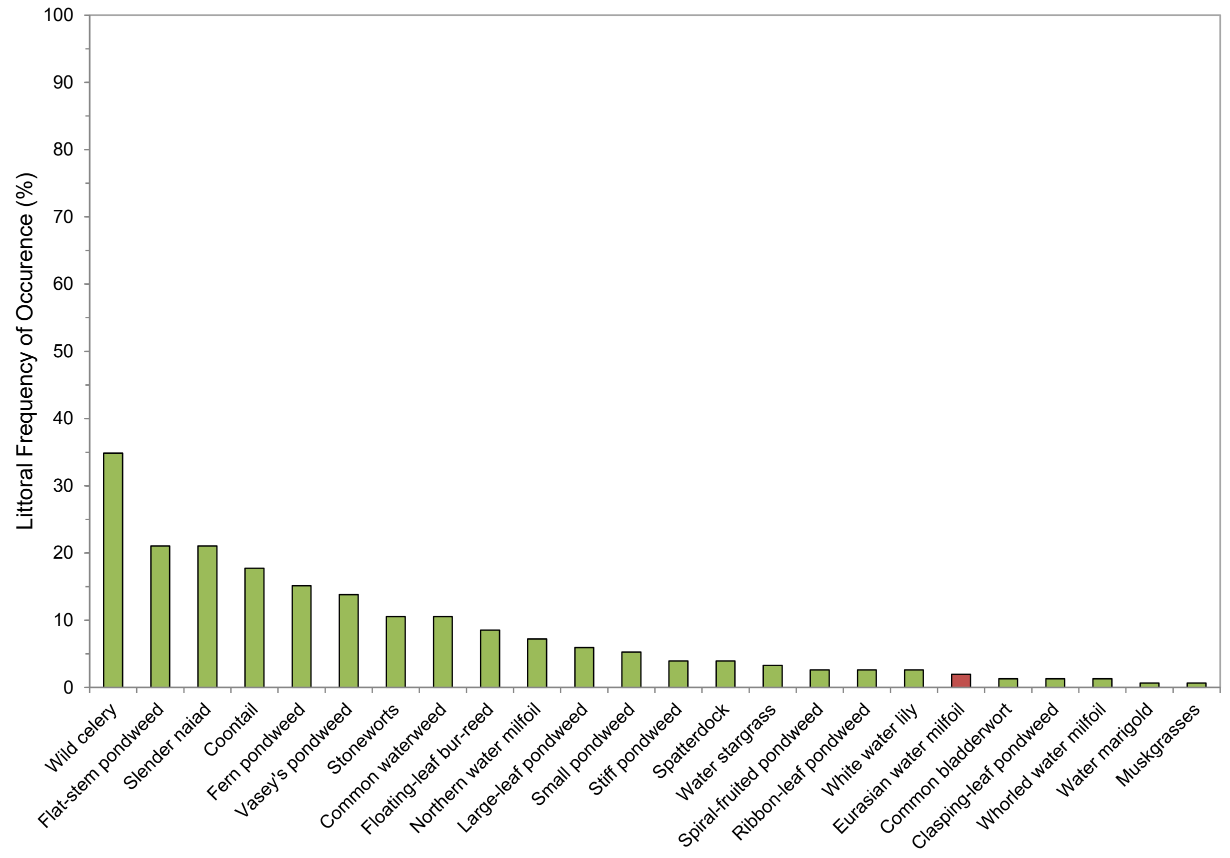


Figure 8.3.4-2. Voyageur Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

To determine if the 2008-2012 Eurasian watermilfoil control project on Voyageur Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.3.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Voyageur Lake.

As illustrated, the occurrence of Eurasian watermilfoil in Voyageur Lake was reduced by a statistically valid 77.4%, from an occurrence of 8.8% in 2006 to 2.0% in 2012. Three native aquatic plant species, spatterdock, whorled watermilfoil, and small pondweed exhibited statistically valid reductions in their occurrence between the 2006 and 2012 surveys. Like Eurasian watermilfoil, spatterdock and whorled watermilfoil are dicots and are sensitive to 2,4-D applications that have occurred in Voyageur Lake. However, unlike Eurasian watermilfoil, small pondweed is a monocot and was historically not thought to be susceptible to dicot-selective herbicides like 2,4-D. However, emerging research conducted by the WDNR and US Army Corps of Engineers (USACE) is indicating that some of these species, including small pondweed, may be prone to decline following these types of treatments. It is possible that the declines observed in these native aquatic plants in Voyageur Lake are a result of the Eurasian watermilfoil spatially targeted spot-treatments that have been occurring since 2008.

Four native aquatic plant species, wild celery, slender naiad, flat-stem pondweed, and stoneworts displayed statistically valid increases in their occurrence from 2006 to 2012. The occurrences of the other native aquatic plant species, including three dicots, were not statistically different from 2006 to 2012.

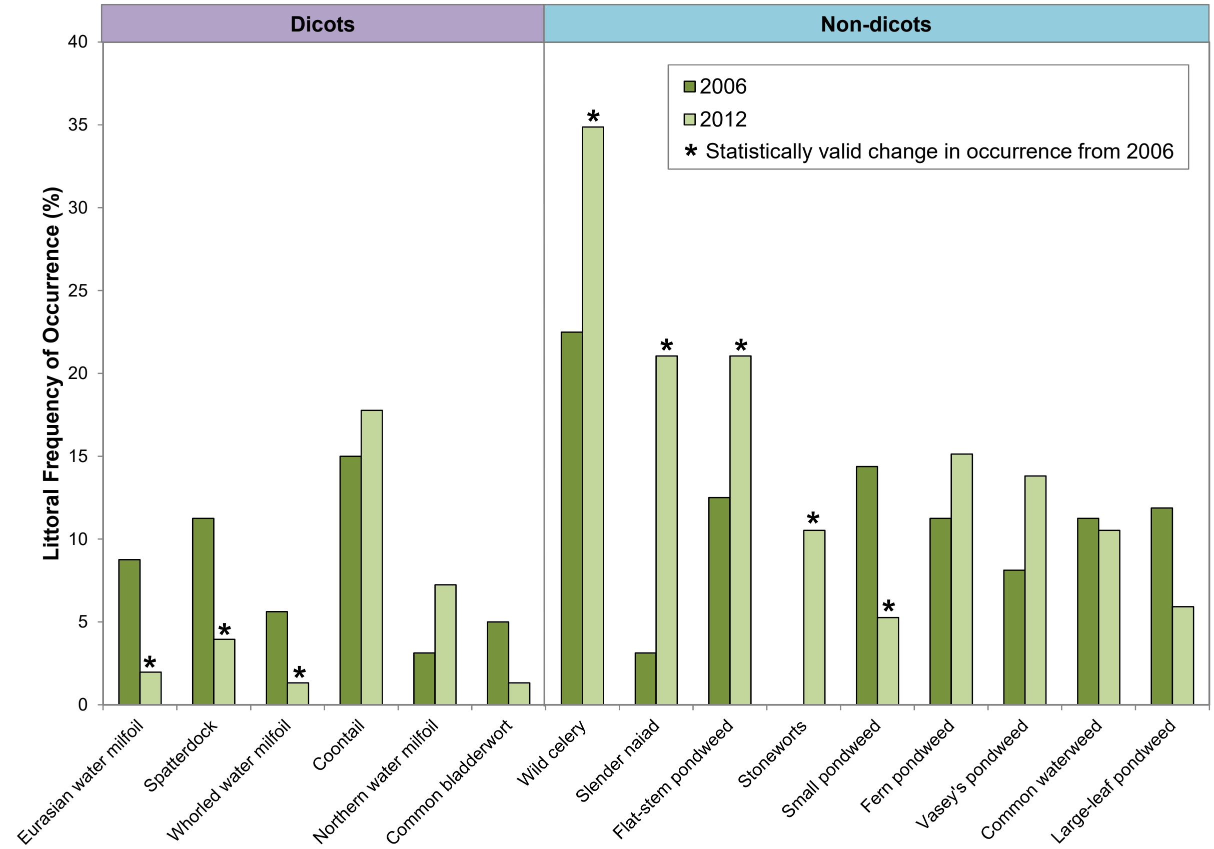


Figure 8.3.4-3. Voyageur Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total 37 native aquatic plant species were located in Voyageur Lake during the 2012 and 2014 surveys, 23 were encountered on the rake during the 2012 point-intercept survey. These 23 native species and their conservatism values were used to calculate the FQI of Voyageur Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.3.4-4 compares the FQI components of Voyageur Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Voyageur Lake's native species richness (23) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.8) is higher than both the median values for lakes in the ecoregion and the state. Combining Voyageur Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 32.7, which greatly exceeds the ecoregional and state median values (Figure 8.3.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Voyageur Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Voyageur Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

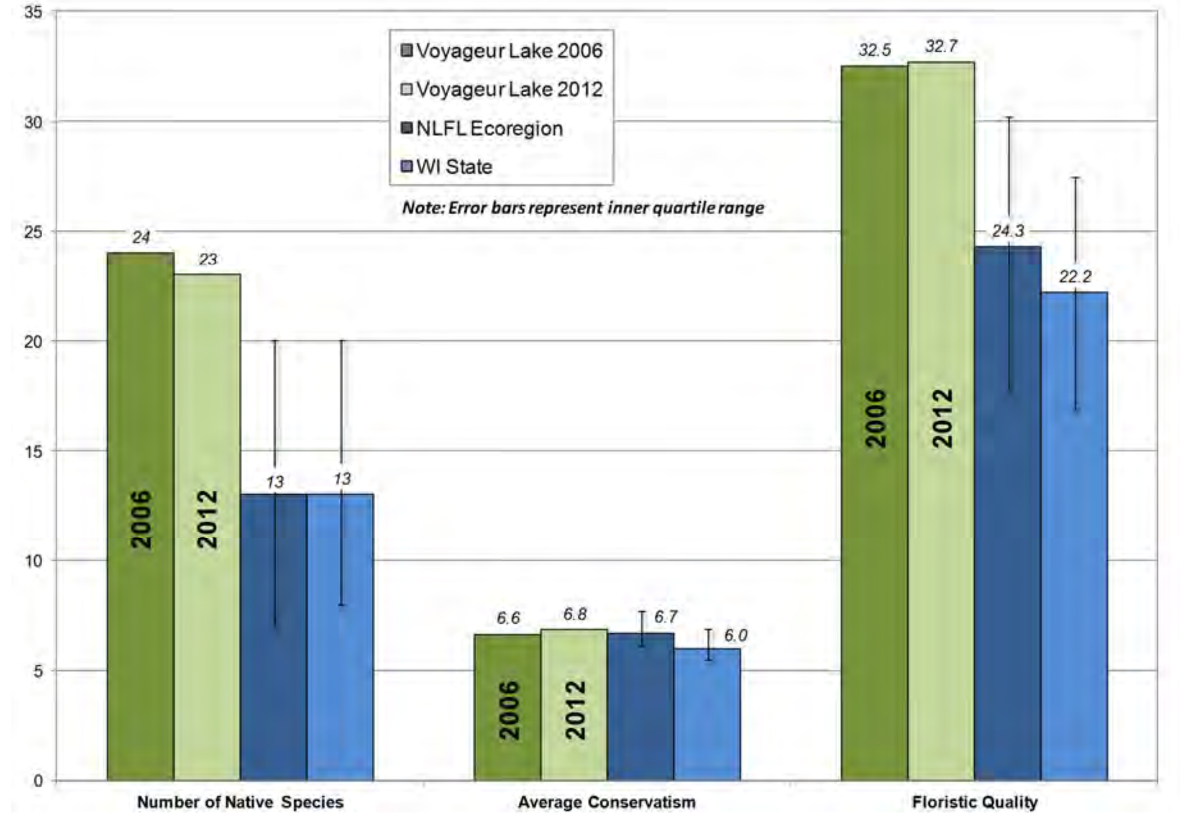


Figure 8.3.4-4. Voyageur Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the Chain-Wide Section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants.

In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Voyageur Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Voyageur Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.3.4-5). Using the data collected form the 2012 point-intercept survey, Voyageur Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.92, falling above the upper quartile value for lakes in both the ecoregion and the state. Voyageur Lake's 2012 diversity was very similar to the diversity calculated from data collected during the 2006 point-intercept survey (0.93).

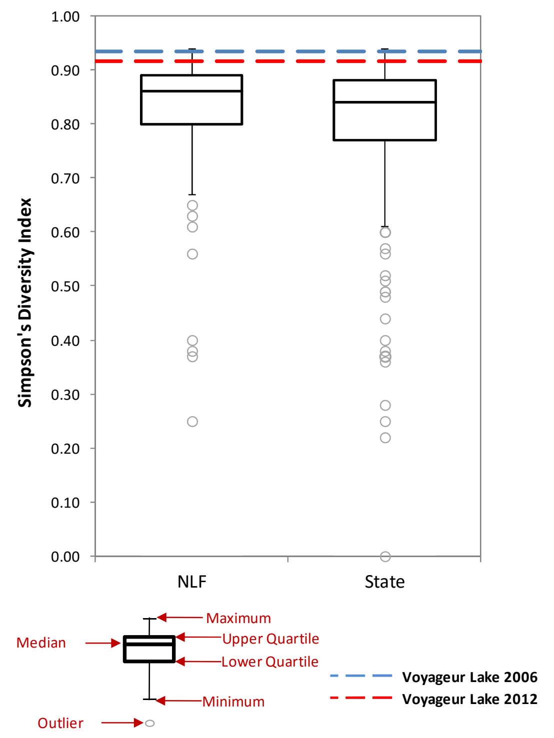


Figure 8.3.4-5. Voyageur Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 8.3.4-6 displays the relative frequency of occurrence of aquatic plant species in Voyageur Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

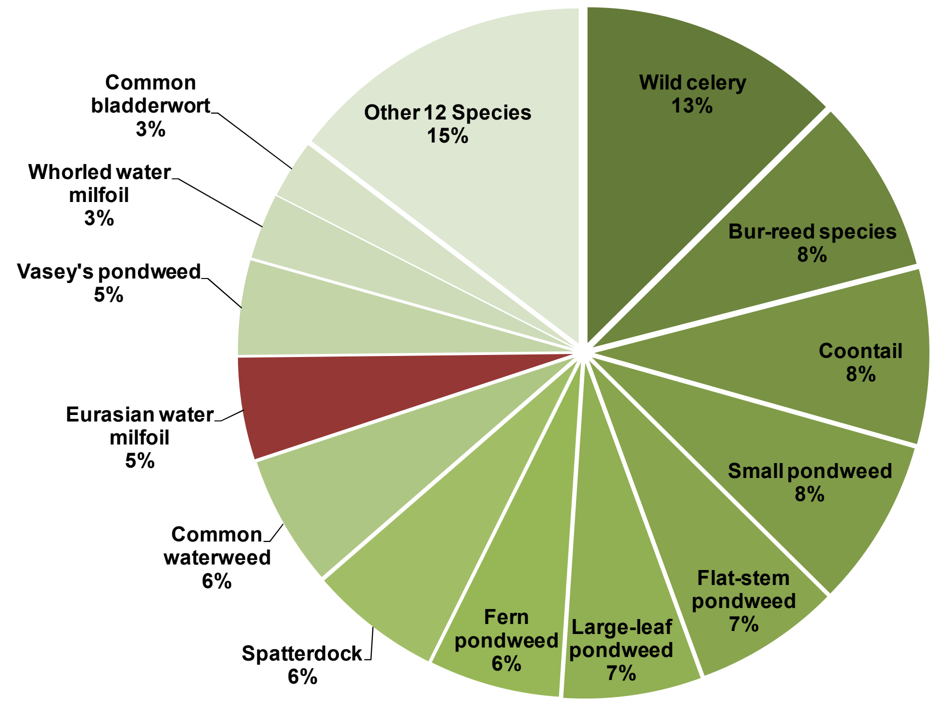


Figure 8.3.4-6. Voyageur Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

The 2014 aquatic plant community mapping survey revealed that Voyageur Lake contains approximately 29.7 acres of emergent and floating-leaf aquatic plant communities (Table 8.3.4-2, Voyageur Lake – Map 4). Thirteen emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2014 (Table 8.3.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Voyageur Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.3.4-2. Acres of emergent and floating-leaf aquatic plant communities in Voyageur Lake. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	2014 Acres
Emergent	5.3
Floating-Leaf	24.4
Mixed Emergent & Floating-Leaf	0.0
Total	**29.7**

8.3.4 Voyageur Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Voyageur Lake's Implementation Plan illustrates how Voyageur Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Voyageur Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Voyageur Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	David Tidmarsh, current Voyageur Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Voyageur Lake have been collecting water quality data intermittently since 1993. Voyageur Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Voyageur Lake currently has an active volunteer (David Tidmarsh) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis. Voyageur Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of David Tidmarsh, the current CLMN volunteer, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. David Tidmarsh, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. David Tidmarsh, current CLMN volunteer, notifies Dave Mueller or current Lakes and Shores Committee chair when a new Voyageur Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Voyageur Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 25% (0.9 miles) of the shoreline are in an urbanized or developed-unnatural state, 28% (1.0 miles) is in a developed-semi-natural state, and 47% (1.7 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 25% of Voyageur Lake's shoreline is in a highly-developed state, approximately 47% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Voyageur Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Voyageur Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Voyageur Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Voyageur Lake shoreland assessment, approximately 17 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Voyageur Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action:	Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.
Description:	Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Voyageur Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Voyageur Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA. Voyageur Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Voyageur Lake Association and ERCLA meetings. Voyageur Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Voyageur Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Voyageur Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action:	ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.
Description:	Voyageur Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Voyageur Lake and its stakeholders.

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

8.4 Eagle Lake

An Introduction to Eagle Lake

Eagle Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 34 feet, a mean depth of 16 feet, and a surface area of approximately 575 acres. The lake is fed via upstream Voyageur Lake (Eagle River) and Scattering Rice Lake (Deerskin River) and drains into downstream Otter Lake. Eagle Lake's surficial watershed encompasses approximately 147,735 acres. Aquatic plant studies conducted by Onterra in 2012 and 2014 located 29 native aquatic plant species, of which slender naiad was the most common. One non-native plant, Eurasian watermilfoil is present within Eagle Lake.

Field Survey Notes

The native aquatic plants slender naiad (Najas flexilis) and wild celery (Vallisneria americana) were the most frequently encountered during the 2012 point-intercept survey. Large, monotypic stands of the native northern watermilfoil (Myriophyllum sibiricum) were also observed along the lake's eastern shore.

Photo 8.4 Eagle Lake, Vilas County

Lake at a Glance* – Eagle Lake

Morphology	
Acreage	575
Maximum Depth (ft)	34
Mean Depth (ft)	16
Volume (acre-feet)	9,200
Shoreline Complexity	2.2
Vegetation	
Curly-leaf Survey Date	July 8, 2014
Comprehensive Survey Date	August 2, 2012
Number of Native Species	25
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil (*Myriophyllum spicatum*)
Simpson's Diversity	0.90
Average Conservatism	6.5
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	253:1

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

8.4.1 Eagle Lake Water Quality

Water quality data was collected from Eagle Lake on six occasions in 2014/2015. 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 2014/2015, any historical data was researched and are included within this report as available.

Near-surface total phosphorus concentration data are available from Eagle Lake in 1979, 1992, 2000-2005, and 2014. In 2014, the average summer near-surface total phosphorus concentration was 26.3 μg/L, slightly higher than the median value of 23.0 μg/L for other deep, lowland drainage lakes throughout Wisconsin and the median value of 21.0 μg/L for lakes within the Northern Lakes and Forests ecoregion (Figure 8.4.1-1). With the exception of the average growing season total phosphorus concentration in 2004 (discussed on next page), near-surface total phosphorus concentrations in Eagle Lake have been relatively consistent over the time period for which data are available. Trends analysis indicates that no trends (positive or negative) in near-surface total phosphorus concentrations are occurring in Eagle Lake at this time. Overall, weighted average near-surface total phosphorus concentrations in Eagle Lake fall within the *good* category for deep, lowland drainage lakes in Wisconsin.

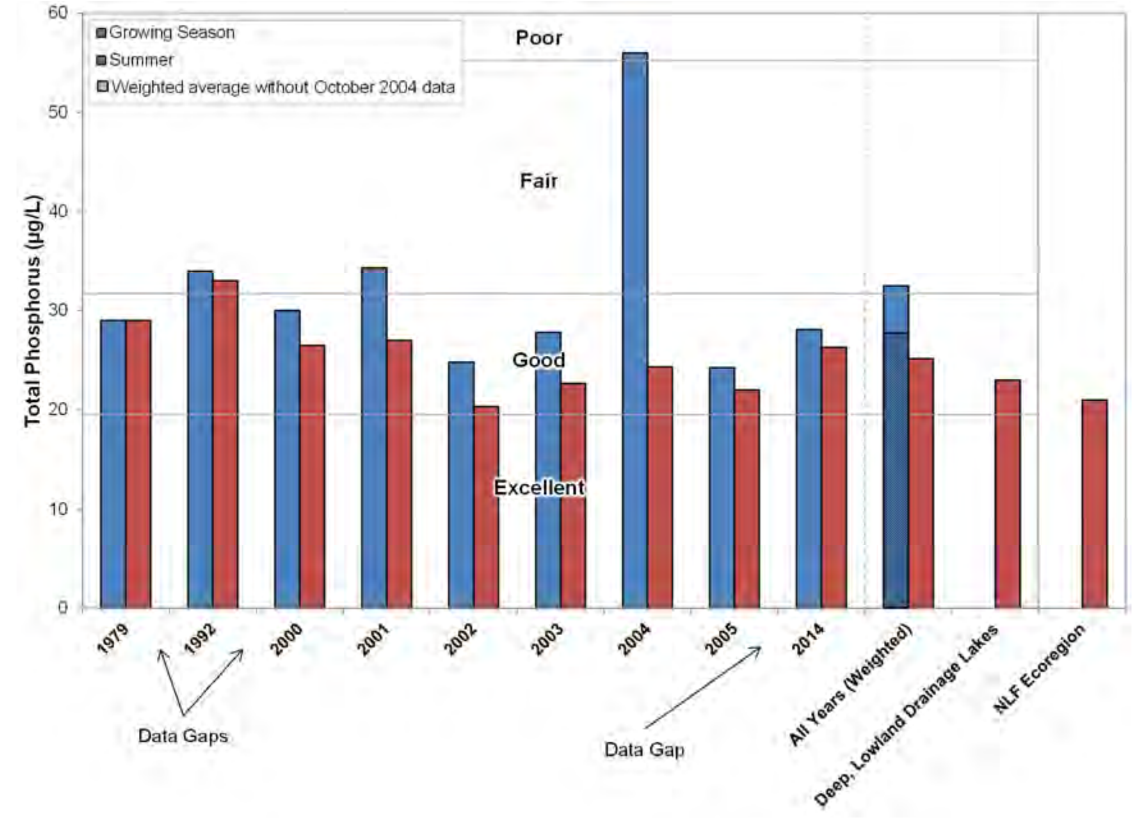


Figure 8.4.1-1. Eagle Lake, statewide deep, lowland drainage lakes, and regional total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

On October 12, 2004, a near-surface total phosphorus concentration of 185 µg/L was measured in Eagle Lake, approximately seven times higher than the growing season average concentration. Adding validation to this measurement, chlorophyll-*a* concentrations were also found to have increased substantially from 14.6 µg/L in August to 69.7 µg/L in October, indicating there was likely a noticeable algae bloom on Eagle Lake in the fall of 2004. Unfortunately, data from upstream lakes in 2004 are not available, so it is not known if this phosphorus originated upstream within the chain or within Eagle Lake. However, given the near-bottom total phosphorus data that area available from Eagle Lake, it is possible that this large increase in phosphorus measured in 2004 originated from within Eagle Lake through the process of internal nutrient loading.

Figure 8.4.1-2 displays near-surface and near-bottom total phosphorus concentrations collected from Eagle Lake in 2014 and the winter of 2015. As illustrated, near-bottom phosphorus concentrations in the late-May and during the summer months was approximately two to three times the concentrations measured near the surface. The higher concentrations of phosphorus measured near the bottoms during these sampling events is an indication that phosphorus is being released from bottom sediments and into the hypolimnion, or the colder, bottom layer of water. During these sampling events the lake was found to be stratified with little or no oxygen measured within the hypolimnion. The absence of oxygen in the water near the sediments allows phosphorus to be released from the sediment and into the water. Most of the time, this process is likely contributing minimal amounts of phosphorus to Eagle Lake. As discussed within the Chain-Wide Section, internal nutrient loading generally becomes a concern when near-bottom phosphorus concentrations exceed 200 µg/L.

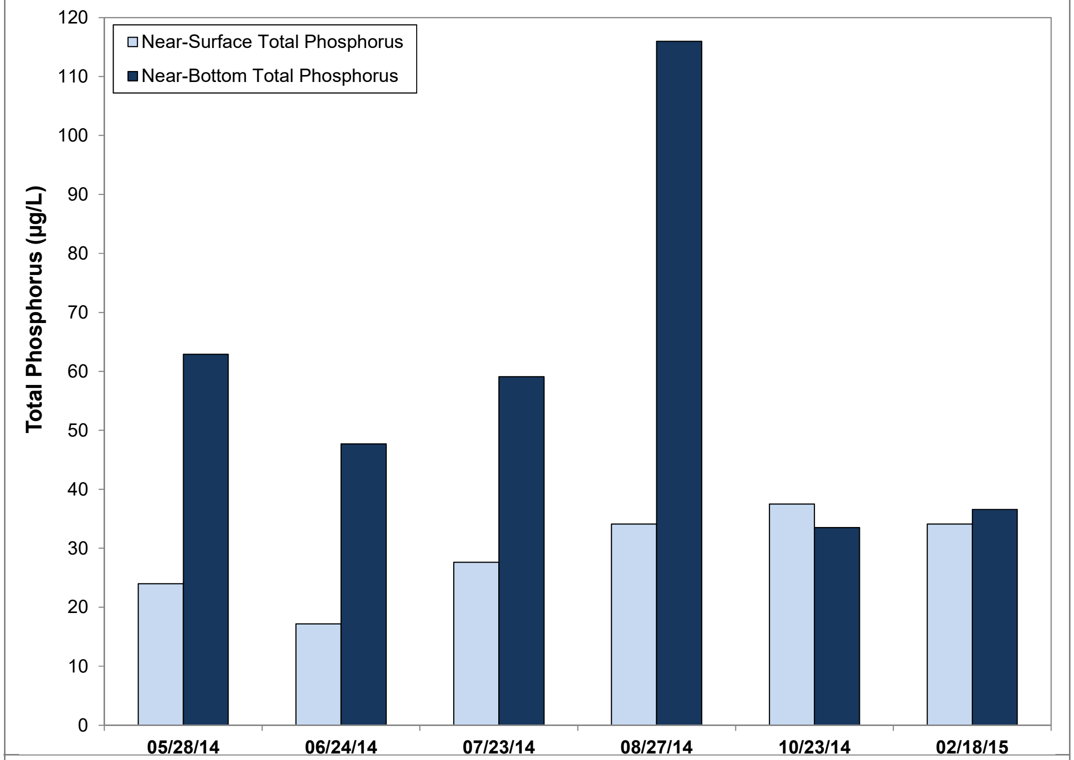


Figure 8.4.1-2. Eagle Lake growing season 2014 and winter 2015 near-surface and near-bottom total phosphorus concentrations.

However, periodically, like in 2004, conditions that either increase the period of stratification or increase the size of the anoxic hypolimnion may allow for higher amounts of phosphorus to build up within the hypolimnion over the course of the summer. In the fall as surface water temperatures cool, the entire water column of the lake mixes, or turns over, and the phosphorus-rich water near the bottom is mixed throughout the water column delivering phosphorus to the surface. Using the total phosphorus data collected in 2004 and the temperature and dissolved oxygen profiles collected in 2014, it was estimated that the concentration of phosphorus within the hypolimnion in 2004 needed to be around 650 μg/L to create the measured concentration of 185 μg/L throughout the water column at turnover. A hypolimnetic phosphorus concentration of 650 μg/L is high, but is within the realm of possibility. However, as the data indicate, this magnitude of internal nutrient loading on Eagle Lake is relatively rare, and likely only occurs when conditions are ideal.

Like near-surface total phosphorus data, chlorophyll-*a* data from Eagle Lake are available from 1979, 1992, 2000-2005, and 2014. The average summer chlorophyll-*a* concentration straddles the *good-fair* threshold for deep, lowland drainage lakes and is higher than the median value for other deep, lowland drainage lakes in Wisconsin and lakes within the NLF ecoregion (Figure 8.4.1-3). While chlorophyll-*a* concentrations vary between years, trends analysis does not indicate a trend is occurring, positive or negative, over the time period for which data are available. The variability in chlorophyll-*a* concentrations between years is expected given changes in precipitation, temperature, and other environmental conditions between years.

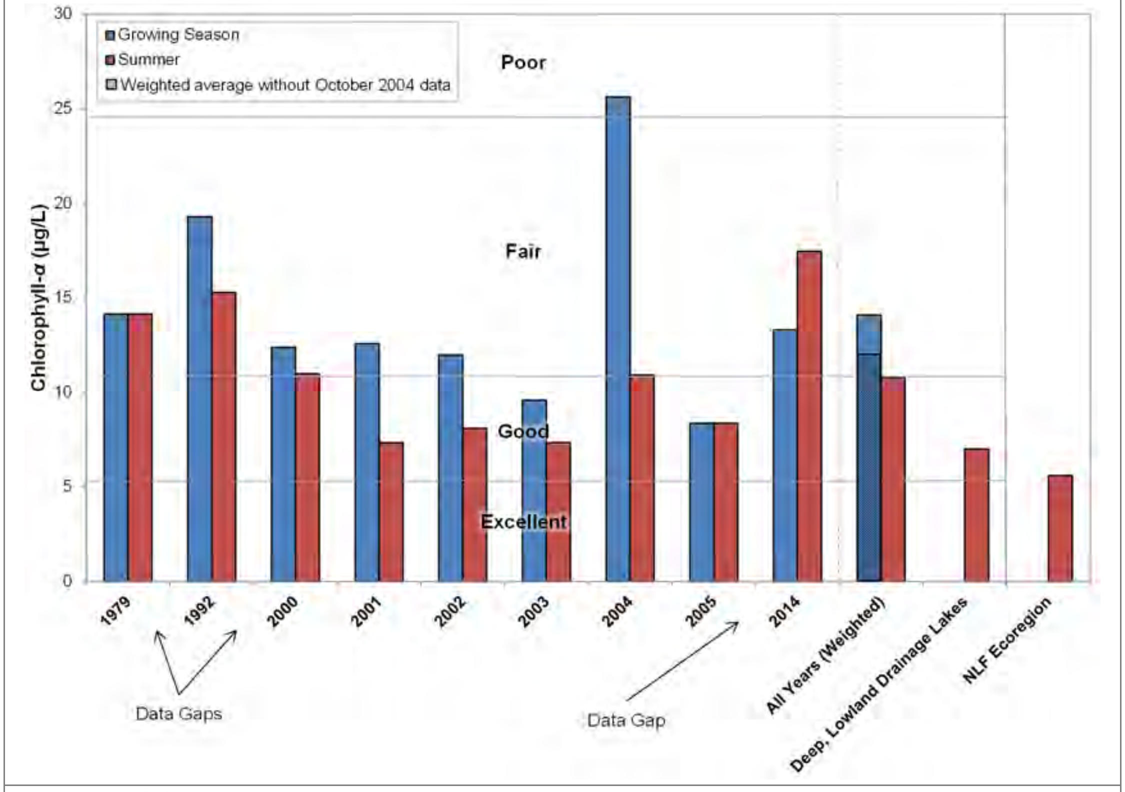


Figure 8.4.1-3. Eagle Lake, statewide deep, lowland drainage lakes, and regional chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available from Eagle Lake from 1979, 1992, 1993, 1996-2005, 2007, 2008, 2012, and 2014 (Figure 8.4.1-4). The average summer Secchi disk transparency value is 6.3 feet, slightly lower than the median values for other deep, lowland drainage lakes in Wisconsin and for lakes within the NLF ecoregion. While water clarity varies between years, trends analysis indicates water clarity has remained relatively consistent over the time period for which data are available. Overall, water clarity in Eagle Lake falls within the *good* category for deep, lowland drainage lakes.

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 Eagle Lake as well as the other lakes in the Eagle River Chain of Lakes, a natural staining of the water plays a role in light penetration, and thus water clarity, as well. The waters of Eagle 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* is a measure of water's transparency after suspended materials have been removed and only dissolved compounds remain. Water samples collected in May and July of 2014 were measured for this parameter, and were found to be 40 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.

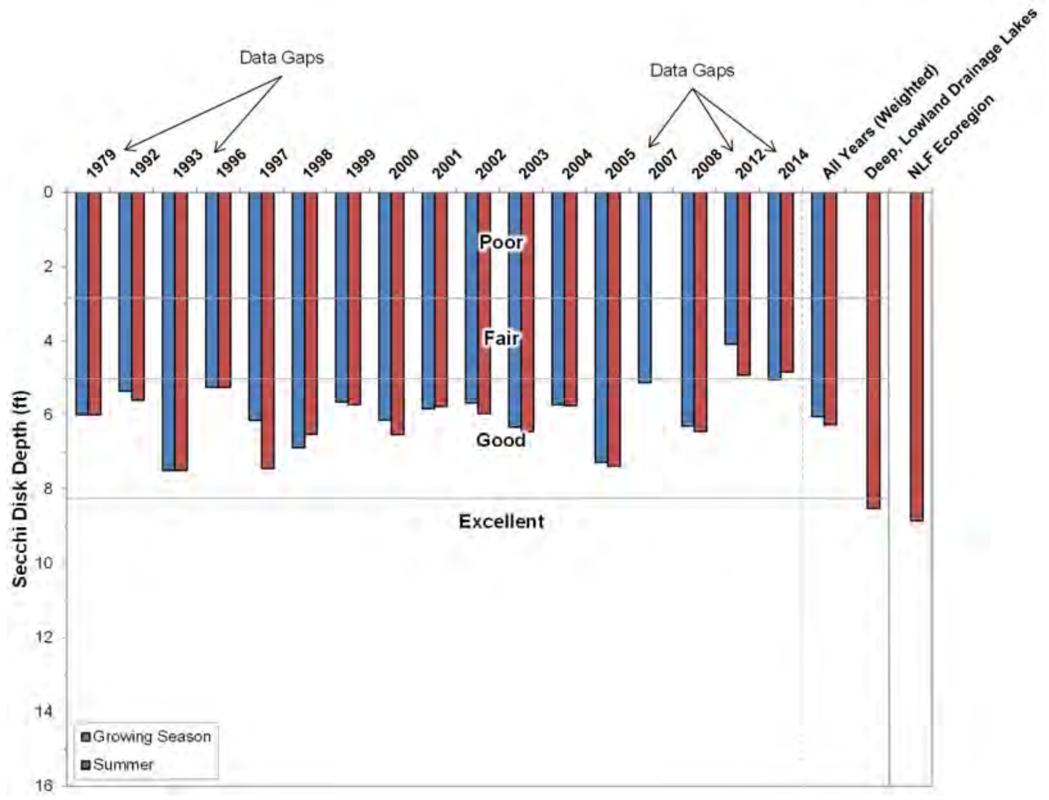


Figure 8.4.1-4. Eagle Lake, statewide deep, lowland drainage lakes, and regional Secchi disk clarity values. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from WDNR PUB WT-913.

Eagle Lake Trophic State

The Trophic State Index (TSI) values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from lower mesotrophic to eutrophic (Figure 8.4.1-5). In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a* because factors other than algae can influence water clarity; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Eagle Lake is in a eutrophic state.

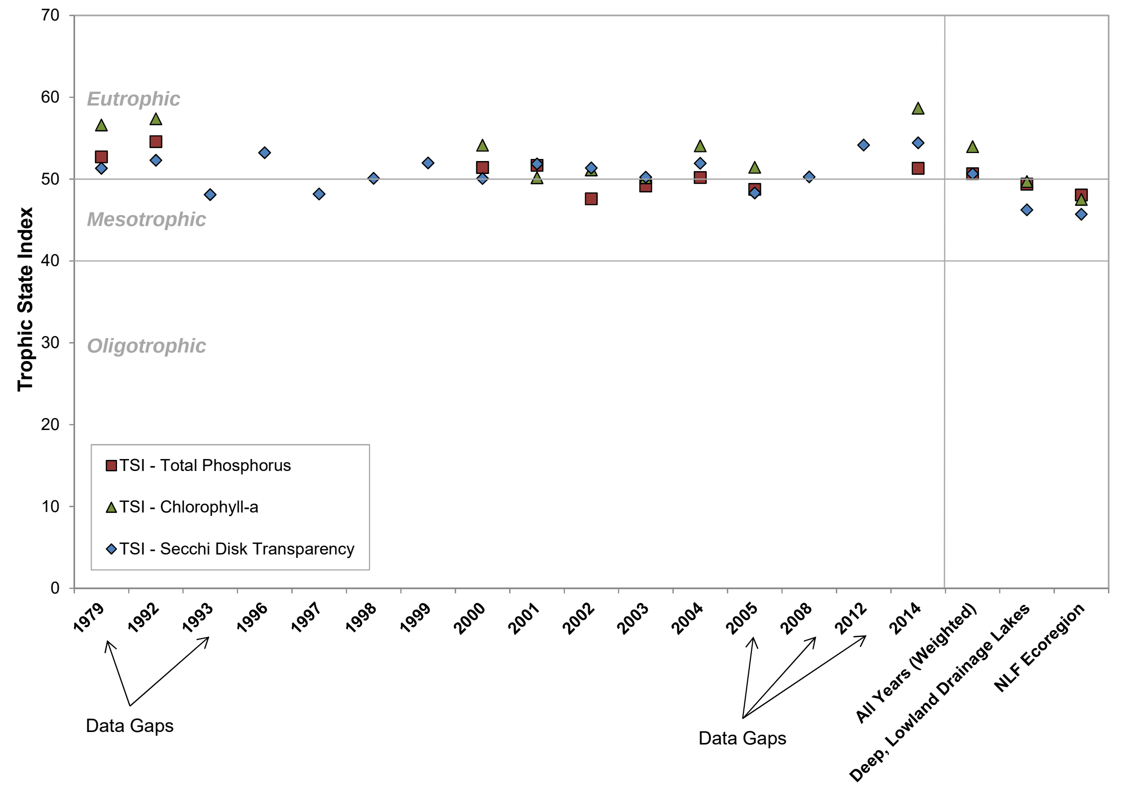


Figure 8.4.1-5. Eagle Lake, statewide deep, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Eagle Lake

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

Eagle 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 devoid 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 2015, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

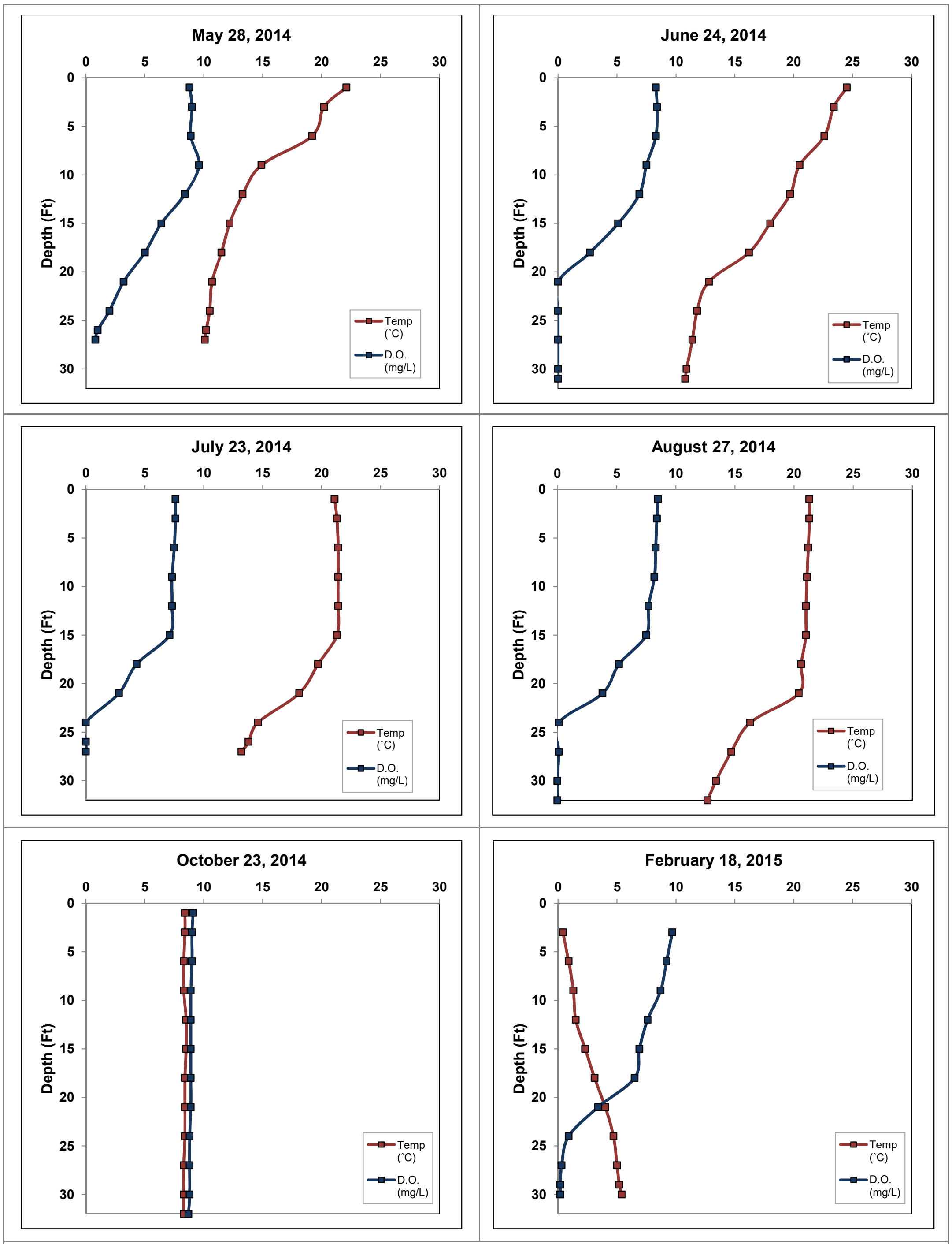


Figure 8.4.1-6. Eagle Lake 2014/2015 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Eagle 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 Eagle 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. Eagle Lake's surface water pH was measured at roughly 7.6 during May and 7.9 during July of 2014. 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 Eagle Lake was measured at 27.9 and 32.6 mg/L as $CaCO_3$ in May and July of 2014, 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 Eagle Lake during 2014. 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 Eagle Lake's pH of 7.6 – 7.9 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 Eagle Lake was found to be 7.36 mg/L in May and 7.94 mg/L in July of 2014, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. Their results were negative for the presence of zebra mussel veligers.

8.4.2 Eagle Lake Watershed Assessment

Eagle Lake's watershed is approximately 147,735 acres in size. Compared to its surface area of 581 acres, this makes for a large watershed to lake area ratio of 253:1.

Exact land cover calculation and modeling of nutrient input to Eagle Lake will be completed towards the end of this project (in 2016-2017). 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.

8.4.3 Eagle 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 2014, Eagle Lake's immediate shoreline was assessed in terms of its development. Eagle Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.6 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.4.3-1). This constitutes about 54% of Eagle 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, 1.4 miles of urbanized and developed–unnatural shoreline (30%) was observed. If restoration of the Eagle 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. Eagle Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

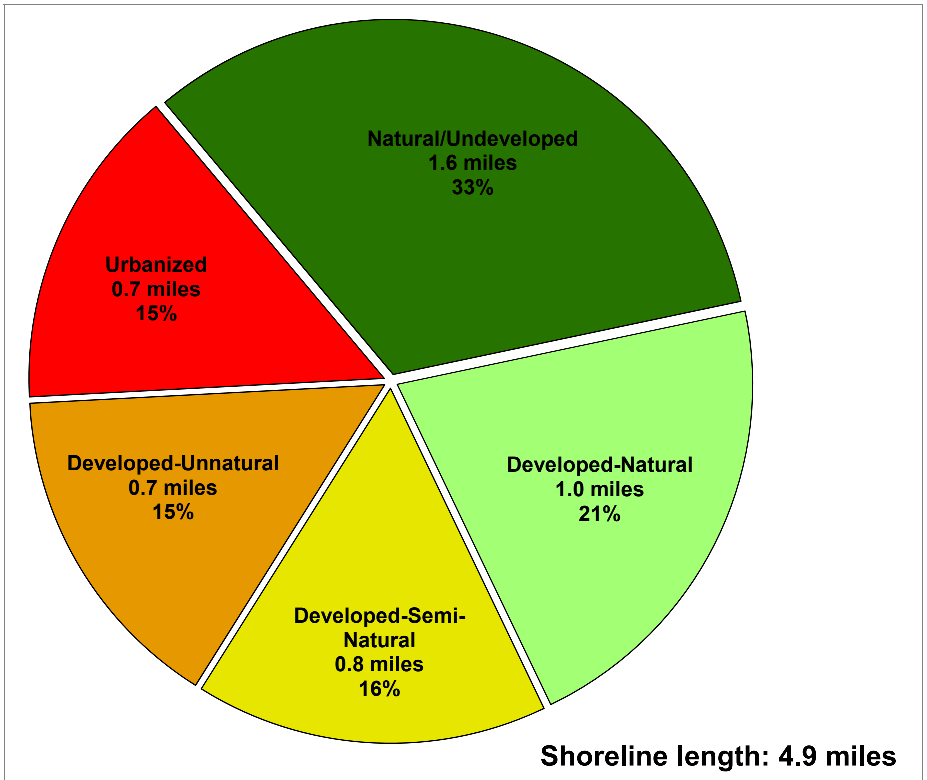


Figure 8.4.3-1. Eagle Lake shoreland categories and total lengths. Based upon a late summer 2014 survey. Locations of these categorized shorelands can be found on Eagle Lake – Map 1.

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 Eagle River 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, 154 total pieces of coarse woody habitat were observed along 4.9 miles of shoreline, which gives Eagle Lake a coarse woody habitat to shoreline mile ratio of 31:1 (Figure 8.4.3-2). Locations of coarse woody habitat are displayed on Eagle 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).

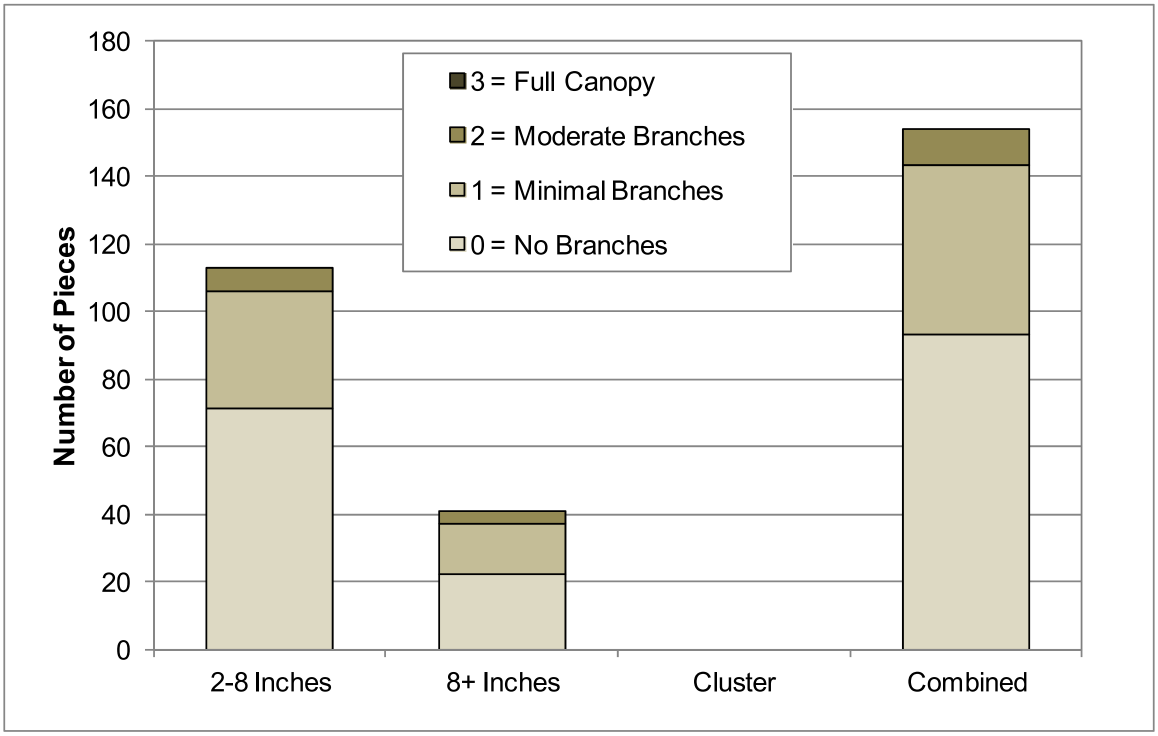


Figure 8.4.3-2. Eagle Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of Eagle Lake coarse woody habitat can be found on Eagle Lake – Map 2.

8.4.4 Eagle Lake Aquatic Vegetation

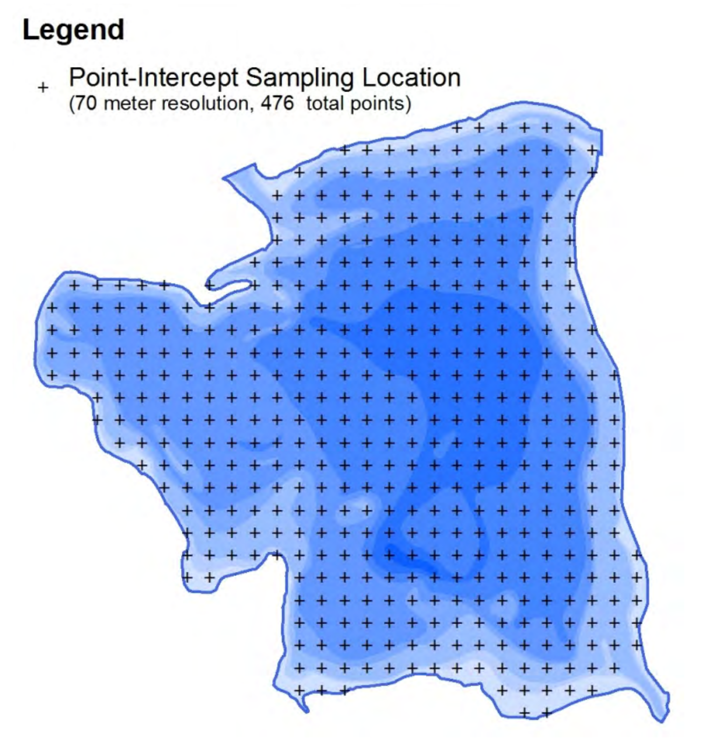


Figure 8.4.4-1. Point-intercept sampling locations on Eagle Lake.

An early season aquatic invasive species survey was conducted on Eagle Lake on July 8, 2014. 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.

The whole-lake aquatic plant point-intercept survey was conducted on Eagle Lake by Onterra on August 2, 2012 (Figure 8.2.4-1), while the aquatic plant community mapping survey was conducted on July 30, 2014. During these surveys, a total of 30 aquatic plant species were located, only one of which is considered to be a non-native, invasive species: Eurasian watermilfoil (Table 8.4.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 84% of the point-intercept locations within littoral areas contained sand, 6% contained fine, organic sediments (muck), and 10% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 9.0 feet, substantially lower than the 17.0 feet recorded during the 2006 survey. As discussed within the Water Quality Section, water quality in terms of light availability fluctuates from year to year and water clarity was likely higher in 2006 allowing plants to grow deeper. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain’s lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.4.4-1 displays the aquatic plant species located in Eagle Lake during the Onterra 2012 point-intercept survey. All of the species recorded in 2006, with the exception of white water crowfoot and arrowhead rosette, were recorded in 2012. An additional 12 species were located during the 2012 and 2014 surveys compared that were not recorded in 2006.

Table 8.4.4-1. Aquatic plant species located in Eagle Lake during 2006 and 2012/2014 aquatic plant surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2014 (Onterra)
E	*Eleocharis palustris*	Creeping spikerush	6	X	X
	Pontederia cordata	Pickerelweed	9		I
	Schoenoplectus acutus	Hardstem bulrush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4	X	X
	Sparganium eurycarpum	Common bur-reed	5		I
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	I
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10		I
Submergent	*Bidens beckii*	Water marigold	8		X
	Ceratophyllum demersum	Coontail	3	X	X
	Chara spp.	Muskgrasses	7	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Isoetes spp.	Quillwort species	8		X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		X
	Potamogeton strictifolius	Stiff pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	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	X
S/E	*Sagittaria* sp. (rosette)	Arrowhead sp. (rosette)	N/A	X	
FF	*Spirodela polyrhiza*	Greater duckweed	5		X

E = Emergent, 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*

Of the 121 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 74% contained aquatic vegetation. Eagle Lake – Map 3 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake, mainly near shore throughout the lake. Thirty-nine percent of the point-intercept locations had a total rake fullness rating of 1, 24% had a total rake fullness rating of 2, and 11% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Of the 25 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, wild celery, small pondweed, and Vasey's pondweed were the four-most frequently encountered (Figure 8.4.4-2). Slender naiad, the most abundant aquatic plant in Eagle Lake in 2012 had a littoral occurrence of nearly 44%. Slender naiad is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.
1997).

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 41%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Small pondweed was the third-most abundant aquatic plant encountered in Eagle Lake in 2012, with a littoral occurrence of approximately 30%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Catfish Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms. Unlike two other narrow-leaved pondweed species located in Catfish Lake, spiral-fruited and Vasey's pondweeds, small pondweed does not produce floating-leaves.

Vasey's pondweed was the forth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like spiral-fruited pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer than spiral-fruited pondweed. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Eagle Lake is an indicator of a high-quality environment.

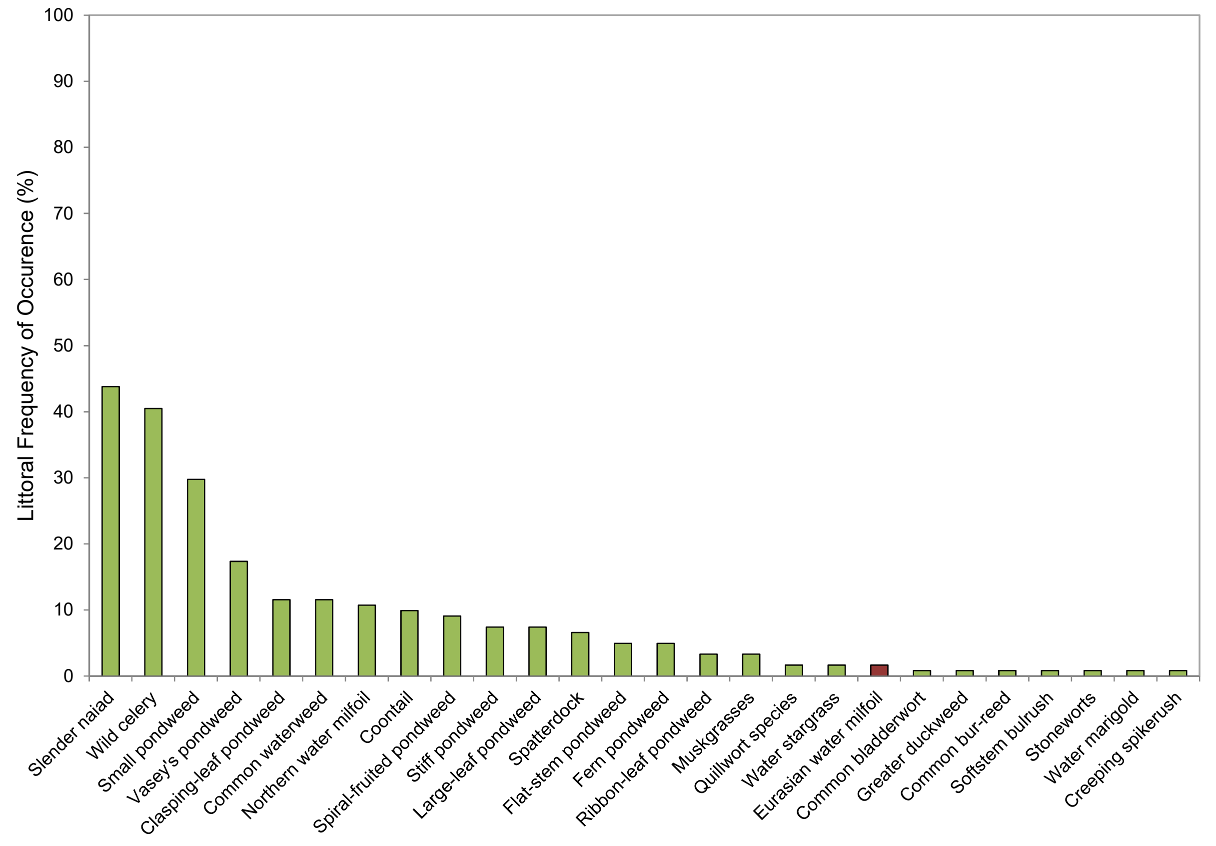


Figure 8.4.4-2. Eagle Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

To determine if the 2008-2012 Eurasian watermilfoil control project on Eagle Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 4.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Eagle Lake.

As illustrated, the occurrence of Eurasian watermilfoil in Eagle Lake was reduced by a statistically valid 74%, from an occurrence of 6.4% in 2006 to 1.7% in 2012. No native plant species exhibited statistically valid reductions in their occurrence from 2006 to 2012, while eight species saw statistically valid increases in occurrence. The fact no native species were shown to have statistically valid declines in occurrence indicates that the Eurasian watermilfoil control program on Eagle Lake did not have any detectable adverse impacts to the populations of native plants.

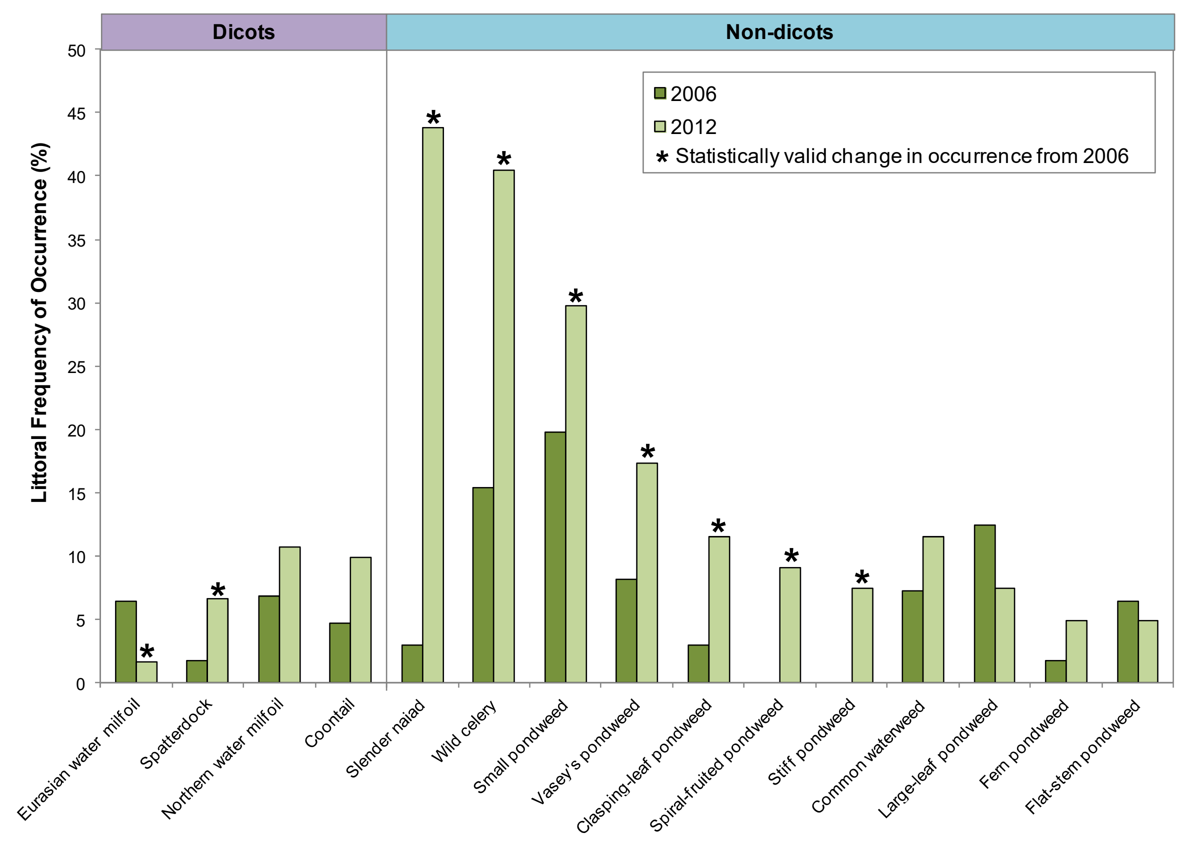


Figure 8.4.4-3. Eagle Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total 30 native aquatic plant species were located in Eagle Lake during the 2012 survey, 25 were encountered on the rake and four were incidentally located. These 25 native species and their conservatism values were used to calculate the FQI of Eagle Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.2.4-4 compares the FQI components of Eagle Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Eagle Lake's native species richness (25) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.6) is slightly lower than the ecoregional median but above the state median. Combining Eagle Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 32.8, which greatly exceeds the ecoregional and state median values (Figure 8.2.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Eagle Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Eagle Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

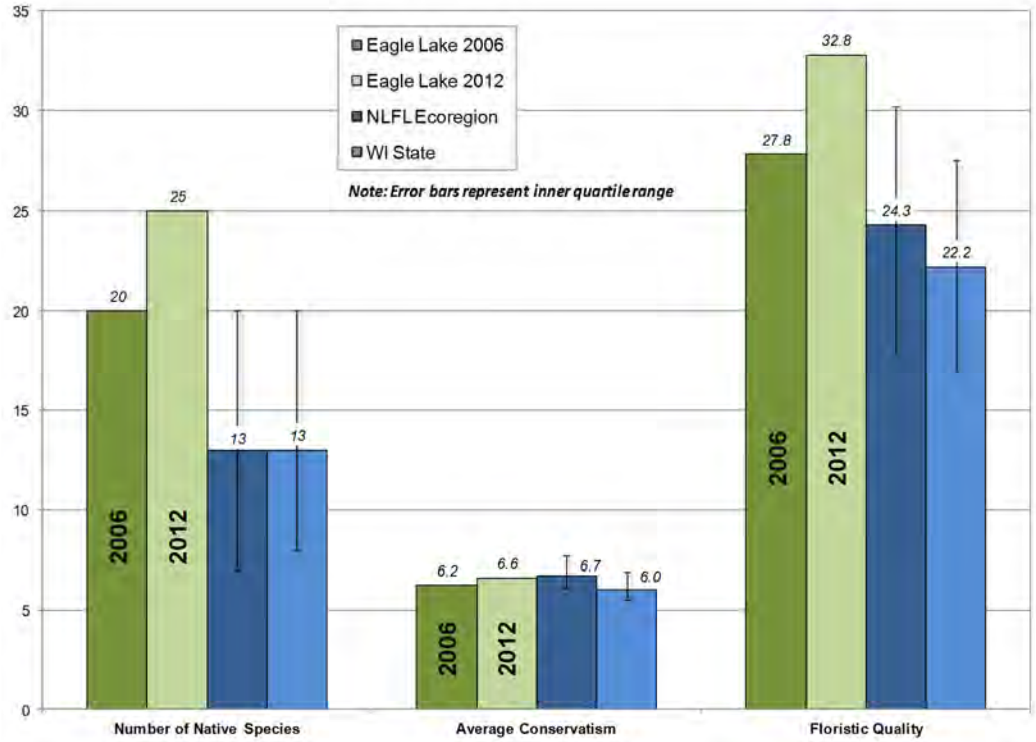


Figure 8.4.4-4. Eagle Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Eagle Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 4.4-5). Using the data collected form the 2012 point-intercept survey, Eagle Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.90, falling above the upper quartile value for lakes in both the ecoregion and the state. Eagle Lake's 2012 diversity was found to be the same as the diversity calculated from data collected in 2006.

Figure 8.2.4-6 displays the relative frequency of occurrence of aquatic plant species in Eagle Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

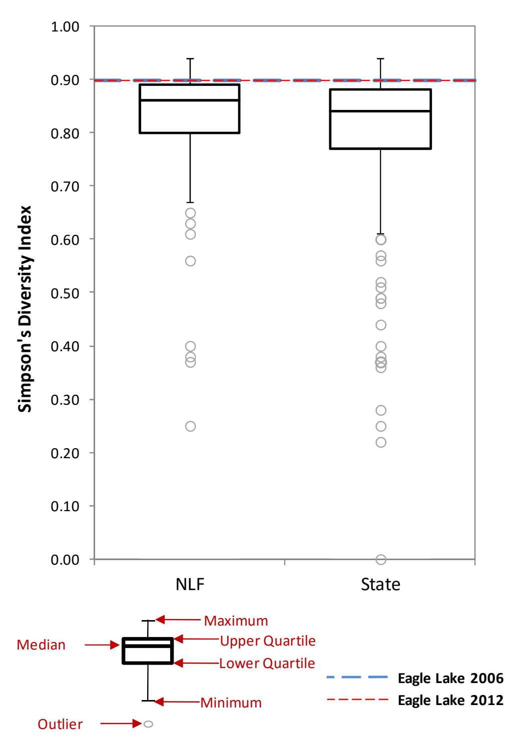


Figure 8.4.4-5. Eagle Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

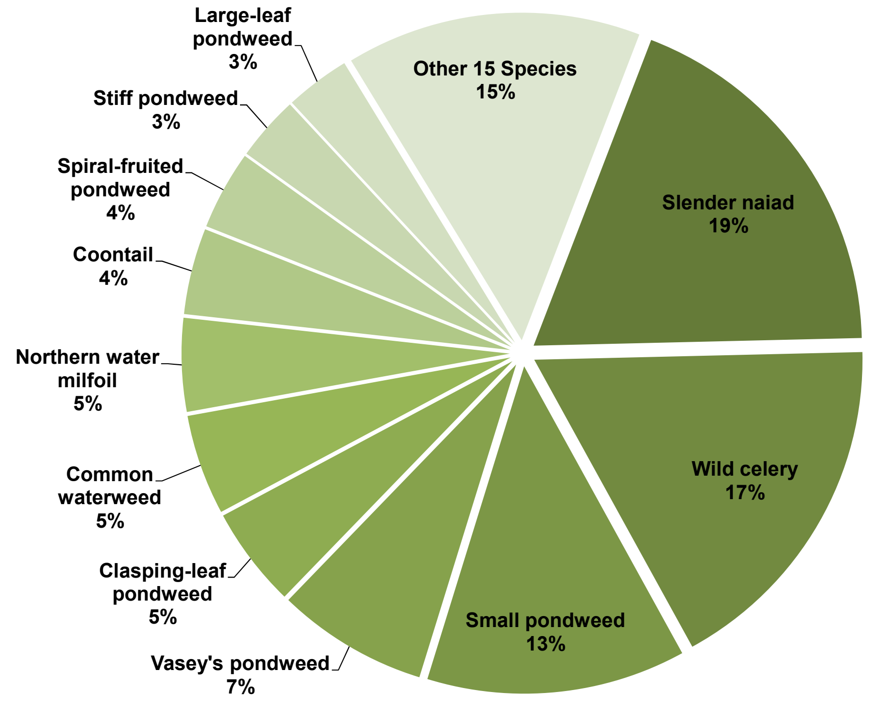


Figure 8.4.4-6. Eagle Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

The 2014 aquatic plant community mapping survey revealed that Eagle Lake contains approximately 11.8 acres of emergent and floating-leaf aquatic plant communities (Table 8.4.4-2, Eagle Lake – Map 4). Eight emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2014 (Table 8.4.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Eagle Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.4.4-2. Acres of emergent and floating-leaf aquatic plant communities in Eagle Lake. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-Leaf	10.0
Mixed Emergent & Floating-Leaf	1.8
Total	**11.8**

8.4.4 Eagle Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Eagle Lake's Implementation Plan illustrates how Eagle Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Eagle Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Eagle Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	David Tidmarsh, current Eagle Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Eagle Lake have been collecting water quality data intermittently since 1993. Eagle Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Eagle Lake currently has an active volunteer (David Tidmarsh) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis. Eagle Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of David Tidmarsh, the current CLMN volunteer, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. David Tidmarsh, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. David Tidmarsh, current CLMN volunteer, notifies Dave Mueller or current Lakes and Shores Committee chair when a new Eagle Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Eagle Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 30% (1.4 miles) of the shoreline are in an urbanized or developed-unnatural state, 16% (0.8 miles) is in a developed-semi-natural state, and 54% (2.6 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for

property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action:	Preserve natural shoreland areas on the Eagle River Chain of Lakes.
Description:	While approximately 30% of Eagle Lake's shoreline is in a highly-developed state, approximately 54% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Eagle Lake and to the entire chain. The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Eagle Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Eagle Lake property owners.

Management Action:	Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.
Description:	During the Eagle Lake shoreland assessment, approximately 31 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion. The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Eagle Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.

Description: Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Eagle Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Eagle Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA.

Eagle Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Eagle Lake Association and ERCLA meetings. Eagle Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Eagle Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Eagle Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action: ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.

Description: Eagle Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Eagle Lake and its stakeholders.

Note: Methodology, explanation of analysis and biological background on Scattering Rice Lake studies are contained within the Eagle River Chain-wide Management Plan document.

8.5 Scattering Rice Lake

An Introduction to Scattering Rice Lake

Scattering Rice Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 17 feet, a mean depth of 8 feet, and a surface area of approximately 263 acres. The lake is fed via the Deerskin River and has a surficial watershed of approximately 42,860 acres. Scattering Rice Lake flows into downstream Eagle Lake. During the 2012 and 2014 aquatic plant studies conducted by Onterra, 22 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. One non-native plant, Eurasian watermilfoil was observed growing in Scattering Rice Lake in 2012.

Field Survey Notes

The native plants wild celery (Vallisneria americana) and fern pondweed (Potamogeton robbinsii) were the most frequently encountered during the 2012 point-intercept survey. Two rare plants, Vasey's pondweed (Potamogeton vaseyi) and apline pondweed (P. alpinus) were also observed. A family of otters was observed feeding on mussels near the bog island in the southern area of the lake.

Photo 8.5 Scattering Rice Lake, Vilas County

Lake at a Glance* – Scattering Rice Lake

Morphology	
Acreage	263
Maximum Depth (ft)	17
Mean Depth (ft)	8
Volume (acre-feet)	2,168
Shoreline Complexity	3.5
Vegetation	
Curly-leaf Survey Date	July 7, 2014
Comprehensive Survey Date	August 2, 2012
Number of Native Species	22
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil (*Myriophyllum spicatum*)
Simpson's Diversity	0.91
Average Conservatism	6.7
Water Quality	
Wisconsin Lake Classification	Shallow (Mixed), Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Phosphorus
Watershed to Lake Area Ratio	160:1

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

8.5.1 Scattering Rice Lake Water Quality

Water quality data were collected from Scattering Rice Lake on six occasions in 2014/2015 as part of the Phase II project. Following analyses of these data in combination with watershed modeling (see Section 8.5.2), it was found that measured phosphorus (and chlorophyll) concentrations in Scattering Rice Lake were significantly higher than those predicted by Wisconsin Lakes Modeling Suite (WiLMS) software. In an attempt to gain further insight into why phosphorus concentrations were higher than expected, additional water quality sampling was completed on Scattering Rice Lake in 2016 under the Phase III project grant. The additional sampling completed in 2016 and potential reasons for higher measured phosphorus concentrations in Scattering Rice Lake are discussed in detail later in the section.

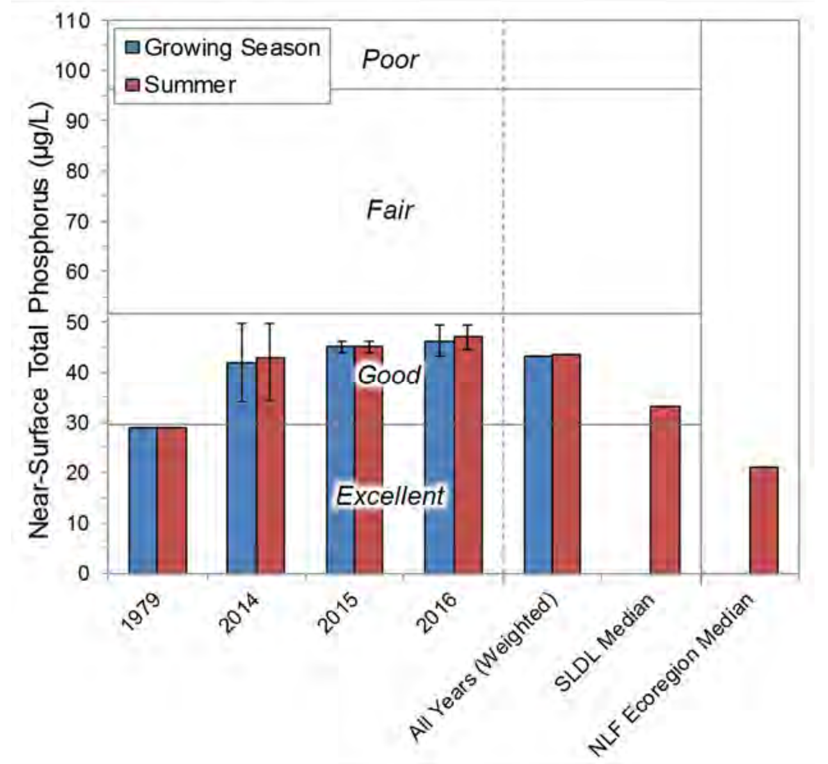


Figure 8.5.1-1. Scattering Rice Lake annual average near-surface total phosphorus and median near-surface total phosphorus concentrations for Wisconsin shallow lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Water quality data were collected from Scattering Rice Lake on five occasions during the growing seasons of 2014 and 2016 (April-October) by Onterra staff. The three water quality parameters of primary interest were total phosphorus, chorophyll-*a*, and Secchi disk transparency. The following figures display these data along with available historical data from Scattering Rice Lake. Near-surface total phosphorus data from Scattering Rice Lake are available from 1979 and annually from 2014-2016 (Figure 8.5.1-1). The phosphorus data from 1979 is from one sample collected in July of that year and it cannot be said if that is representative of the average concentration at that time. The average summer near-surface concentration measured from 2014 to 2016 were relatively similar, ranging from 43 µg/L in 2014 to 47 µg/L in 2016. The weighted average near-surface total phosphorus concentration for Scattering Rice Lake is 44 µg/L, falling into the *good* category for Wisconsin's shallow lowland drainage lakes.

Like total phosphorus, chlorophyll-*a* data from Scattering Rice Lake are available from 1979 and annually from 2014-2016 (Figure 8.5.1-2). Chlorophyll-*a* was measured once in 1979 and likely does not represent an accurate growing season or summer average. While average growing season total phosphorus concentration from 2014-2016 were relatively similar, chlorophyll-*a* concentrations were more variable. Average summer chlorophyll-*a* concentrations from 2014-

2016 ranged from 15 µg/L in 2016 to 32 µg/L in 2015. The weighted average summer chlorophyll- *a* concentration in Scattering Rice Lake straddles the threshold between *good* and *fair* for Wisconsin's shallow lowland drainage lakes and is higher than the median concentration for other shallow lowland drainage lakes in the state and for lakes in the NLF ecoregion.

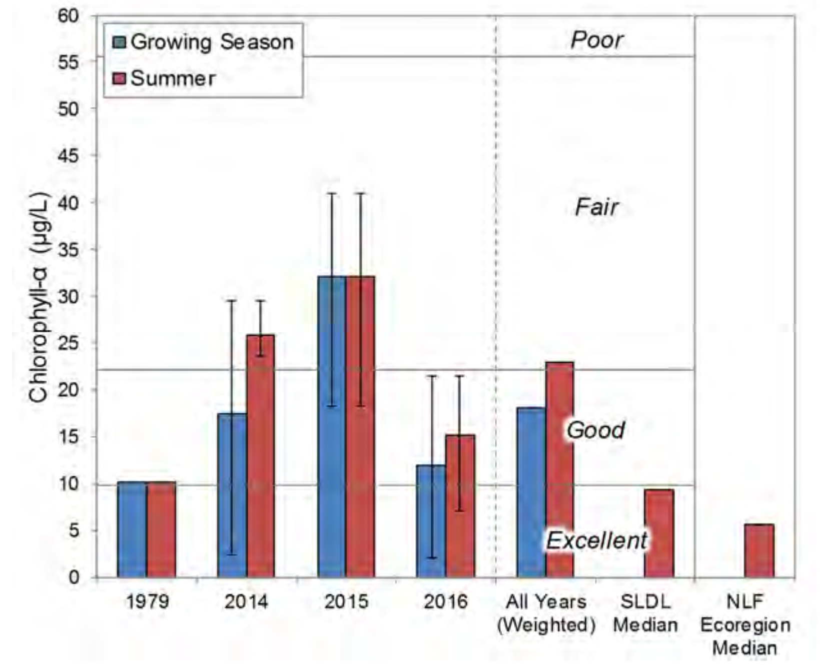


Figure 8.5.1-2. Scattering Rice Lake annual average near-surface chlorophyll-α and median chlorophyll-α concentrations for Wisconsin shallow lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Secchi disk transparency data are available in Scattering Rice Lake from 1979, 1994-1998, 2000-2006, 2010-2011, and 2014-2016 (Figure 8.5.1-3). Secchi disk transparency in 1979 is represented by only one measurement collected in July of that year. Average growing season Secchi disk depth from 1994-2006 ranged from 4.4 feet in 1994 to 5.9 feet in 1997 with an average of 5.1 feet. The average growing season Secchi disk depths collected from 2010-2016 ranged from 3.0 feet in 2010 to 4.0 feet in 2016 with an average of 3.6 feet. Given limited chlorophyll-*a* data are available, it cannot be said if the 1.5-foot decline in Secchi disk depth between these two time periods is the result of increased algal production, tannins, or both.

Annual precipitation data from Eagle River indicate that five of the seven years between 2010-2016 saw above-average rainfall following a period from 2006-2009 with below-average rainfall (Figure 8.5.1-4). Decaying vegetation within forests and wetlands in Scattering Rice Lake's watershed release weak organic acids, such as humic acid and tannic acid, which create the tea-colored water found in Lower Eagle River Chain of Lakes. The concentration of these compounds, and thus the clarity of the water flowing from these areas into Scattering Rice Lake can vary based on the amount and frequency precipitation.

Consistent precipitation does not allow the compounds to accumulate in the wetlands and forests which can lead to consistent water clarity. On the other hand, an extended period of below-normal precipitation reduces the amount of water flowing through the wetlands and forests allowing these organic compounds to accumulate within them while producing clearer water within the lake. Higher precipitation following drier periods flushes the accumulated compounds from the wetlands into the lake reducing water clarity. This may also flush accumulated nutrients, such as phosphorus, into the lake creating a higher abundance of free-floating algae. It is believed changes in annual precipitation are likely the cause of recent reductions in water clarity in Scattering Rice Lake.

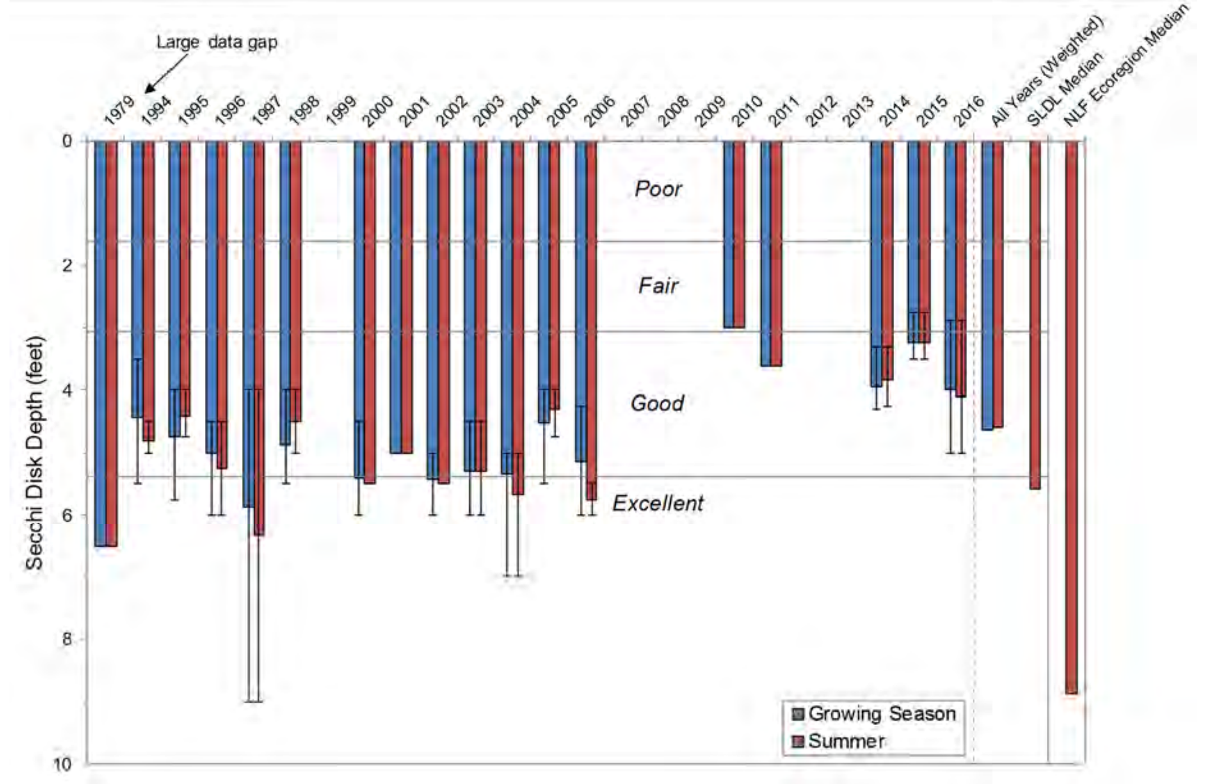


Figure 8.5.1-3. Scattering Rice Lake annual average Secchi disk depth and median Secchi disk depth for Wisconsin shallow lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

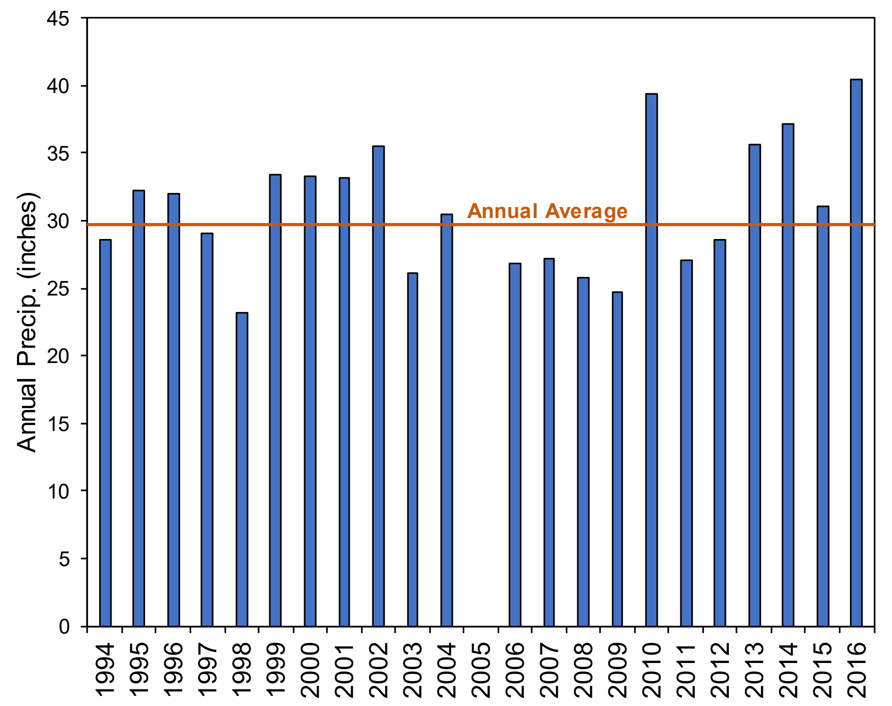


Figure 8.5.1-4. Eagle River annual precipitation from 1994-2016. Data obtained from Midwestern Regional Climate Center.

In 2014, the true color of Scattering Rice Lake's water was measured. True color measures the clarity of the water once all suspended material (e.g. algae and sediments) have been filtered out. Scattering Rice Lake's true color was measured at 50 SU (standard units) indicating the water is *tea-colored* and indicates a higher concentration of dissolved organic acids.

2016 Water Quality Monitoring

As mentioned earlier, additional water quality monitoring was completed on Scattering Rice Lake in 2016 after watershed modeling and the sampling completed in 2014 indicated that phosphorus concentrations were higher than expected. Specifically, WiLMS watershed modeling predicted a growing season mean near-surface total phosphorus concentration of 23 µg/L which is 46% lower than the measured growing season mean of 43 µg/L. The goal of the 2016 monitoring was to determine if a process known as internal nutrient loading occurs in Scattering Rice Lake and if this process can account for the higher phosphorus concentrations measured within the lake. Near-surface and near-bottom total phosphorus concentrations were collected by Onterra ecologists in May, June, July, August, October of 2016 and in February of 2017. Scattering Rice Lake volunteers collected temperature and dissolved oxygen data on a weekly basis from May through October of 2016.

Primer on Internal Nutrient Loading

In general, lakes tend to act as phosphorus sinks, meaning they tend accumulate phosphorus over time and export less phosphorus than the amount that is loaded to the lake from its watershed. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates over time. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel 2001). If this phosphorus remains bound within bottom sediments it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available. This release of phosphorus (and other nutrients) from bottom sediments into the overlying water is termed *internal nutrient loading*.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson 1998). Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density. As surface water warms in late-spring/early summer, it becomes less dense and floats atop the colder, denser layer of water below. The large density gradient between the upper, warm layer of water (epilimnion) and lower, cold layer of water (hypolimnion) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper, dimictic lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton. Dimictic lakes are those which remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall. In dimictic lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate cyanobacterial blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in polymictic lakes, or lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes, and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms at the surface. In shallower lakes which experience periods of stratification, it is also possible for certain species of phytoplankton to migrate down into deeper waters to obtain sediment-released nutrients and then return to the surface (Molot et al. 2014).

Evidence for Internal Nutrient Loading in Scattering Rice Lake

While a continuum exists between dimictic and polymictic lakes, the Osgood Index (Osgood 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake's mean depth to its surface area. Lakes with an Osgood Index of less than 4.0 are deemed polymictic. Scattering Rice Lake's Osgood Index is 2.4, indicating it is a polymictic system which likely experiences periods of stratification and mixing throughout the open-water season. Figure 8.5.1-5 displays temperature and dissolved oxygen isopleths created using data collected by the Scattering Rice Lake volunteers in 2016. An isopleth is a graph of two variables (e.g. temperature and depth) with contour lines representing equal values.

The 2016 dissolved oxygen data show that Scattering Rice Lake developed anoxia in bottom waters during the summer months. In June and July, the lake alternated between periods of stratification (anoxia in bottom waters) and mixing (oxygen present in bottom waters). However, bottom waters from late-July thought August remained anoxic when thermal stratification was strongest or the gradient in temperatures between the surface and the bottom was greatest. The temperature and dissolved oxygen data collected in 2016 indicate that Scattering Rice Lake is a polymictic lake.

Near-surface total phosphorus concentrations in 2016 remained relatively consistent over the course of the growing season averaging 46 µg/L (Figure 8.5.1-6). However, total phosphorus concentrations measured near the bottom increased from 42 µg/L in May to 87 µg/L in July. The increase in near-bottom total phosphorus concentrations over the course of the growing season is an indication phosphorus is being released from bottom sediments during anoxia and internal nutrient loading is occurring in Scattering Rice Lake. The increase in near-bottom total phosphorus concentrations was also measured in Scattering Rice Lake in 2014 (Figure 8.5.1-6).

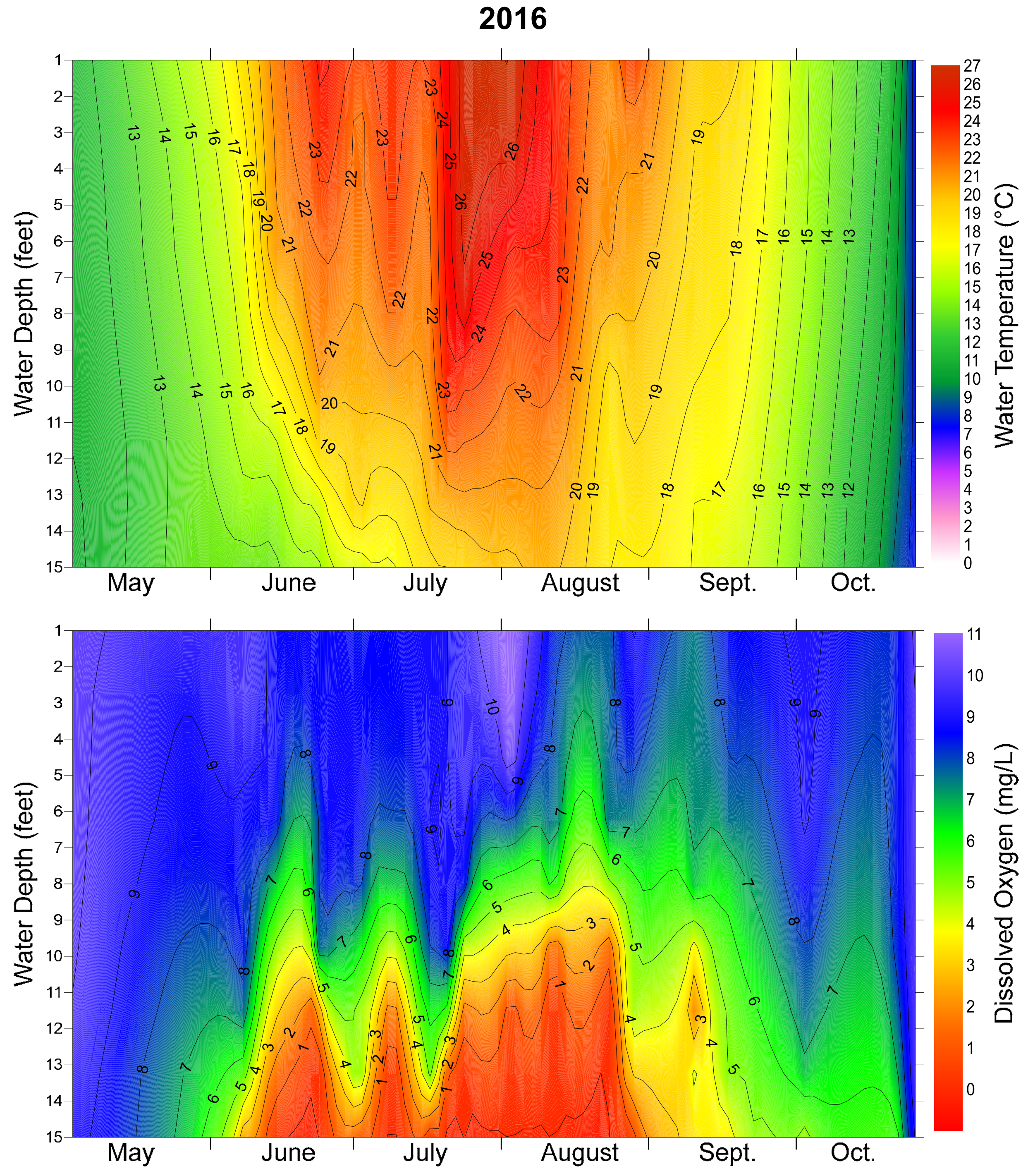


Figure 8.5.1-5. Scattering Rice Lake 2016 temperature (top) and dissolved oxygen (bottom) isopleths. Data collected by Scattering Rice volunteers at the deep hole sampling location.

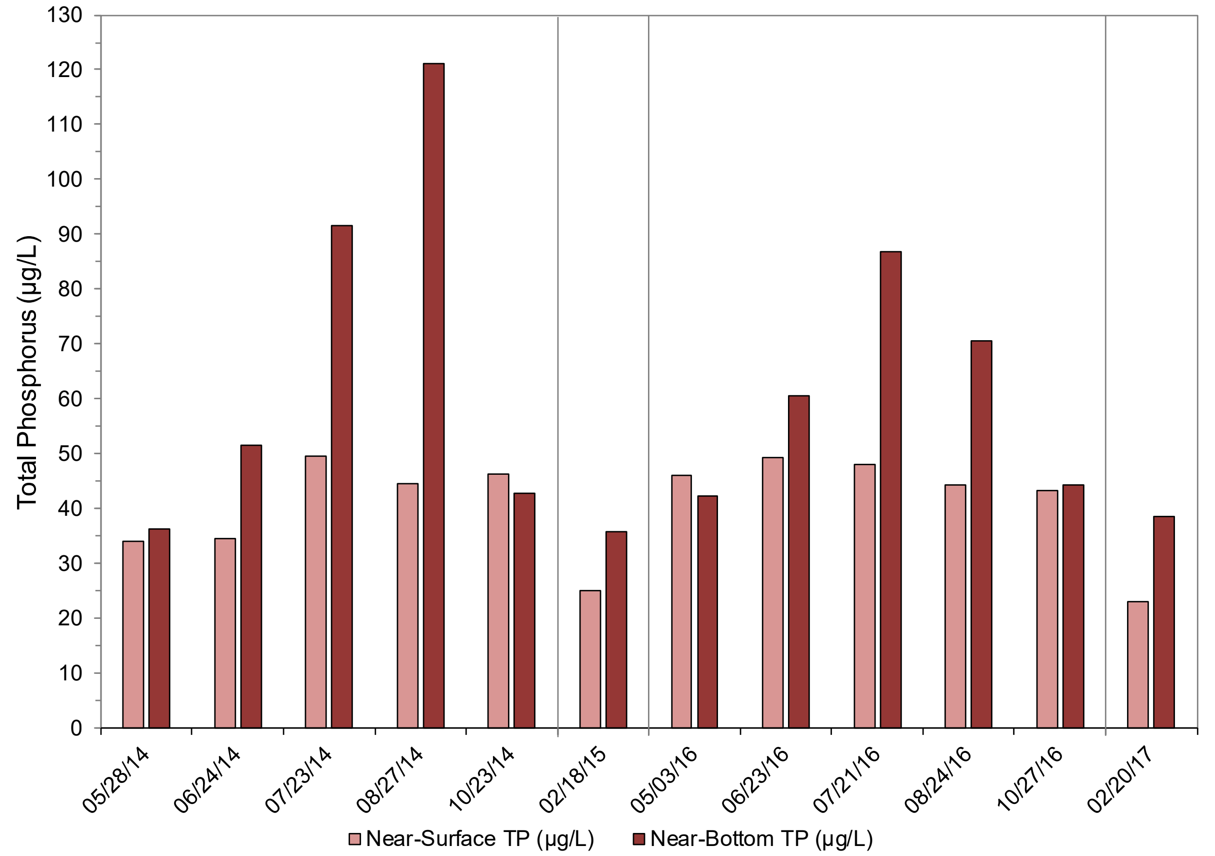


Figure 8.5.1-6. Scattering Rice Lake 2014-2017 near-surface and near-bottom total phosphorus concentrations.

To determine if internal nutrient loading in Scattering Rice Lake can account for the difference between the WiLMS predicted phosphorus concentration and measured concentrations, the estimated net internal load (P_{internal}) of phosphorus in pounds in Scattering Rice Lake using data from 2014 and 2016 were calculated using the following equation from James et al. 2015:

$$\Delta P_{\text{lake storage}} = (P_{\text{external load}} - P_{\text{outflow}}) + P_{\text{internal}},$$

Where:

$\Delta P_{\text{lake storage}}$ is the change in total phosphorus mass in pounds within the lake between spring overturn and the late-summer mixing events.

$P_{\text{external load}}$ is the external load of phosphorus in pounds from the watershed between spring overturn and the late-summer mixing events as estimated from WiLMS.

P_{outflow} is the estimated outflow of phosphorus in pounds from the lake between the spring overturn and late-summer mixing events as estimated from WiLMS.

Using the equation above, it is estimated that approximately 680 pounds of phosphorus are released from bottom sediments into the overlying from May through August on average annually in Scattering Rice Lake. While this estimate represents a significant amount of phosphorus, the WiLMS model indicates that an additional 680 pounds of phosphorus from internal nutrient loading would only raise near-surface total phosphorus concentrations from the predicted 23 µg/L to 28 µg/L, still 35% lower than measured concentrations. This modeling indicates that while internal nutrient loading likely elevates Scattering Rice Lake's phosphorus by approximately 5 µg/L, it alone cannot account for the higher phosphorus concentrations measured within the lake. WiLMS indicates that an additional phosphorus load of approximately 2,600 pounds per year are needed to achieve the measured growing season mean concentration of 43 µg/L.

In an effort to quantify where this unaccounted 2,600 pounds of phosphorus is originating, Scattering Rice Lake's surficial watershed was examined in greater detail. Specifically, total phosphorus concentrations measured at various locations in the Deerskin River were analyzed (Figure 8.5.1-7). Four sampling stations spanning the length of the river had available total phosphorus data (Scattering Rice Lake – Map 1). Total phosphorus concentrations were measured on six occasions over the course of the growing season in 2015 at the Myzska Road and Blackjack Road sampling locations. The average concentration measured at the Myzska Road station was 17 µg/L and is similar to the concentration measured in upstream Long Lake in 2015. Downstream at the Blackjack Road station, phosphorus concentrations were on average twice as high at 35 µg/L when compared to the Myzska Road station. Similarly, total phosphorus concentrations measured in 2011 at the Rangeline Road station, the downstream-most station, averaged 33 µg/L.

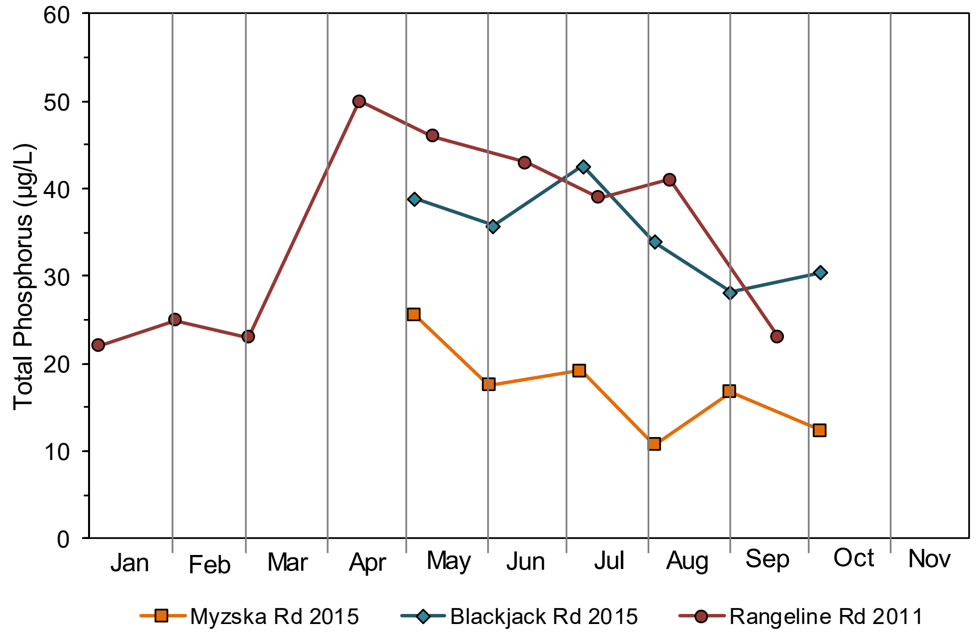


Figure 8.5.1-7. Deerskin River total phosphorus concentrations from the Myzska Rd station, Blackjack Rd station, and Rangeline Rd station.

These phosphorus concentrations measured in the Deerskin River indicate that somewhere between the Myzska Road station and Blackjack Road station sufficient phosphorus is being loaded to the river to effectively double the concentration of phosphorus. The watershed for this section of the river is largely comprised of forests and wetlands; however, the Town of Phelps wastewater treatment facility (WWTF) discharges into an adjacent wetland which flows into an unnamed tributary of the Deerskin River between the Myzska Road and Blackjack Road sampling locations (Scattering Rice Lake – Map 1). In an effort to determine if the Phelps WWTF could be contributing a significant amount of phosphorus to the Deerskin River and Scattering Rice Lake, Onterra ecologists reached out to WDNR scientists to obtain phosphorus loading estimates from the Phelps WWTF.

Information provided by WDNR scientists indicated that the Phelps WWTF discharges on average 0.0467 million gallons of water per day with an average effluent phosphorus concentration of 2,244 µg/L. Using the average discharge rate and effluent concentration, it is estimated that the Phelps WWTF discharges approximately 319 pounds of phosphorus per year. Adding this additional annual discharge and phosphorus from the Phelps WWTF into WiLMS watershed model yields a predicted in-lake growing season phosphorus concentration of 29 µg/L, still 48% lower than the measured 43 µg/L. While the Phelps WWTF is likely a contributor of phosphorus to Scattering Rice Lake, the amount discharged is only predicted to increase the lake's phosphorus concentrations by 4 µg/L and it cannot account for the additional 2,370 pounds WiLMS indicates is required to achieve the measured concentration of 43 µg/L. As is discussed within the Scattering Rice Lake Watershed Section (Section 8.5.2), phosphorus loading from riparian septic systems was also estimated using data collected from the 2013 stakeholder survey. These data indicate that septic systems account for only 17 pounds of phosphorus to Scattering Rice annually.

Given the total estimated amount of phosphorus from internal loading, the Phelps WWTF, and riparian septic systems cannot account for the additional phosphorus WiLMS indicates is required to achieve the measured phosphorus concentration of 43 µg/L, it is believed that the WiLMS model is underestimating the amount of phosphorus originating from natural areas within the watershed. WiLMS uses heavily averaged export coefficients for different land cover types within the watershed (forests, wetlands, etc.) and the model creators suggest using local export coefficients when possible. Unfortunately, local phosphorus export coefficients are not available. It is possible that the wetlands in Scattering Rice Lake's watershed, particularly the ones adjacent to the Deerskin River, likely have higher phosphorus export rates than the one WiLMS utilizes and is the reason WiLMS predicted a lower in-lake concentration of phosphorus.

Currently, the WDNR is developing a Total Maximum Daily Load (TMDL) for waterbodies within the Wisconsin River Watershed which includes Scattering Rice Lake. The Clean Water Act established the term TMDL, which is the maximum amount of a given pollutant (i.e. phosphorus) that a waterbody can receive and still meet the defined water quality standards. The Clean Water Act requires that the WDNR provides the Environmental Protection Agency with a list of waterbodies in Wisconsin that do not meet water quality standards under the Clean Water Act, or waterbodies that considered to be impaired. Scattering Rice Lake was proposed for listing on the list of impaired waterbodies for total phosphorus concentrations which exceed the thresholds for recreational use and aquatic life use. The completion of the TMDL for the Wisconsin River Watershed will identify waterbodies that are currently impaired and develop TMDLs for each of these waterbodies.

While it is believed that the discrepancy between the WiLMS predicted and measured total phosphorus in Scattering Rice Lake are due to underestimates of phosphorus originating from natural sources in the watershed by WiLMS, a more detailed study would need to be completed to determine if this is truly the case. This study would likely involve sampling at numerous locations along the Deerskin River multiple times per year over a two- to three-year period. If this study were to show that natural sources of phosphorus were higher than rates used in the model, there would be no management actions that could be taken to reduce these natural sources of phosphorus.

Scattering Rice Lake Trophic State

The Trophic State Index (TSI) values calculated with Secchi disk, chlorophyll-*a*, and total phosphorus values range in values spanning from upper mesotrophic to eutrophic (Figure 8.5.1-3). In general, the best values to use in judging a lake's trophic state are total phosphorus and chlorophyll-*a* because water clarity can be influenced by factors other than algae; therefore, relying primarily on total phosphorus and chlorophyll-*a* TSI values, it can be concluded that Scattering Rice Lake is in a eutrophic state.

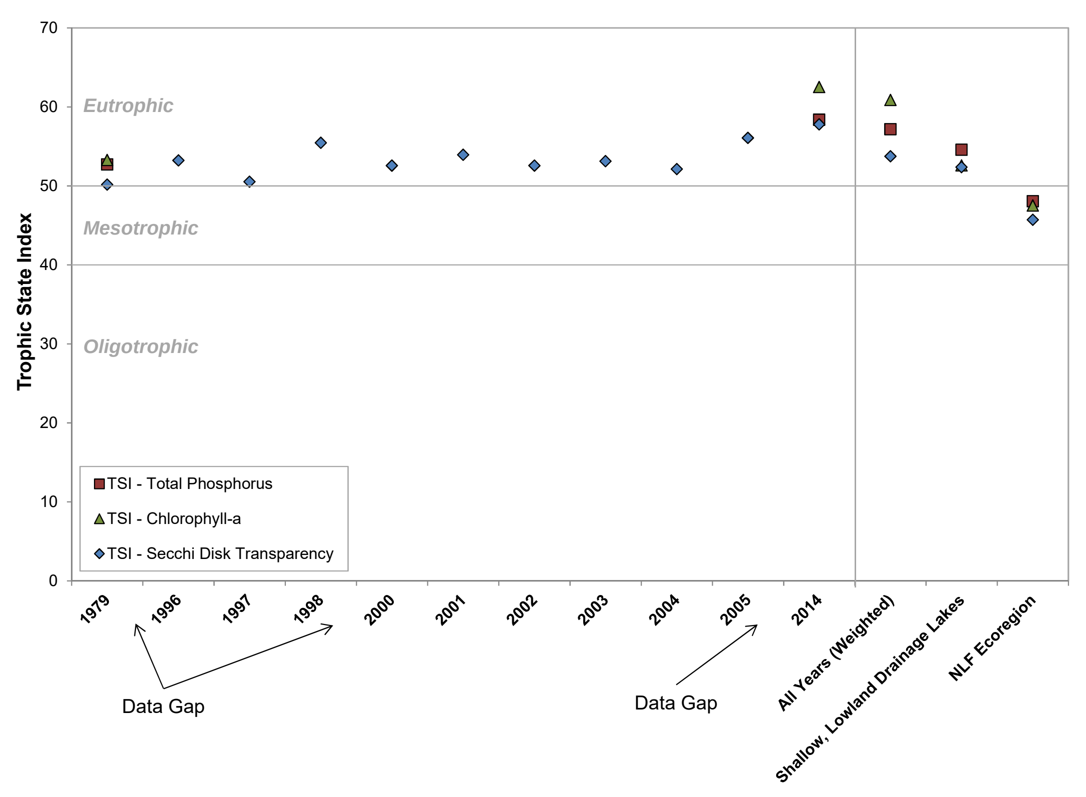


Figure 8.5.1-3. Scattering Rice Lake, statewide shallow, lowland drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Scattering Rice Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Scattering Rice Lake by Onterra staff. Graphs of those data are displayed in Figure 8.5.1-4 for all sampling events. As discussed previously, the temperature and dissolved oxygen profiles illustrate that Scattering Rice Lake weakly stratifies during the summer months, but increases in water temperature near the bottom over the summer indicate periodic mixing. In February of 2015, oxygen levels remained sufficient throughout most of the water column to support most aquatic life in northern Wisconsin lakes.

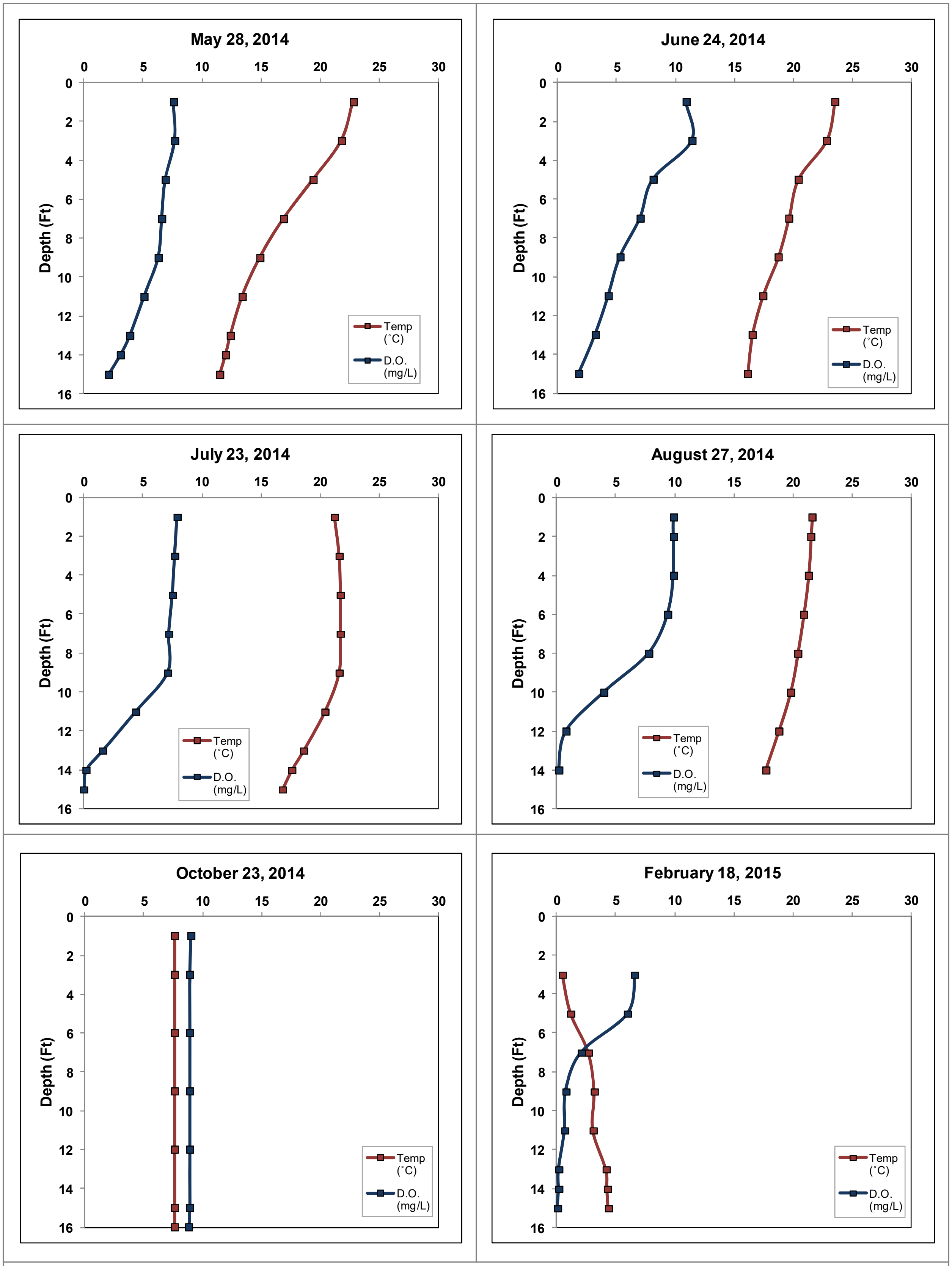


Figure 8.5.1-4. Scattering Rice Lake 2014/2015 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Scattering Rice 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 Scattering Rice 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. Scattering Rice Lake's surface water pH was measured at roughly 7.5 during May and 7.8 during July of 2014. 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 Scattering Rice Lake was measured at 36.6 and 44.1 mg/L as $CaCO_3$ in May and July of 2014. 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 Scattering Rice Lake during 2014. 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 Scattering Rice Lake's pH of 7.5 – 7.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Scattering Rice Lake was found to be 10.4 mg/L in May and 9.11 mg/L in July of 2014, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2014 and these samples were processed by the WDNR for larval zebra mussels. Their analysis was negative for the presence of zebra mussel veligers.

True color is a measure of water clarity once suspended material (i.e. algae, sediments) has been removed is called true color. True color measures the amount of light scattered and absorbed by organic materials dissolved within the water. Many lakes in the northern region of Wisconsin have natural dissolved organic materials from decomposing plant material delivered from wetlands within the watershed. These give the water a tea-like color and decrease water clarity. Scattering Rice Lake had an average true color value of 50.0 SU (standard units), indicating the water is most often lightly tea-colored. Lakes with large areas of forests and wetlands within their watersheds tend to have tea-colored or stained water, as these dissolved organic materials within the lake's water originate from decaying vegetation within the watershed.

8.5.2 Scattering Rice Lake Watershed Assessment

Scattering Rice Lake's watershed is approximately 42,860 acres in size. Compared to its surface area of 263 acres, this makes for a large watershed to lake area ratio of 160:1.

Exact land cover calculation and modeling of nutrient input to Scattering Rice Lake will be completed towards the end of this project (in 2016-2017). 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.

8.5.3 Scattering Rice 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 2014, Scattering Rice Lake's immediate shoreline was assessed in terms of its development. Scattering Rice Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 2.8 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.5.3-1). This constitutes about 63% of Scattering Rice 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, 0.8 miles of urbanized and developed–unnatural shoreline (17%) was observed. If restoration of the Scattering Rice 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. Scattering Rice Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

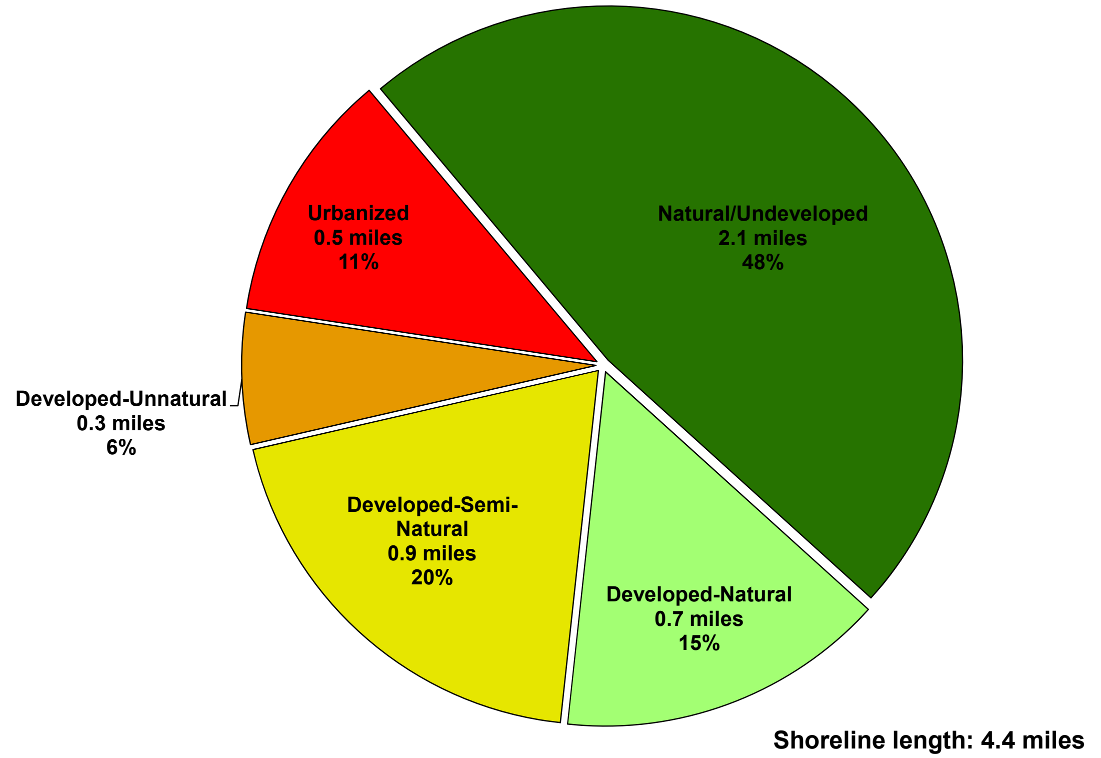


Figure 8.5.3-1. Scattering Rice Lake shoreland categories and total lengths. Based upon a late summer 2014 survey. Locations of these categorized shorelands can be found on Scattering Rice Lake – Map 1.

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 Eagle River 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, 155 total pieces of coarse woody habitat were observed along 4.4 miles of shoreline, which gives Scattering Rice Lake a coarse woody habitat to shoreline mile ratio of 36:1 (Figure 8.5.3-2). Locations of coarse woody habitat are displayed on Scattering Rice 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).

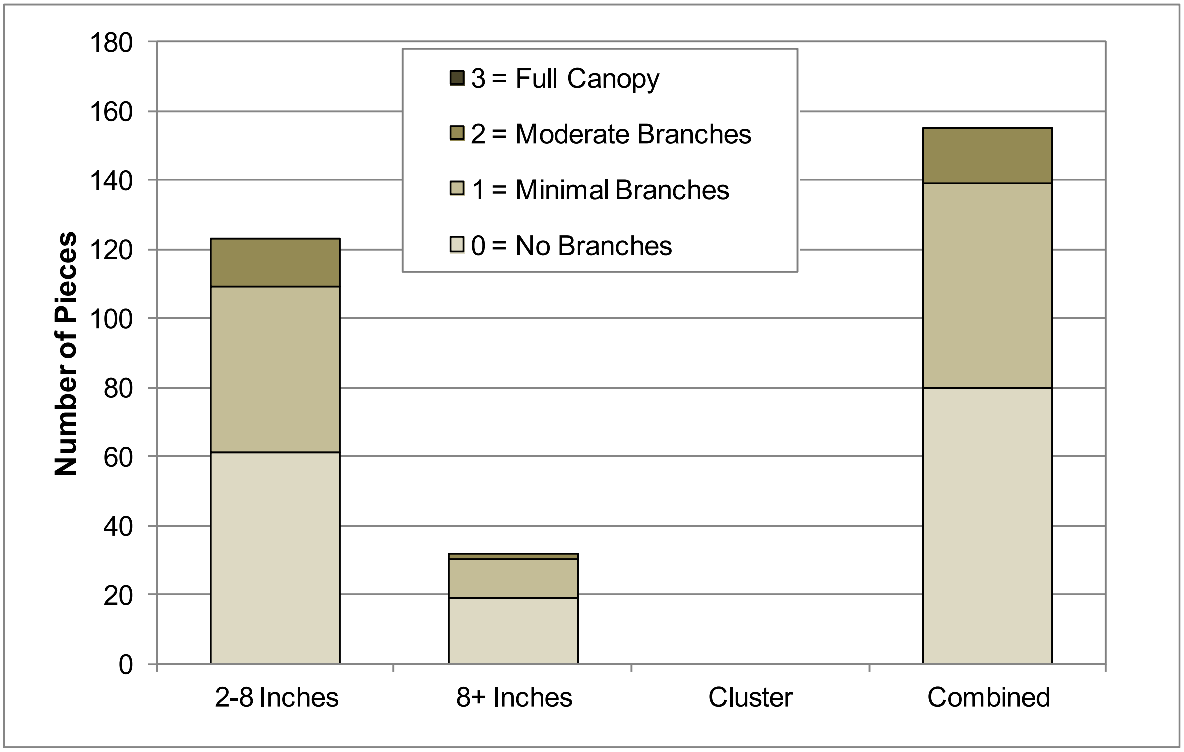


Figure 8.5.3-2. Scattering Rice Lake coarse woody habitat survey results. Based upon a late summer 2014 survey. Locations of Scattering Rice Lake coarse woody habitat can be found on Scattering Rice Lake – Map 2.

8.5.4 Scattering Rice Lake Aquatic Vegetation

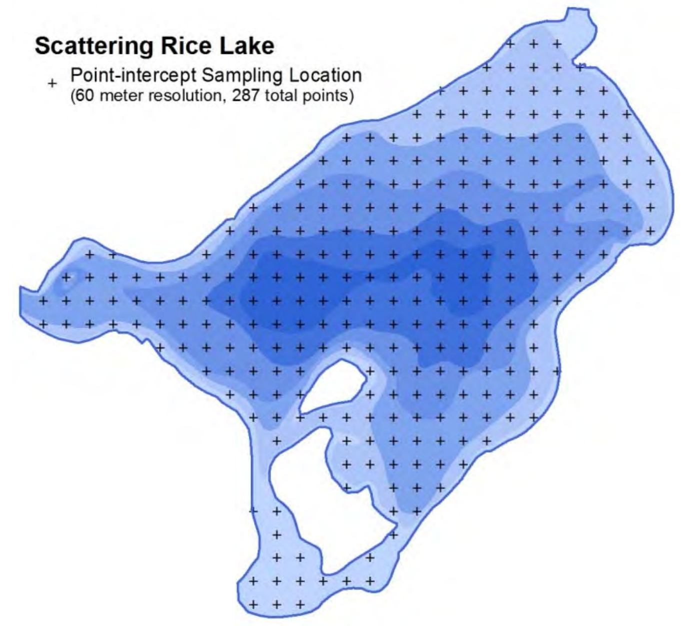


Figure 8.5.4-1. Point-intercept locations on Scattering Rice Lake.

An early season aquatic invasive species survey was conducted on Scattering Rice Lake on July 7, 2014. 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.

The whole-lake aquatic plant point-intercept survey was conducted on Scattering Rice Lake by Onterra on August 2, 2012 (Figure 8.2.4-1), while the aquatic plant community mapping survey was conducted on July 30, 2014. During these surveys, a total of 35 aquatic plant species were located, two of which are considered to be a non-native, invasive species: Eurasian watermilfoil and purple loosestrife (Table 8.5.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 22% of the point-intercept locations within littoral areas contained sand, 78% contained fine, organic sediments (muck), and 0% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 9 feet, similar to 10 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Table 8.5.4-1. Aquatic plant species located in Scattering Rice Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2014 (Onterra)
E	*Calla palustris*	Water arum	9		I
	Carex utriculata	Common yellow lake sedge	7		I
	Eleocharis palustris	Creeping spikerush	6		I
	Lythrum salicaria	Purple loosestrife	Exotic		I
	Pontederia cordata	Pickerelweed	9	X	X
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
FL	*Nuphar variegata*	Spatterdock	6	X	X
	Nymphaea odorata	White water lily	6	X	X
FL/E	*Sparganium androcladum*	Shining bur-reed	8		X
	Sparganium eurycarpum	Common bur-reed	5		I
Submergent	*Bidens beckii*	Water marigold	8	X	X
	Ceratophyllum demersum	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6	X	X
	Myriophyllum sibiricum	Northern water milfoil	7	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	I
	Najas flexilis	Slender naiad	6		X
	Nitella spp.	Stoneworts	7		X
	Potamogeton alpinus	Alpine pondweed	9		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton natans	Floating-leaf pondweed	5	X	I
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8	X	X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Utricularia minor	Small bladderwort	10		X
	Utricularia vulgaris	Common bladderwort	7	X	X
	Vallisneria americana	Wild celery	6	X	X
S/E	*Sagittaria cristata*	Crested arrowhead	9		I
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	N/A	X	
FF	*Lemna trisulca*	Forked duckweed	6		X
	Lemna turionifera	Turion duckweed	2	X	
	Riccia fluitans	Slender riccia	7		X
	Spirodela polyrhiza	Greater duckweed	5	X	

E = Emergent, 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*

Of the 120 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 24% contained aquatic vegetation. This is lower than what was found in the 2006 survey where approximately 36% of the littoral sampling locations contained aquatic vegetation. Map Scat-2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake. Nineteen percent of the point-intercept locations had a total rake fullness rating of 1, 17% had a total rake fullness rating of 2, and 8% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.5.4-1 displays the aquatic plant species located in Scattering Rice Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006, except for arrowhead sp. (rosette), turion duckweed, and greater duckweed, were recorded in 2012. Arrowhead sp. (rosette) was only recorded at two sampling locations in 2006, so it is likely it just went undetected during the 2012 point-intercept survey due to its low abundance. Both turion duckweed and greater duckweed are small, free-floating species that were also recorded in low abundance in 2006. An additional 15 native aquatic plant species were located in Scattering Rice Lake in 2012 that had not been recorded in 2006, including two environmentally sensitive species, alpine pondweed and small bladderwort.

Of the 25 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, fern pondweed, coontail, and slender naiad were the four-most frequently encountered (Figure 4.5-2). Wild celery, or tape grass, was the third-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 19%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Fern pondweed was the second-most abundant plant in Scattering Rice Lake in 2012 with a littoral occurrence of approximately 13%. As its name suggests, has the appearance of a fern’s leaf and is a common pondweed found in lakes in northern Wisconsin. 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.

Coontail was the third-most frequently encountered aquatic plant in Scattering Rice Lake in 2012 with a littoral occurrence of approximately 13%. Resembling the shape of a raccoon’s tail, coontail is arguably one of the most common aquatic plant species in Wisconsin. Able to grow in a range of conditions, its dense whorls of stiff leaves provide excellent habitat for macroinvertebrates and other wildlife.

Slender naiad, the fourth-most abundant aquatic plant in Scattering Rice Lake in 2012 with a littoral occurrence of nearly 11%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997).

In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

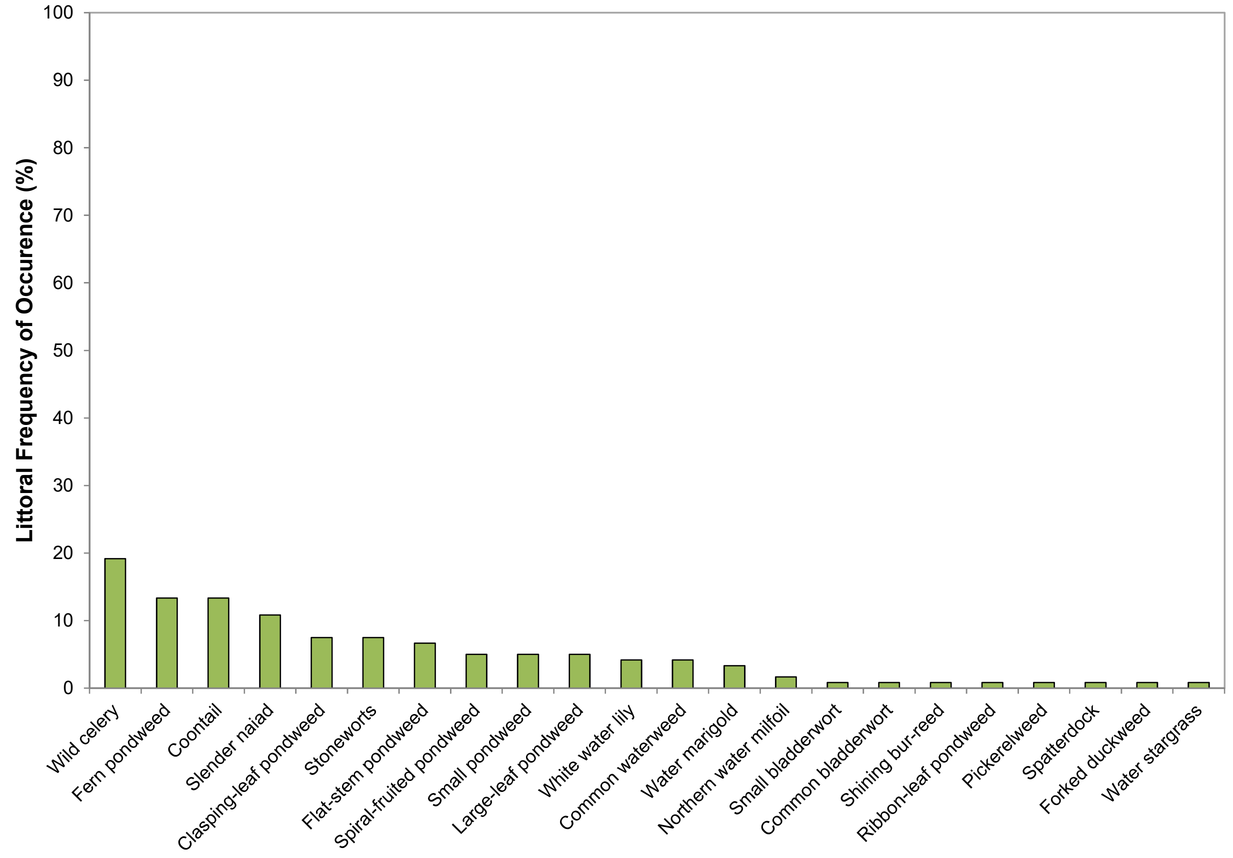


Figure 8.5.4-2. Scattering Rice Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

To determine if the 2008-2012 Eurasian watermilfoil control project on Scattering Rice Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Unlike the other lakes within the chain that only had spot treatments targeting specific areas for Eurasian watermilfoil control over the course of the project, Scattering Rice Lake underwent a low-dose, whole-lake liquid 2,4-D treatment in 2010 with the intent of targeting Eurasian watermilfoil at the lake-wide level.

Figure 4.5-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that have occurred in Scattering Rice Lake. As illustrated, the occurrence of Eurasian watermilfoil in Scattering Rice Lake was reduced by a statistically valid 100%, from an occurrence of nearly 18% in 2006 to 0% in 2012. While Eurasian watermilfoil was not recorded during the 2012 point-intercept survey, it is still present in very low abundance Scattering Rice Lake.

Five native aquatic plant species exhibited statistically valid reductions in their littoral occurrence from 2006 to 2012 (Figure 4.5-3). These include coontail, northern watermilfoil, spatterdock, flat-stem pondweed, and common waterweed. Like Eurasian watermilfoil, coontail, northern watermilfoil, and spatterdock are dicots, and are susceptible to types of treatments that have occurred on Scattering Rice Lake. Flat-stem pondweed and common waterweed are monocots, and were not historically believed to be sensitive to dicot-selective herbicides like 2,4-D. However, emerging research being conducted by the WDNR and US Army Corps of Engineers indicates that both flat-stem pondweed and common waterweed may be prone to decline following low-dose, whole-lake 2,4-D treatments. Five other native aquatic plant species saw statistically valid increases in their occurrence from 2006 to 2012, while the occurrences of three others were not statistically different (Figure 4.5-3).

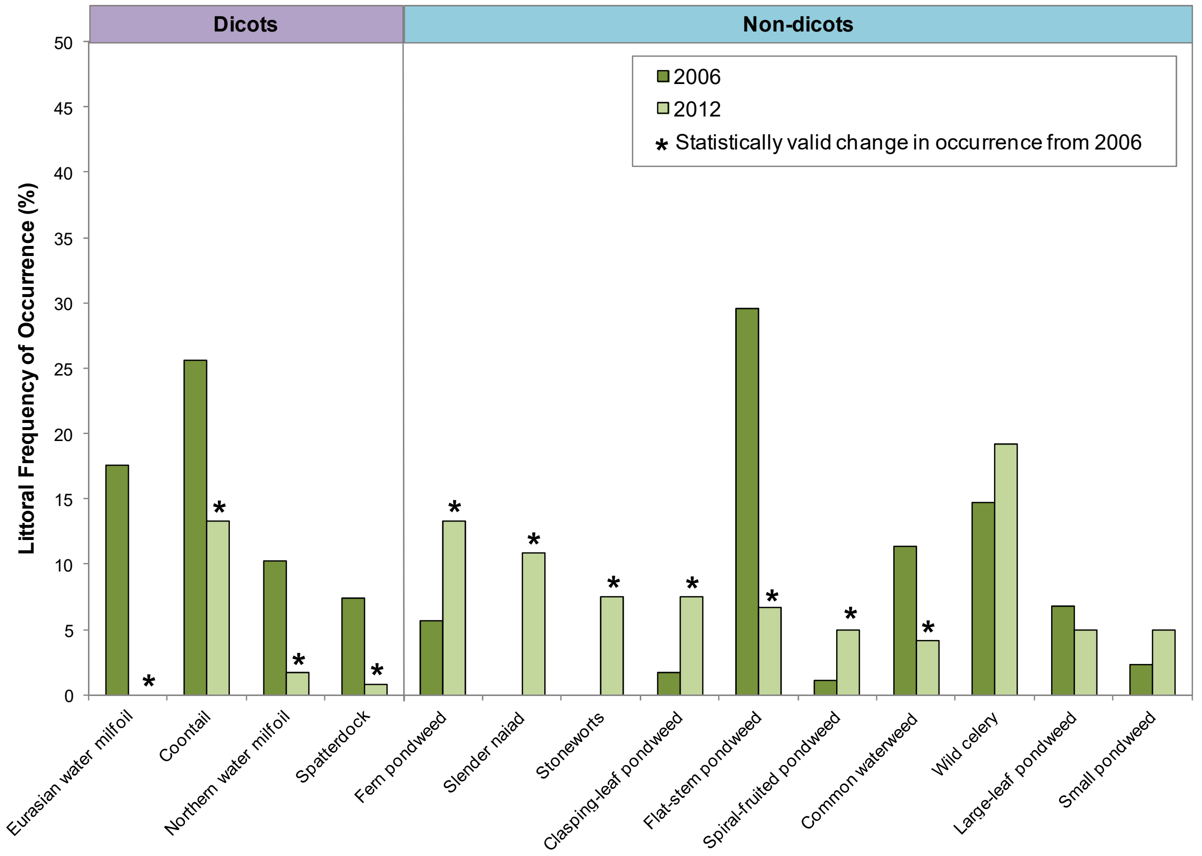


Figure 8.5.4-3. Scattering Rice Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total 33 native aquatic plant species were located in Scattering Rice Lake during the 2012 survey, 25 were encountered on the rake and eight were incidentally located. These 25 native species and their conservatism values were used to calculate the FQI of Scattering Rice Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.2.4-4 compares the FQI components of Scattering Rice Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Scattering Rice Lake's native species richness (25) is significantly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.9) is slightly higher than the ecoregional median but above the state median. Combining Scattering Rice Lake's 2012 native species richness and average conservatism values yields an exceptionally high FQI value of 34.6, which greatly exceeds the ecoregional and state median values (Figure 8.2.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Scattering Rice Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Scattering Rice Lake's aquatic plant community is of higher quality than the majority of lakes within the ecoregion and the entire state.

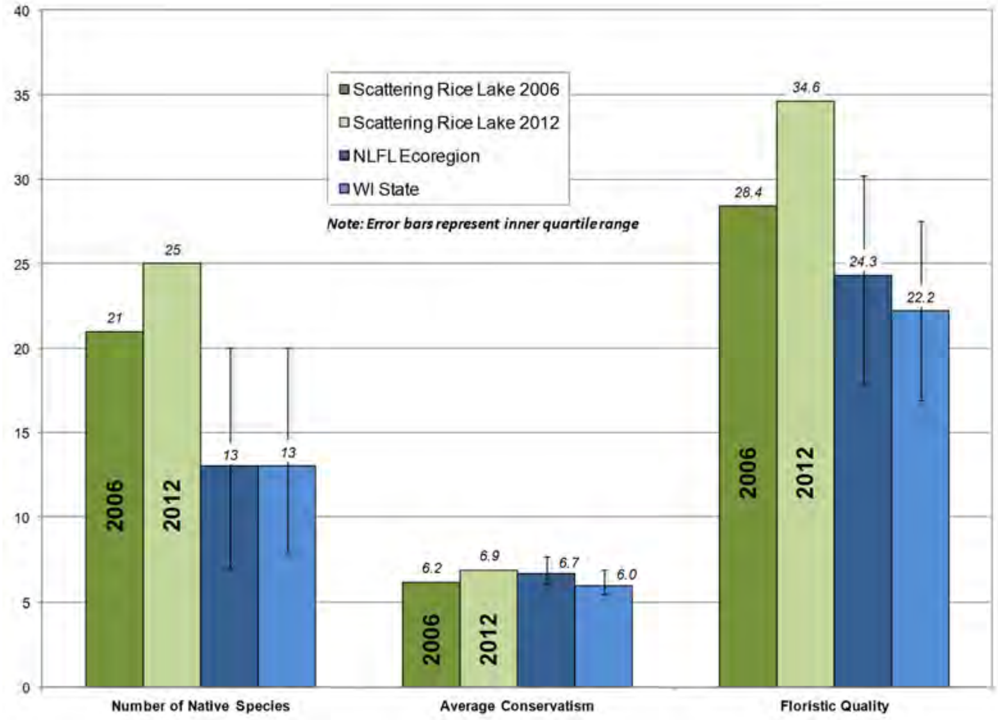


Figure 8.5.4-4. Scattering Rice Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

As explained in the primer section, lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. In addition, a plant community with a mosaic of species with differing morphological attributes provides zooplankton, macroinvertebrates, fish, and other wildlife with diverse structural habitat and various sources of food. Because Scattering Rice Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity.

However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Scattering Rice Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.2.4-5). Using the data collected from the 2012 point-intercept survey, Scattering Rice Lake's aquatic plant community was shown to have exceptionally high species diversity with a Simpson's diversity value of 0.92, falling above the upper quartile value for lakes in both the ecoregion and the state. Scattering Rice Lake's 2012 diversity was the same diversity calculated from data collected during the 2006 point-intercept survey (0.82).

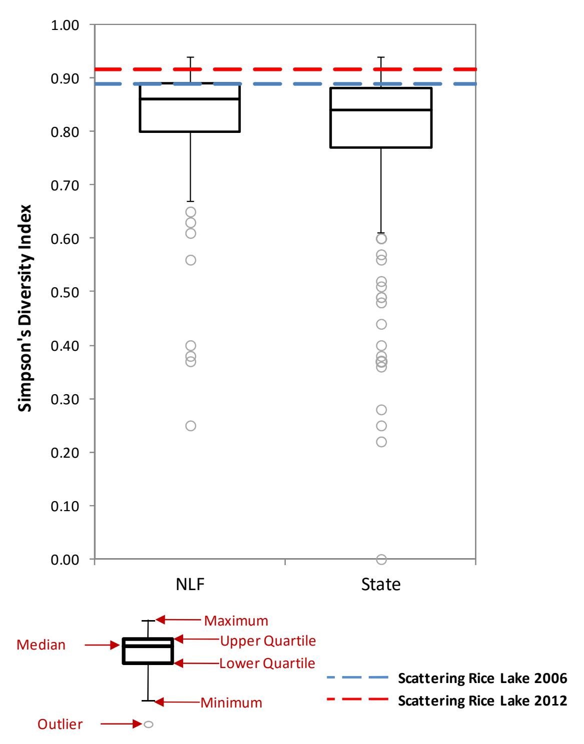


Figure 8.5.4-5. Scattering Rice Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 8.2.4-6 displays the relative frequency of occurrence of aquatic plant species in Scattering Rice Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

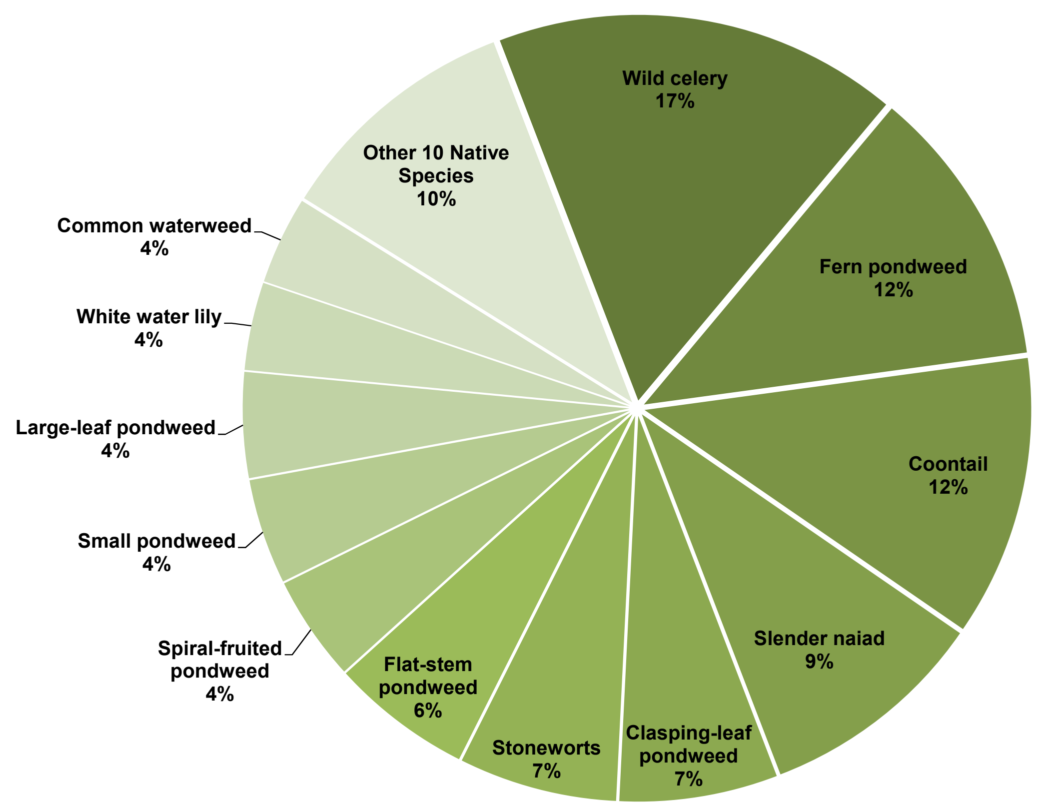


Figure 8.5.4-6. Scattering Rice Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

The 2014 aquatic plant community mapping survey revealed that Scattering Rice Lake contains approximately 21.3 acres of emergent and floating-leaf aquatic plant communities (Table 8.5.4-2, Scattering Rice Lake – Map 4). Eleven emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2014 (Table 8.5.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a ‘snapshot’ of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Scattering Rice Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

Table 8.5.4-2. Acres of emergent and floating-leaf aquatic plant communities in Scattering Rice Lake. Created using data from 2014 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-Leaf	17.6
Mixed Emergent & Floating-Leaf	3.7
Total	**21.3**

8.5.4 Scattering Rice Lake Implementation Plan

The Implementation Plan below is a result of collaborative efforts between Scattering Rice Lake stakeholders, ERCLA, and ecologists/planners from Onterra. This plan provides goals and actions created to protect the quality and integrity of Scattering Rice Lake and will serve as reference for keeping stakeholders on track and focused upon these science-driven management activities. While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas.

However, a couple management challenges specific to Scattering Rice Lake were also discussed. These include the buildup of sediment in the lower reaches and at the mouth of the Deerskin River and measured phosphorus and chlorophyll-*a* concentrations that are higher than watershed modeling predicted. As is discussed in the Chain-Wide Water Quality Section (Section 3.1), of the Phase I and Phase II lakes studied thus far, Cranberry, Catfish, Voyageur, and Eagle Lakes had relatively similar water quality while Scattering Rice Lake's nutrient and algae levels were slightly higher. Scattering Rice Lake's Implementation Plan illustrates how Scattering Rice Lake stakeholders should proceed in implementing lake-specific goals as well as applicable portions of the Chain-wide Implementation Plan for their lake.

Scattering Rice Management Goal 1: Instill an Understanding of the Cause of Increased Sedimentation within the Deerskin River and the Feasibility of Sediment Removal to Scattering Rice Lake Stakeholders

Management Action:	Educate Scattering Rice Lake stakeholders on the cause of sedimentation within the Deerskin River, its effects on the lake, and the feasibility of sediment removal.
Timeframe:	Initiate 2016
Facilitator:	Suggested: Scattering Rice Lake Planning Committee
Description:	During the Phase II Planning Committee Meetings, one of the concerns the Scattering Rice Lake Planning Committee brought forward was the relatively recent buildup of sediment within the lower reaches and in the mouth of the Deerskin River. The buildup of sediment at the mouth of a river is a natural process due to the reduction in water velocity and its inability to no longer carry sediment particles. However, the relatively recent and rapid buildup of sediment noted by Scattering Rice Lake riparians is due to the removal of a dam in the early 2000s approximately 3.5 miles upstream from Scattering Rice Lake. This dam was removed due to safety concerns as well as for restoration of the river, which is designated a Class II trout stream. Prior to its removal, the dam produced a small reservoir on the Deerskin River, which over time accumulated sediment. Following the removal of the dam, this accumulated sediment has been making

its way downstream and settling within the lower reaches of the Deerskin River where water velocity slows. Consequently, Scattering Rice Lake riparians have noted a reduction in water depth from the mouth of the Deerskin River upstream to the culvert at Rangeline Road.

After noting the increased sedimentation, Scattering Rice stakeholders contacted the Wisconsin Department of Natural Resources (WDNR) and were told that the increased sedimentation was to be expected and that it could take decades or longer for the sediment from the now drained reservoir to make its way downstream. The WDNR indicated that large-scale dredging of this portion of the Deerskin River and Scattering Rice Lake was not a feasible option, and the reasons for this were discussed at the Phase II second planning meeting. These reasons are as follows:

1) Hydraulic dredging is costly due to labor, permitting, and disposal. Dredging expenses cost anywhere from about $10-$15 per cubic yard of sediment removed. This equates to a cost of approximately $50,000 to $73,000 to remove 3 feet of sediment over one acre.
2) Hydraulic dredging represents a large disturbance to the aquatic environment. Dredging resuspends bottom sediments and nutrients and also opens up new areas for colonization by pioneering, invasive plant species like EWM.

The Scattering Rice Lake Planning Committee understood that hydraulic dredging of the Deerskin River was not a feasible option. However, they want to educate other Scattering Rice Lake stakeholders on why dredging is not a feasible option, what impact the sediment has on the lake, and what they can do if sediment is building up around their pier or boat lift.

In terms of the sediment’s impact on the lake, the buildup of organic sediment in the river and near the mouth will likely lead to increased aquatic plant growth in these areas. Surveys conducted by Onterra ecologists have found mainly native aquatic plant species in this area, and while EWM was in high abundance within this area in the recent past, active management has greatly reduced its occurrence in this area. If aquatic plant growth increases around riparian’s piers, they can manually remove (hand-pull/rake) these plants within an area 30 feet wide and as far out into the lake/river that they need to. However, this 30-foot wide area must include their pier or boatlift within it. All aquatic plants and fragments that are removed must be collected and removed from the water.

If sediment has accumulated around a pier or boat lift, lake riparians can manually remove a total of two cubic yards of sediment per year without submitting a WDNR permit. However, if motorized equipment is to be used, a WDNR permit will be required. The Scattering Rice Lake Planning Committee will educate other lake stakeholders with this information at their annual meeting and/or through ERCLA's Newsletter.

Action Steps:

1. See description above.

Scattering Rice Management Goal 2: Gain Further Insight into Scattering Rice Lake Internal Phosphorus Recycling

Management Action: Conduct additional water quality data from Scattering Rice Lake in 2016.

Timeframe: Initiate December 2015

Facilitator: Scattering Rice Lake Planning Committee with assistance from Onterra

Description: As discussed within the Chain-Wide Water Quality Section (Section 3.1) and the Scattering Rice Lake Water Quality Section (Section 8.5.1), the total phosphorus and chlorophyll-*a* data collected from Scattering Rice Lake in 2014 are higher than can be accounted for in phosphorus loads entering from the watershed. The data indicate that this is likely due to a naturally occurring phenomenon known as internal phosphorus loading, or internal phosphorus recycling. While the 2014 data indicate this is occurring, additional water quality data including the collection of temperature and dissolved oxygen profiles at regular intervals over the course of the growing season, would bring about a higher level of confidence that internal phosphorus loading is occurring.

This additional water quality sampling is proposed to occur in Scattering Rice Lake in 2016. Onterra ecologists would collect near-surface and near-bottom total phosphorus from the lake's deep hole in April/May, June, July, August, and October 2016, and through the ice in February 2017. Near-surface chlorophyll-*a* concentrations would also be measured during the open-water sampling events. Onterra will also lend a temperature/dissolved oxygen probe for use by Scattering Rice Lake volunteers to collect temperature and dissolved oxygen profiles at the lake's deep hole once per week from May through August 2016. These data will allow for a determination of how often Scattering Rice Lake mixes over the course of the growing season and an estimate of how much phosphorus is released from bottom sediments into the overlying water column. Funding for this monitoring would be sought within the Phase III WDNR AIS-

Education, Planning and Prevention Grant being submitted in December 2015.

Action Steps:

1. Scattering Rice Planning Committee recruits volunteer(s) to collect/record a temperature/dissolved oxygen profile at the lake's deep hole once per week from May – August 2016.
2. Consultant solidifies sampling design.
3. Create preliminary project cost estimate.
4. Additional cost of monitoring to be included within the WDNR AIS-EPP Phase III grant being applied for in December of 2015.

Chain-wide Implementation Plan – Specific to Scattering Rice Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action: Continue water clarity monitoring in Scattering Rice Lake through the WDNR Citizen Lake Monitoring Network (CLMN).

Timeframe: Continuation of current effort

Facilitator: Dennis Burg, current Scattering Rice Lake CLMN volunteer

Description: Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Scattering Rice Lake have been collecting water quality data intermittently since 1993. Scattering Rice Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide

Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Scattering Rice Lake currently has an active volunteer (Dennis Burg) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis. Scattering Rice Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Dennis Burg, the current CLMN volunteer, to notify Dave Mueller, the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, when a change in the collection volunteer occurs or is needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. Dennis Burg, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. Dennis Burg, current CLMN volunteer, notifies Dave Mueller or current Lakes and Shores Committee chair when a new Scattering Rice Lake volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Scattering Rice Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 17% (0.8 miles) of the shoreline are in an urbanized or developed-unnatural state, 20% (0.9 miles) is in a developed-semi-natural state, and 63% (2.8 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 17% of Scattering Rice Lake’s shoreline is in a highly-developed state, approximately 63% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake’s overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Scattering Rice Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Scattering Rice River Chain’s shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Scattering Rice Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Scattering Rice Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Scattering Rice Lake shoreland assessment, approximately 36 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Scattering Rice Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action:	Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.
Description:	Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Scattering Rice Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Scattering Rice Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA. Scattering Rice Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Scattering Rice Lake Association and ERCLA meetings. Scattering Rice Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Scattering Rice Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Scattering Rice Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action:	ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.
Description:	Scattering Rice Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Scattering Rice Lake and its stakeholders.

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

8.6 Otter Lake

An Introduction to Otter Lake

Otter Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 30 feet, a mean depth of 12 feet, and a surface area of approximately 195 acres. During the 2012 and 2016 aquatic plant studies conducted by Onterra, 27 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. Two non-native plants, Eurasian watermilfoil and pale-yellow iris can be found in Otter Lake.

Photo 8.6-1. Otter Lake, Vilas County, Wisconsin.

Lake at a Glance* – Otter Lake

Morphology	
Acreage	195
Maximum Depth (ft)	30
Mean Depth (ft)	12
Volume (acre-feet)	2,131
Shoreline Complexity	4.2
Vegetation	
Curly-leaf Survey Date	July 6, 2016
Comprehensive Survey Date	August 2, 2012
Number of Native Species	27
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil; Pale-yellow iris
Simpson's Diversity	0.88
Average Conservatism	6.5
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Transitional between phosphorus and nitrogen
Watershed to Lake Area Ratio	762:1

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

8.6.1 Otter Lake Water Quality

Water quality data were collected from Otter Lake on six occasions in 2016/2017. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Please note that the data in these graphs represent were collected during the growing season (April-October), summer months (June-August) or winter (February-March)

as indicated with each dataset. In addition to sampling efforts completed in 2016/2017, any historical data was researched and are included within this report as available.

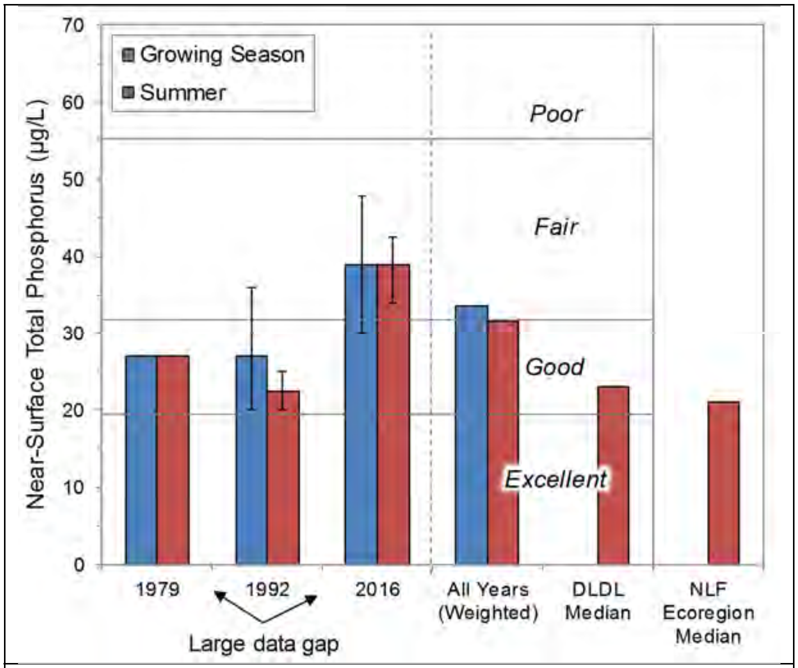


Figure 8.6.1-1. Otter Lake annual average near-surface total phosphorus and median near-surface total phosphorus concentrations for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Historical total phosphorus and chlorophyll-*a* data from Otter Lake are limited and are available from 1979 and 1992. Summer average near-surface total phosphorus was 27.0 µg/L in 1979, 22.5 µg/L in 1992, and 39.0 µg/L in 2016 (Figure 8.6.1-1). The weighted summer average total phosphorus concentration for Otter Lake is 31.5 µg/L and is higher than the median phosphorus concentration for other deep lowland drainage lakes in Wisconsin (23.0 µg/L) and the median concentration for lakes within the NLF ecoregion (21.0 µg/L), but still falls within the *good* category for Wisconsin's deep lowland drainage lakes. Given the limited amount of historical total phosphorus data from Otter Lake, it cannot be determined if phosphorus concentrations have changed or are changing over time. While near-surface total phosphorus concentrations were higher in 2016 when compared to 1979 and 1992, these higher concentrations were also measured in upstream lakes within the chain. The higher phosphorus concentrations measured in 2016 were likely due to above-average precipitation and increased runoff to these lakes.

To determine if internal phosphorus loading from bottom sediments is a significant source of phosphorus to Otter Lake, near-surface total phosphorus concentrations are compared to concentrations measured near the bottom. Figure 8.6.1-2 displays sampling events where both near-surface and near-bottom total phosphorus concentrations were measured. As illustrated, near-bottom total phosphorus concentrations were higher than those at the surface during the summer when the lake was thermally stratified. During stratification, water near the bottom becomes devoid of oxygen (anoxic) and phosphorus bound within the sediment gets released into the overlying water. The higher concentrations of phosphorus near the bottom in Otter Lake indicate that internal nutrient loading is occurring to some degree. However, the near-bottom concentrations of phosphorus are still relatively low and indicate that internal nutrient loading in Otter Lake is likely not a significant source of phosphorus to the lake.

Like total phosphorus, chlorophyll-*a* data from Otter Lake are limited and are available from 1979, 1992, and 2016 (Figure 8.6.1-3). Summer average chlorophyll-*a* concentrations were 14.0 µg/L in 1979, 11.6 µg/L in 1992, and 16.1 µg/L in 2016. The weighted average summer chlorophyll-*a* concentration in Otter Lake is 14.2 µg/L, falling above the median concentration for Wisconsin's deep lowland drainage lakes (7.0 µg/L) and the median concentration for lakes in the NLF ecoregion (5.6 µg/L). Otter Lake falls into the *fair* category for chlorophyll-*a* in a deep lowland drainage lake. The concentrations of chlorophyll-*a* measured in Otter Lake in 2016 are close to predicted concentrations based on measured near-surface total phosphorus concentrations.

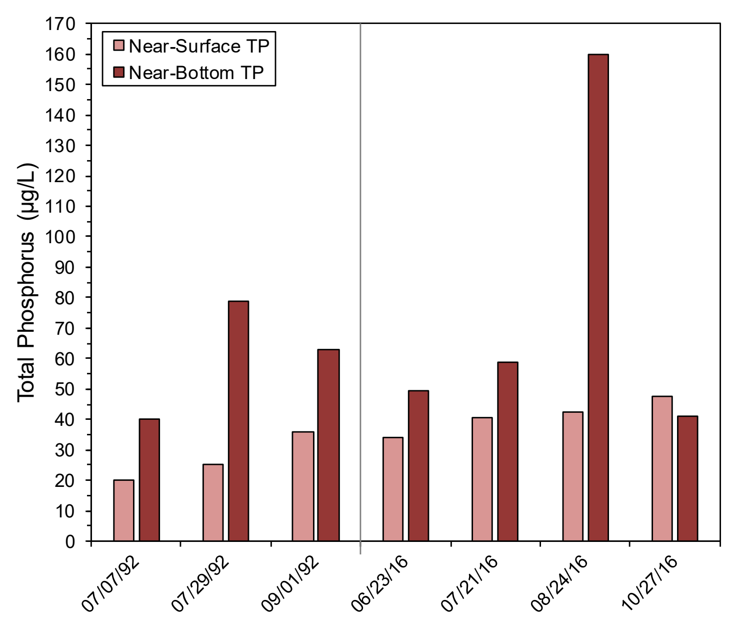


Figure 8.6.1-2. Otter Lake near-surface and near-bottom total phosphorus concentrations.

While total phosphorus and chlorophyll-*a* data are limited from Otter Lake, Secchi disk transparency data are available from 1979, 1992-1993, 2002-2013, and 2015-2016 (Figure 8.6-1-4). Average summer Secchi disk depth ranged from 3.8 feet in 1992 to near 7.0 feet in 1979 and 2004. The weighted summer average Secchi disk depth is 5.3 feet and falls into the *good* category for Wisconsin's deep lowland drainage lakes. Average summer Secchi disk depth in 2016 was lower than the historical average at 4.1 feet and lower than the 2015 measured Secchi disk depth of 6.1 feet. The below-average water clarity in 2016 was likely due to increased nutrients, algae, and tannins as a result of above-average precipitation. The annual Secchi disk data from 2002-2016 do not indicate any trends (positive or negative) in water clarity have occurred over

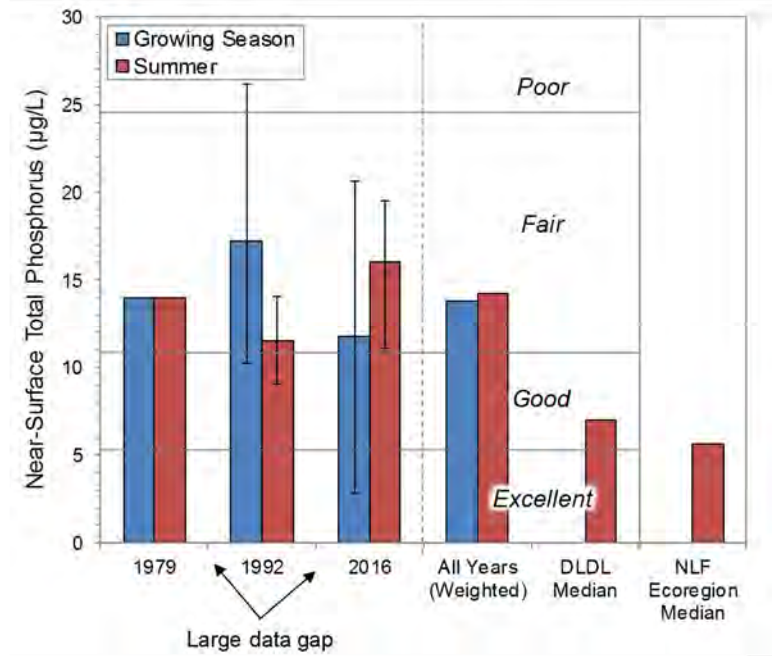


Figure 8.6.1-3. Otter Lake annual average chlorophyll-α and median chlorophyll-α concentrations for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

this time period. Overall, Otter Lake's Secchi disk depth falls below the median Secchi disk depth for Wisconsin's deep lowland drainage lakes (8.5 feet) and the median for lakes in the NLF ecoregion (8.9 feet).

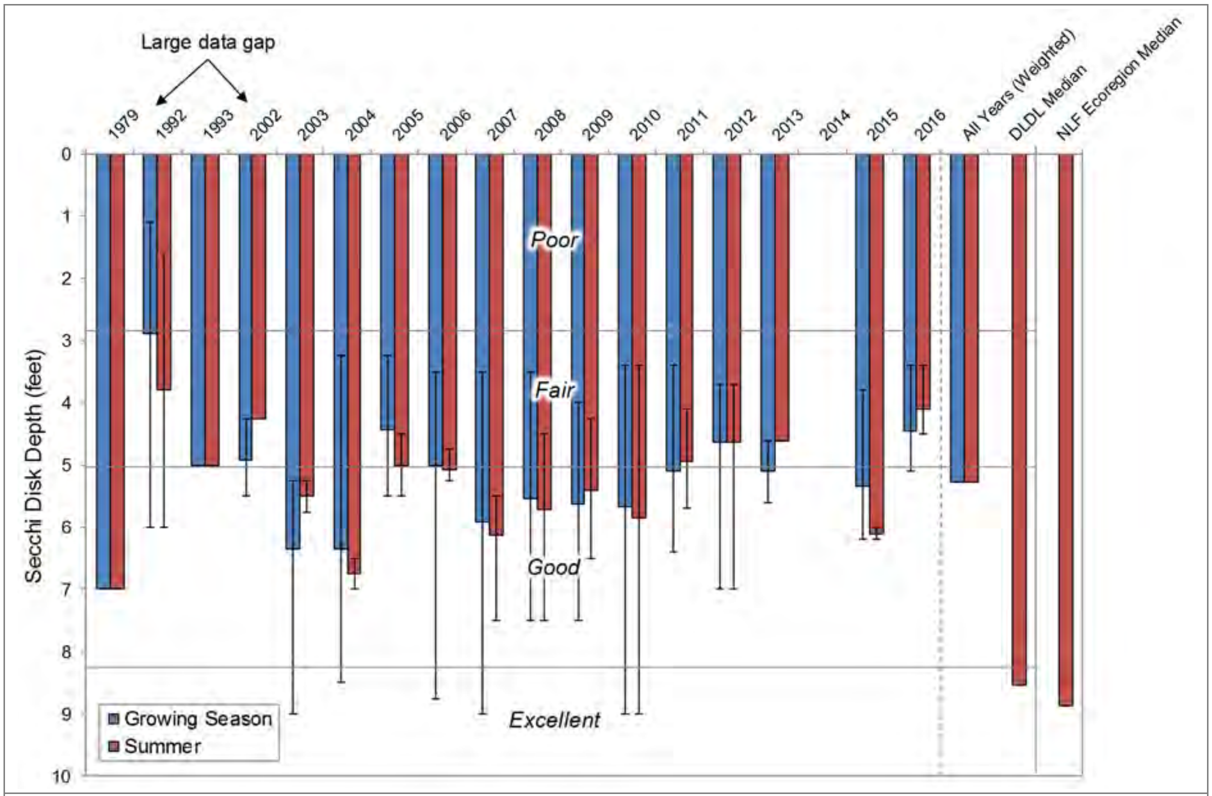


Figure 8.6.1-4. Otter Lake annual average Secchi disk depth and median Secchi disk depths for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Abiotic suspended particulates, such as sediment, also influence a lake's water clarity. *Total suspended solids*, a measure of both biotic (plankton) and abiotic suspended particles within the water were relatively low in Otter Lake in 2016. Apart from suspended particles, water clarity can also be influenced by dissolved compounds within the water. Many lakes in the northern region of Wisconsin contain higher concentrations of dissolved organic acids (tannins) that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all of the suspended material (i.e. plankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Otter Lake in 2016 averaged 40 SU (standard units), indicating the lake's water is *tea-colored*. The higher concentrations of dissolved organic acids in the lake reduce the water's clarity. It is important to note that the tea-colored water in Otter Lake and the rest of the chain is natural, and is not an indication of degraded conditions.

Limiting Nutrient in Otter Lake

As discussed in the Chain-Wide Report, in the majority of Wisconsin's lakes, phosphorus is the limiting nutrient, or the nutrient in shortest supply and is the primary nutrient regulating algal production. To determine whether phosphorus or nitrogen is the nutrient regulating algal production within a lake, the mid-summer total nitrogen (TN) to total phosphorus (TP) ratio is calculated. If the TN:TP is greater than 15, the lake is said to be phosphorus-limited. If the TN:TP is less than 10, the lake is said to be nitrogen limited. And if the TN:TP is between 10 and 15, the lake is said to be able to transition between nitrogen and phosphorus limitation.

In 2016, the mid-summer TN:TP ratio in Otter Lake was 13:1, indicating Otter Lake likely transitions between nitrogen and phosphorus limitation depending on the availability of either nutrient. Nitrogen concentrations measured in the Phase III lakes (Otter, Lynx, and Duck) in 2016 were lower than concentrations measured in the upstream Phase I and II lakes. It is believed that this perceived decrease in nitrogen concentration downstream is the result of collecting samples in different years. Changes in environmental conditions (e.g. precipitation) likely caused changes in nitrogen (and phosphorus) concentration between these years. As is discussed in the next subsection, chlorophyll-*a* concentrations in Otter Lake are closely correlated with total phosphorus concentrations, indicating that phosphorus is the primary nutrient regulating algal production in Otter Lake.

Otter Lake Trophic State

Figure 8.6.1-5 contains the Trophic State Index (TSI) values for Otter Lake calculated from the data collected in 2016 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation. The TSI values for total phosphorus, chlorophyll, and Secchi disk in Otter Lake are very similar indicating a high degree of correlation. The high degree of correlation between total phosphorus and chlorophyll-*a* indicates that while the lake may transition between phosphorus and nitrogen limitation, phosphorus is likely most often the nutrient regulating algal production within the lake. The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Otter Lake indicate the lake is in currently in a eutrophic state. Otter Lake is more productive when compared to other deep lowland drainage lakes in Wisconsin and other lakes within the NLF ecoregion.

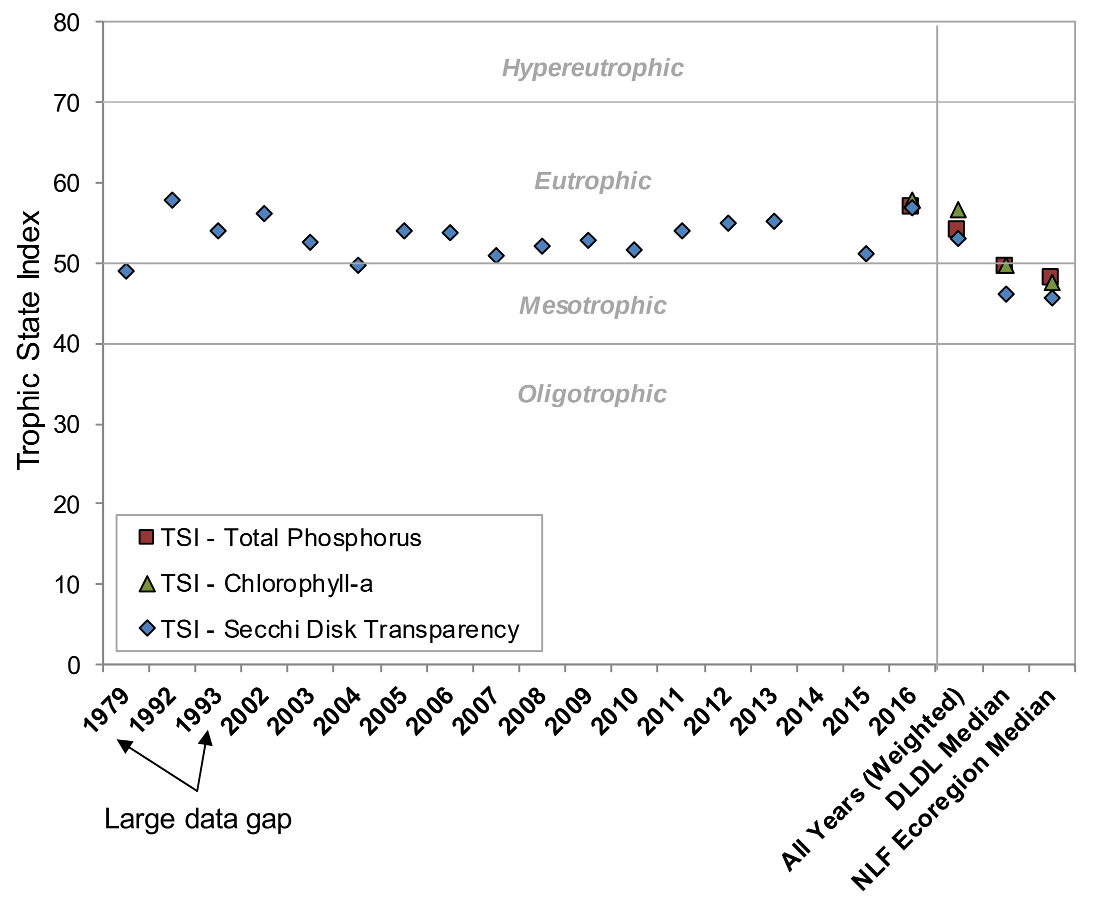
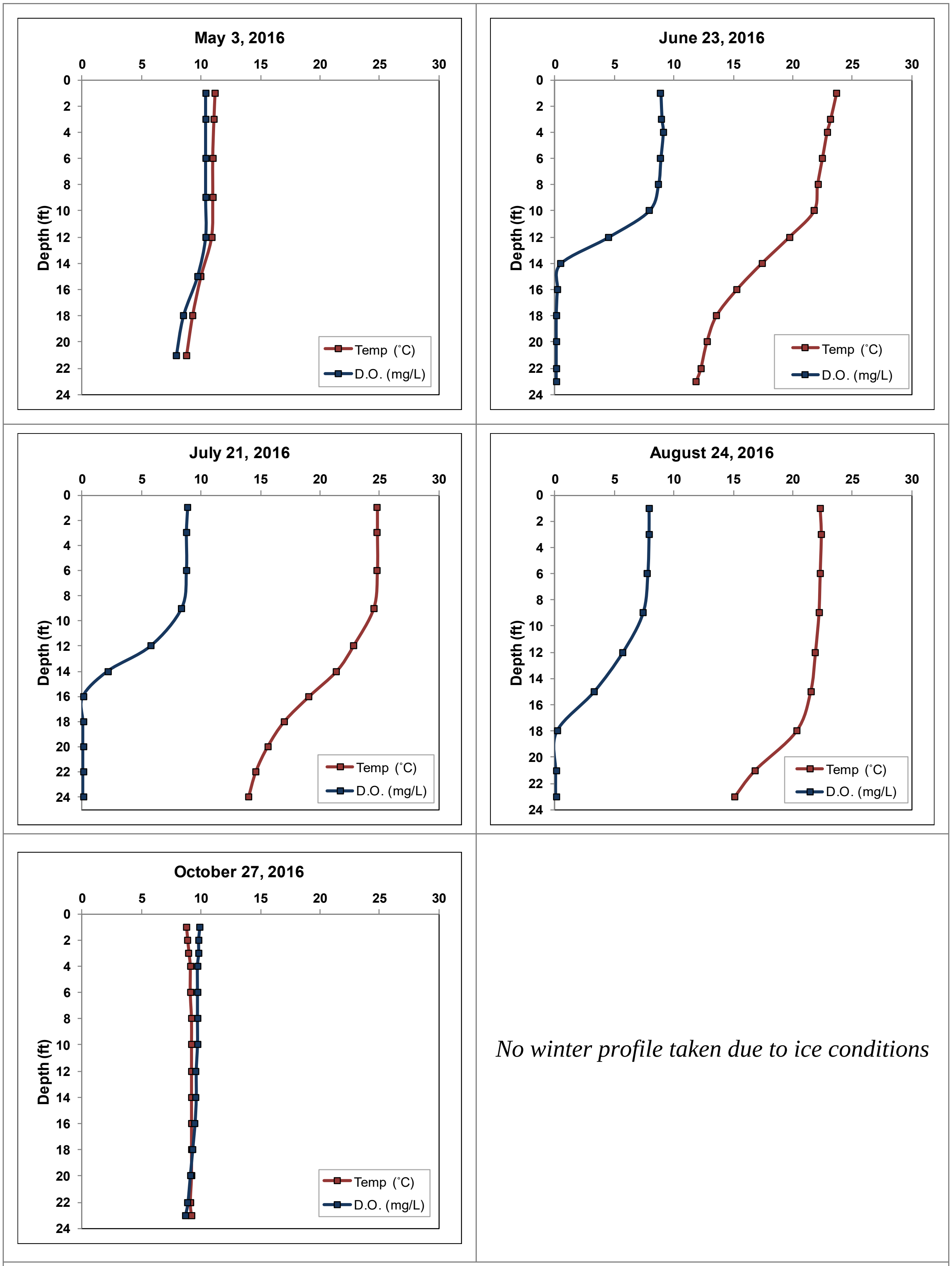


Figure 8.6.1-5. Otter Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Otter Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Otter Lake by Onterra staff. Graphs of those data are displayed in Figure 8.6.1-6 for all sampling events. An attempt to sample Otter Lake during the winter was made in February 2017, but the sampling did not occur due to unsafe ice conditions. The temperature and dissolved oxygen data indicate that Otter Lake was beginning to thermally stratify in early-May during the first sampling event. By June, the lake had formed a distinct epilimnion, metalimnion, and hypolimnion. The hypolimnion was devoid of oxygen during the summer months, and the epilimnion was gradually eroded deeper over the course of the summer. By October, surface temperatures had cooled and temperature and dissolved oxygen were relatively uniform throughout the water column indicating fall turnover was occurring.



No winter profile taken due to ice conditions

Figure 8.6.1-6. Otter Lake 2016 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Otter Lake

The previous section is centered on parameters relating to Otter Lake's trophic state. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Otter 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. Otter Lake's surface water pH was measured at roughly 7.6 during May and 7.4 during July of 2016. 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 Otter Lake was measured at 28.5 and 31.0 mg/L as $CaCO_3$ in May and July of 2016, 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 Otter Lake during 2016. 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 Otter Lake's pH of 7.4 – 7.6 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 Otter Lake was found to be 8.1 mg/L in May and 8.6 mg/L in July of 2016, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2016 and these samples were processed by the WDNR for larval zebra mussels. Their analysis was negative for the presence of zebra mussel veligers.

8.6.2 Otter Lake Watershed Assessment

Otter Lake's watershed is approximately 148,786 acres in size. Compared to its surface area of 195 acres, this makes for a large watershed to lake area ratio of 762:1.

Exact land cover calculation and modeling of nutrient input to Otter Lake will be completed in the final phase of this project (in 2017-18). 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.

8.6.3 Otter Lake Shoreland Condition

Shoreland Development

As mentioned previously in the Chain-wide Shoreland Condition Section (Section 3.3), one of the most sensitive areas of the watershed is the immediate shoreland area. This area of land is a source of protection for a lake against surface water runoff and is also a critical area for wildlife habitat. In fall of 2016, Otter Lake's immediate shoreline was assessed in terms of its development. Otter Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 1.6 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.6.3-1). This constitutes about 39% of Otter 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, 1.1 miles of urbanized and developed–unnatural shoreline (30%) was observed. If restoration of the Otter 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. Otter Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

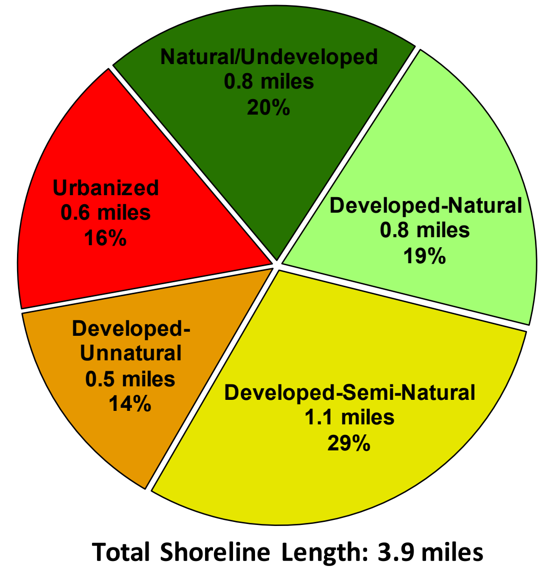


Figure 8.6.3-1. Otter Lake shoreland development categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Otter Lake – Map 1.

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 Eagle River 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.

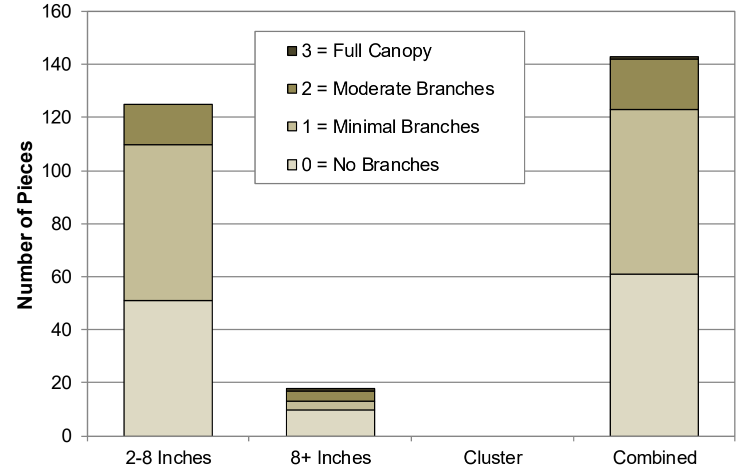


Figure 8.6.3-2. Otter Lake coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of Otter Lake coarse woody habitat can be found on Otter Lake – Map 2.

During this survey, 143 total pieces of coarse woody habitat were observed along 3.9 miles of shoreline, which yields a coarse woody habitat to shoreline mile ratio of 37:1 in Otter Lake (Figure

8.6.3-2). Locations of coarse woody habitat are displayed on Otter 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).

8.6.4 Otter Lake Aquatic Vegetation

An early season aquatic invasive species survey was conducted on Otter Lake on July 6, 2016. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of 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.

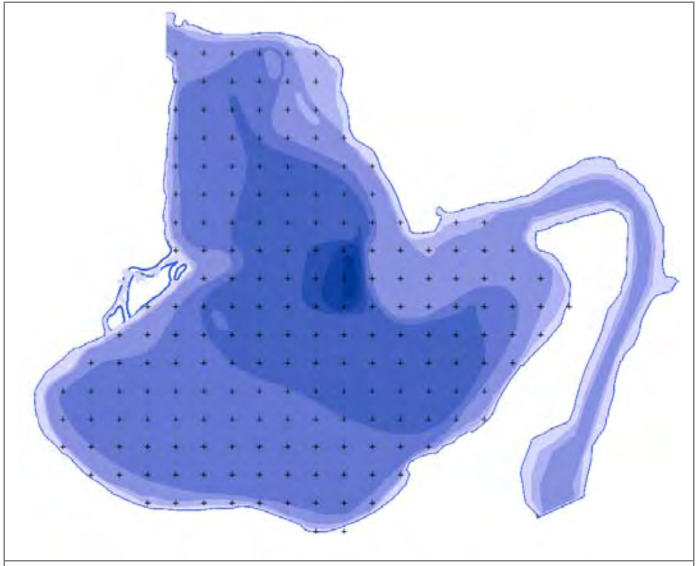


Figure 8.6.4-1. Point-intercept locations on Otter Lake.

The whole-lake aquatic plant point-intercept survey was conducted on Otter Lake by Onterra on August 2, 2012 (Figure 8.6.4-1), while the aquatic plant community mapping survey was conducted on July 12, 2016. During these surveys, a total of 29 aquatic plant species were located, two of which are considered to be a non-native, invasive species: Eurasian watermilfoil and pale-yellow iris (Table 8.6.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of *special concern* because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 83% of the point-intercept locations within littoral areas contained sand, 15% contained fine, organic sediments (muck), and 3% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2012 point-intercept survey, aquatic plants were found growing to a maximum depth of 9 feet, similar to 10 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Of the 59 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 85% contained aquatic vegetation. This is higher than what was found in the 2006 survey where approximately 72% of the littoral sampling locations contained aquatic vegetation. Map Otter Lake-2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake. Thirty percent of the point-intercept locations had a total rake fullness rating of 1, 46% had a total rake fullness rating of 2, and 24% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.6.4-1 displays the aquatic plant species located in Otter Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 were recorded in 2012. An additional 17 native aquatic plant species were located in Otter Lake in 2012 that had not been recorded in 2006, including one environmentally sensitive species, Vasey's pondweed.

Table 8.6.4-1. Aquatic plant species located in Otter Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2016 (Onterra)
Emergent	*Calla palustris*	Water arum	9		I
	Iris pseudacorus	Pale yellow iris	Exotic		I
	Pontederia cordata	Pickerelweed	9		I
	Sagittaria latifolia	Common arrowhead	3		I
	Schoenoplectus pungens	Three-square rush	5		I
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Typha spp.	Cattail spp.	1		I
FL	*Nuphar variegata*	Spatterdock	6	X	I
	Nymphaea odorata	White water lily	6		I
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		I
	Sparganium eurycarpum	Common bur-reed	5		I
	Sparganium fluctuans	Floating-leaf bur-reed	10		I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Heteranthera dubia	Water stargrass	6		X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		X
	Potamogeton strictifolius	Stiff pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Vallisneria americana	Wild celery	6	X	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*

Of the 27 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, slender naiad, small pondweed, and spiral-fruited pondweed were the four-most frequently encountered (Figure 8.6.4-2). Wild celery, or tape grass, was the most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 42%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

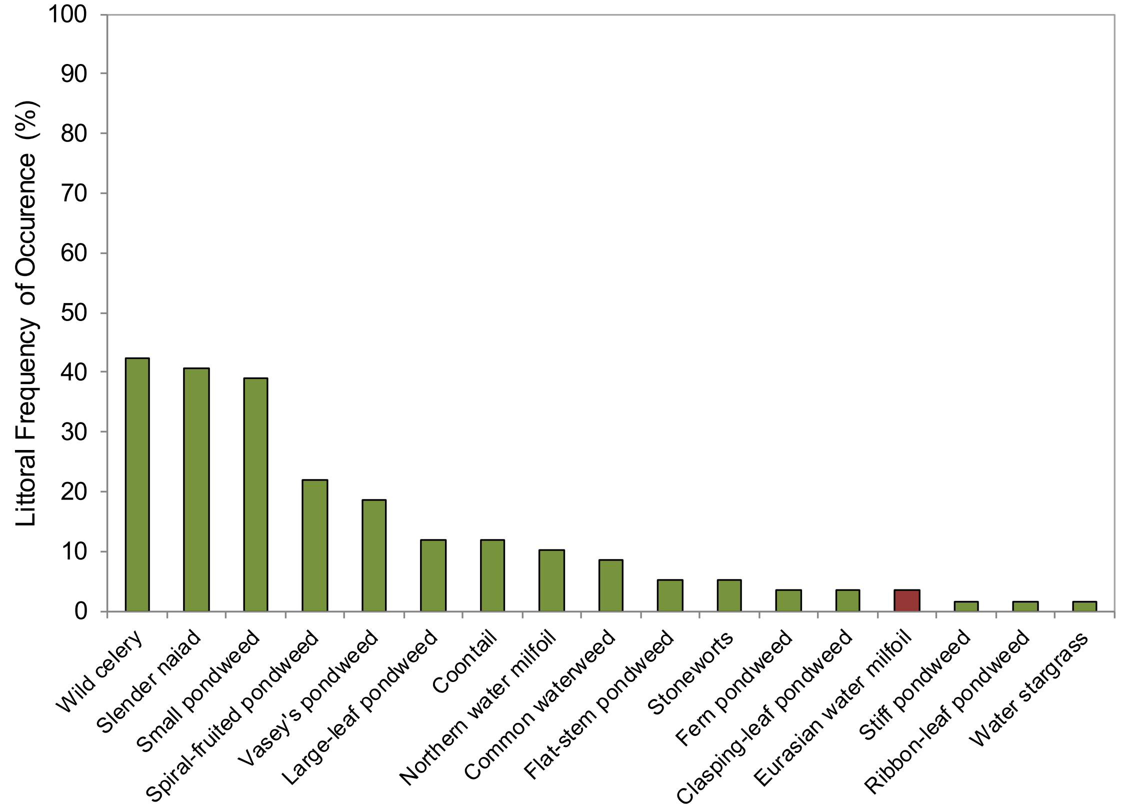


Figure 8.6.4-2. Otter Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Slender naiad, the second-most abundant aquatic plant in Otter Lake in 2012 with a littoral occurrence of nearly 41%, is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Small pondweed was the third-most abundant aquatic plant encountered in Otter Lake in 2012, with a littoral occurrence of approximately 39%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Otter Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms.

Spiral-fruited pondweed was the fourth-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 22%. As its name indicates, this plant produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Like slender naiad, spiral-fruited pondweed is food and habitat source for wildlife.

To determine if the 2008-2012 Eurasian watermilfoil control project on Otter Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.6.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Otter Lake.

The occurrence of Eurasian watermilfoil in Otter Lake in 2012 was not statistically different from its occurrence in 2006 (Figure 8.6.4-3). One native species, common waterweed, exhibited a statistically valid decline in occurrence between 2006 and 2012, while the native species wild celery, slender naiad, and spiral-fruited pondweed all exhibited statistically valid increased in their occurrence over this time period. The occurrences of the remaining native aquatic plant species were not statistically different between 2006 and 2012.

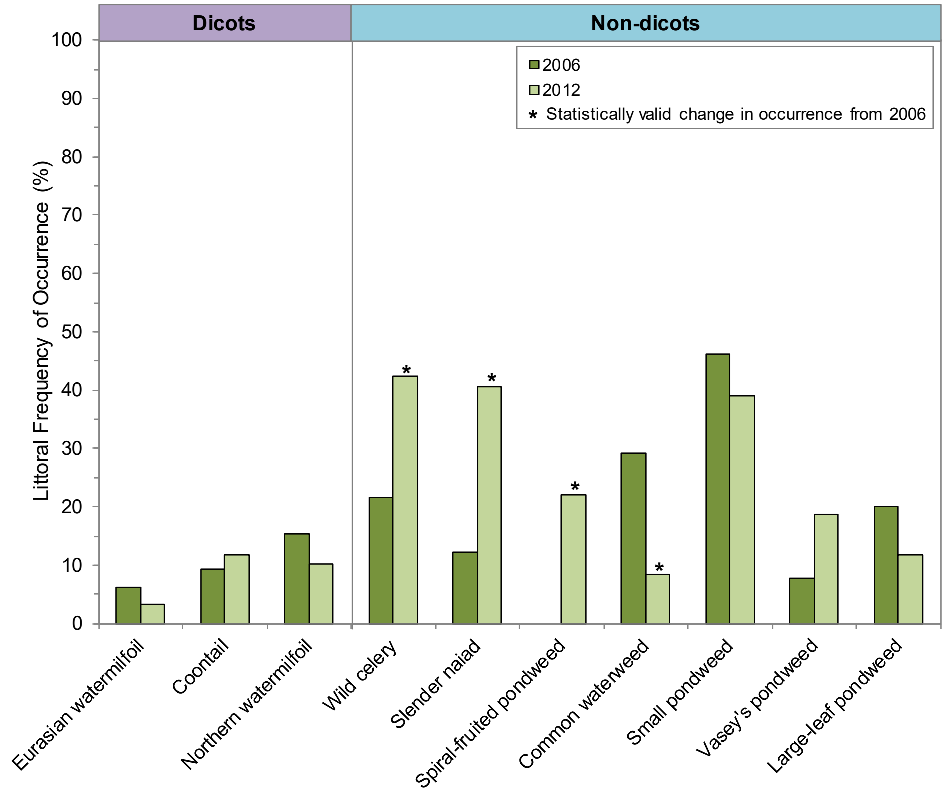


Figure 8.6.4-3. Otter Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

As discussed in the primer 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. For example, while a total of 27 native aquatic plant species were located in Otter Lake during the 2012 and 2016 surveys, 16 were encountered on the rake during the 2012 point-intercept survey. The remaining 11 species were located *incidentally*. Incidental species include those that were not encountered at any of the point-intercept sampling survey locations but were observed on the lake. Incidental species typically include emergent and floating-leaf plants which tend to grow on the margins of the lake or submersed species that are relatively rare within the community. The sixteen native species and their conservatism values were used to calculate the FQI of Otter Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.6.4-4 compares the FQI components of Otter Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Otter Lake's native species richness (16) is slightly higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.6) is slightly lower than the ecoregional median but above the state median.

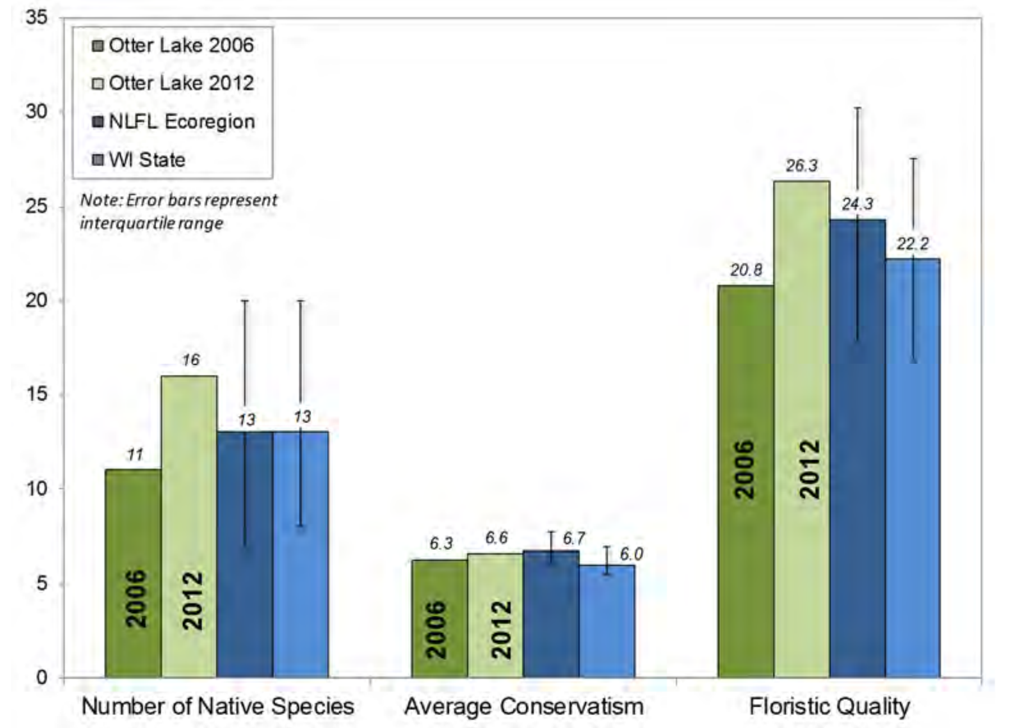


Figure 8.6.4-4. Otter Lake Floristic Quality Index. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

Combining Otter Lake's 2012 native species richness and average conservatism values yields a FQI value of 26.3, which is higher than the ecoregional and state median values (Figure 8.6.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Otter Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Otter Lake's aquatic plant community is of slightly higher quality than the majority of lakes within the ecoregion and the entire state.

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 Otter Lake contains a high number of native aquatic plant species, one may assume the aquatic plant community also has high species diversity. However, species diversity is also influenced by how evenly the plant species are distributed within the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Otter Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.6.4-5). Using the data collected from the 2012 point-intercept survey, Otter Lake's aquatic plant community was shown to have a high species diversity with a Simpson's diversity value of 0.88, falling within the upper quartile value for lakes in both the ecoregion and the state. Otter Lake's 2012 diversity was a higher diversity calculated from data collected during the 2006 point-intercept survey (0.86).

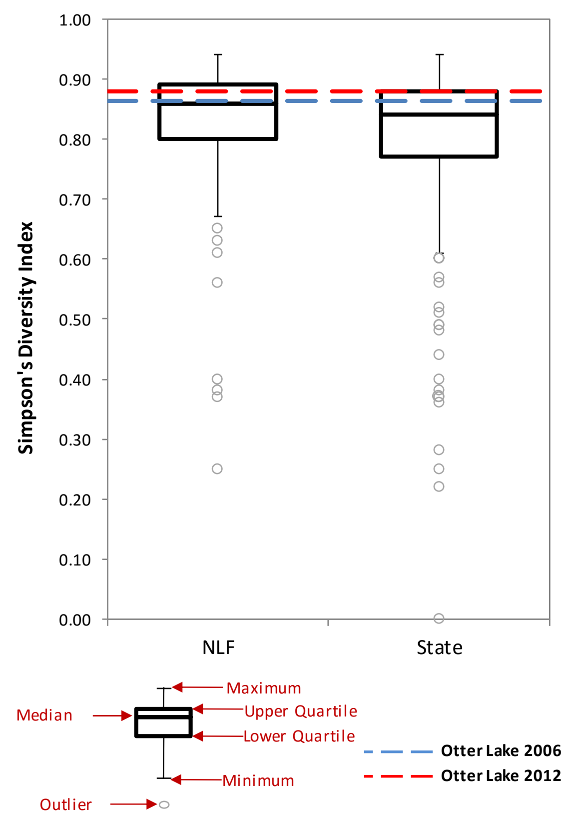


Figure 8.6.4-5. Otter Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

Figure 8.6.4-6 displays the relative frequency of occurrence of aquatic plant species in Otter Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another. The aquatic plant species are relatively evenly distributed within the community, yielding higher species diversity.

The 2016 aquatic plant community mapping survey revealed that Otter Lake contains approximately 1.4 acres of emergent and floating-leaf aquatic plant communities (Table 8.6.4-2, Otter Lake – Map 4). Twelve emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2016 (Table 8.6.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Otter Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

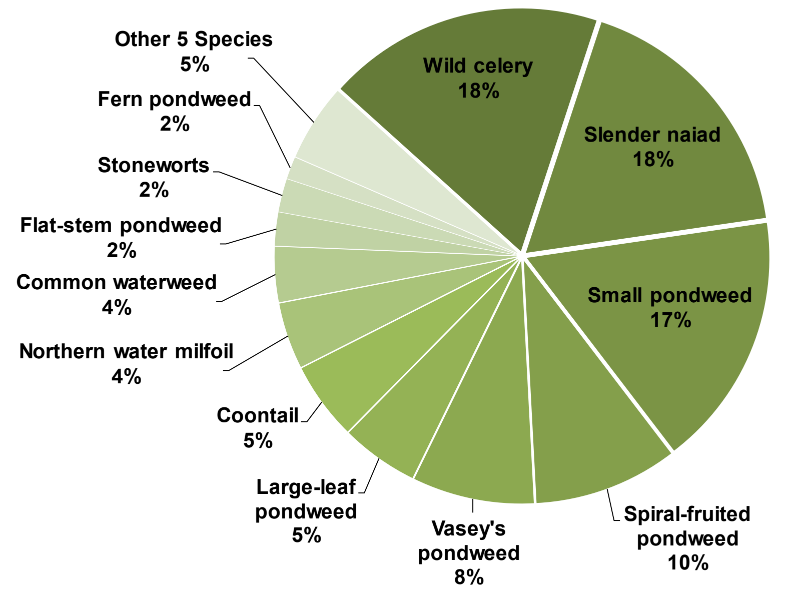


Figure 8.6.4-6. Otter Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Table 8.6.4-2. Acres of emergent and floating-leaf aquatic plant communities in Otter Lake. Created using data from 2016 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-Leaf	1.2
Mixed Emergent & Floating-Leaf	0.2
Total	1.4

8.6.4 Otter Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Otter Lake's Implementation Plan illustrates how Otter Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Otter Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Otter Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Dave Mueller, current Otter Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Otter Lake have been collecting water quality data intermittently since 1992. Otter Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Otter Lake currently has an active volunteer (Dave Mueller) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis.

Otter Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Dave Mueller, the current CLMN volunteer and the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, to appoint a new monitoring volunteer as needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. Dave Mueller, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. Dave Mueller, current CLMN volunteer, appoints new water quality volunteer for Otter Lake as needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Otter Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 30% (1.1 miles) of the shoreline are in an urbanized or developed-unnatural state, 29% (1.1 miles) is in a developed-semi-natural state, and 39% (1.6 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for

property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 30% of Otter Lake's shoreline is in a highly-developed state, approximately 39% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Otter Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Otter Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Otter Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Otter Lake shoreland assessment, approximately 37 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Otter Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.

Description: Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Otter Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Otter Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA.

Otter Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Otter Lake Association and ERCLA meetings. Otter Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Otter Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Otter Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action: ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.

Description: Otter Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Otter Lake and its stakeholders.

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

8.7 Lynx Lake

An Introduction to Lynx Lake

Lynx Lake, Vilas County, is a deep, lowland drainage lake with a maximum depth of 20 feet and a surface area of approximately 31 acres. During the 2012 and 2016 aquatic plant studies conducted by Onterra, 25 native aquatic plant species were located in the lake, of which slender naiad (*Najas flexilis*) was the most common. One non-native plant, Eurasian watermilfoil has been observed growing in Lynx Lake.

Photo 8.7-1. Lynx Lake, Vilas County, Wisconsin.

Lake at a Glance* –Lynx Lake

Morphology	
Acreage	31
Maximum Depth (ft)	20
Mean Depth (ft)	10
Volume (acre-feet)	308
Shoreline Complexity	1.4
Vegetation	
Curly-leaf Survey Date	July 6, 2016
Comprehensive Survey Date	August 2, 2012
Number of Native Species	27
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil (*Myriophyllum spicatum*)
Simpson's Diversity	0.88
Average Conservatism	6.0
Water Quality	
Wisconsin Lake Classification	Deep, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Transitional between phosphorus and nitrogen
Watershed to Lake Area Ratio	4,985:1

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

8.7.1 Lynx Lake Water Quality

Water quality data were collected from Lynx Lake on six occasions in 2016/2017. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Please note that the data in these graphs represent were collected during the growing season (April-October), summer months (June-August) or winter (February-March)

as indicated with each dataset. In addition to sampling efforts completed in 2016/2017, any historical data was researched and are included within this report as available.

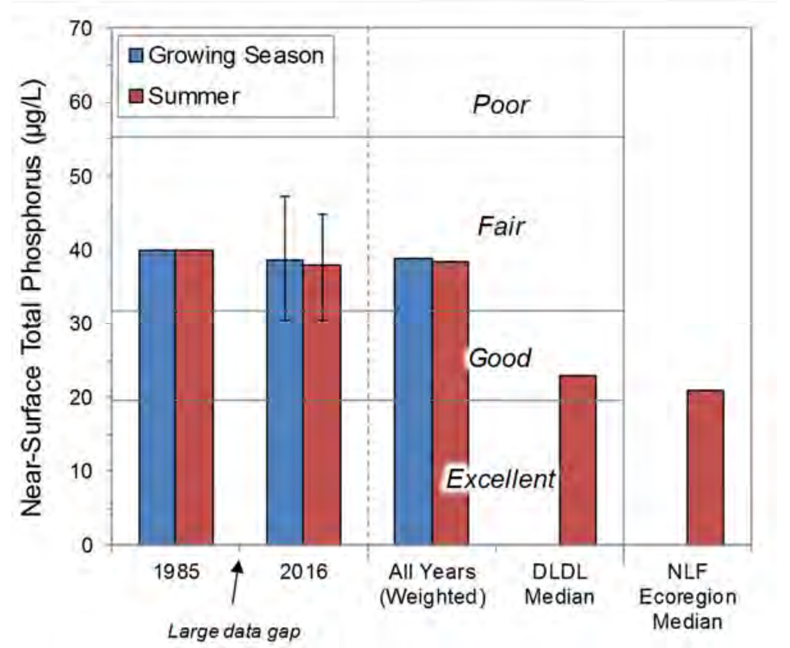


Figure 8.7.1-1. Lynx Lake annual average near-surface total phosphorus and median near-surface total phosphorus concentrations for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Historical total phosphorus data from Lynx Lake are limited and are available from 1985. Summer average near-surface total phosphorus was 40.0 µg/L in 1985 and 38.0 µg/L in 2016 (Figure 8.7.1-1). The weighted summer average total phosphorus concentration for Lynx Lake is 38.5 µg/L and is higher than the median phosphorus concentration for other deep lowland drainage lakes in Wisconsin (23.0 µg/L) and the median concentration for lakes within the NLF ecoregion (21.0 µg/L). Lynx Lake's summer average total phosphorus concentration falls within the *fair* category for Wisconsin's deep lowland drainage lakes. Given the limited amount of historical total phosphorus data from Lynx Lake, it cannot be determined if phosphorus concentrations have changed or are changing over time. Phosphorus concentrations measured in 2016 were similar to those measured in 1985. However, other lakes on the chain which have a larger historical dataset indicate that phosphorus concentrations in most of the lakes were above average in 2016 likely due to an increase in precipitation.

To determine if internal phosphorus loading from bottom sediments is a significant source of phosphorus to Lynx Lake, near-surface total phosphorus concentrations are compared to concentrations measured near the bottom. Figure 8.7.1-2 displays sampling events where both near-surface and near-bottom total phosphorus concentrations were measured. As illustrated, near-bottom total phosphorus concentrations were higher than those at the surface during the summer when the lake was thermally stratified. During stratification, water near the bottom becomes devoid of oxygen (anoxic) and phosphorus bound within the sediment gets released into the overlying water. The higher concentrations of phosphorus near the bottom in Otter Lake indicate that internal nutrient loading is occurring to some degree. However, the near-bottom concentrations of phosphorus are still relatively low and indicate that internal nutrient loading in Lynx Lake is likely not a significant source of phosphorus to the lake.

No historical chlorophyll-*a* data are available from Lynx Lake, and 2016 represented the first time this parameter was measured within the lake. The average summer chlorophyll-*a* concentration in 2016 in Lynx Lake was 14.8 µg/L, falling into the *fair* category for Wisconsin's deep lowland drainage lakes (Figure 8.7.1-3). These chlorophyll-*a* concentrations are expected based on the level of total phosphorus within the lake.

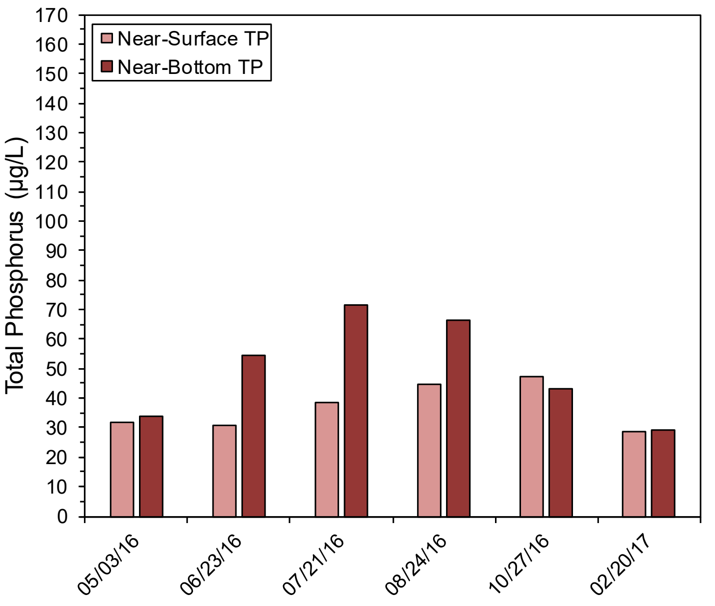


Figure 8.7.1-2. Lynx Lake near-surface and near-bottom total phosphorus concentrations.

While total phosphorus and chlorophyll-*a* data are limited from Lynx Lake, Secchi disk transparency data are available from 1985 and 2010-2016 (Figure 8.7-1-4). Average summer Secchi disk depth ranged from 2.0 feet in 2014 to near 6.0 feet in 2015. The weighted summer average Secchi disk depth is 4.5 feet and falls into the *fair* category for Wisconsin's deep lowland drainage lakes. Average summer Secchi disk depth in 2016 was lower than the historical average at 4.4 feet and lower than the 2015 measured Secchi disk depth of 6.0 feet. The below-average water clarity in 2016 was likely due to increased nutrients, algae, and tannins as a result of above-average precipitation. The annual Secchi disk data from 2010-2016 do not indicate any trends (positive or negative) in water clarity have occurred over this time period. Overall, Lynx Lake's Secchi disk depth falls below the median Secchi disk depth for Wisconsin's deep lowland drainage lakes (8.5 feet) and the median for lakes in the NLF ecoregion (8.9 feet).

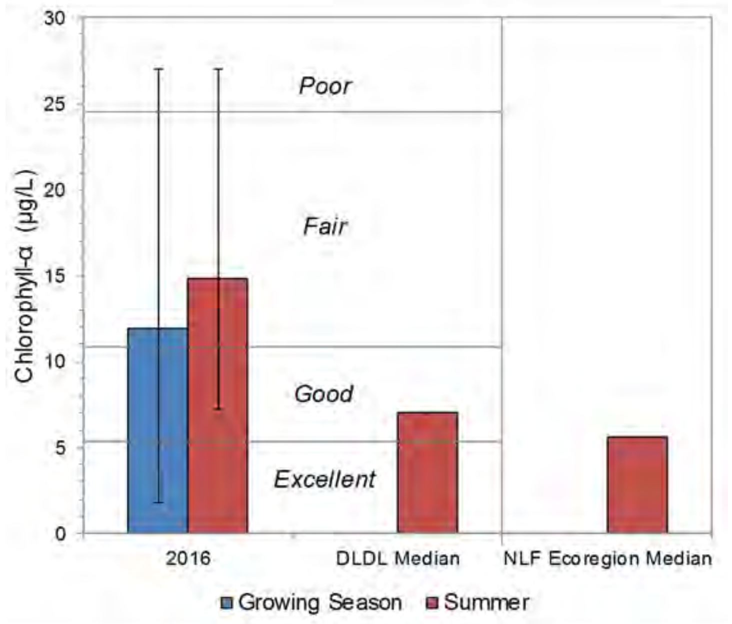


Figure 8.6.1-3. Otter Lake annual average chlorophyll-α and median chlorophyll-α concentrations for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Abiotic suspended particulates, such as sediment, also influence a lake's water clarity. *Total suspended solids*, a measure of both biotic (plankton) and abiotic suspended particles within the water were relatively low in Lynx Lake in 2016. Apart from suspended particles, water clarity can also be influenced by dissolved compounds within the water. Many lakes in the northern region of Wisconsin contain higher concentrations of dissolved organic acids (tannins) that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all of the suspended material (i.e. plankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Lynx Lake in 2016 averaged 40 SU (standard units), indicating the lake's water is *tea-colored*. The higher concentrations of dissolved organic acids in the lake reduce the water's clarity. It is important to note that the tea-colored water in Lynx Lake and the rest of the chain is natural, and is not an indication of degraded conditions.

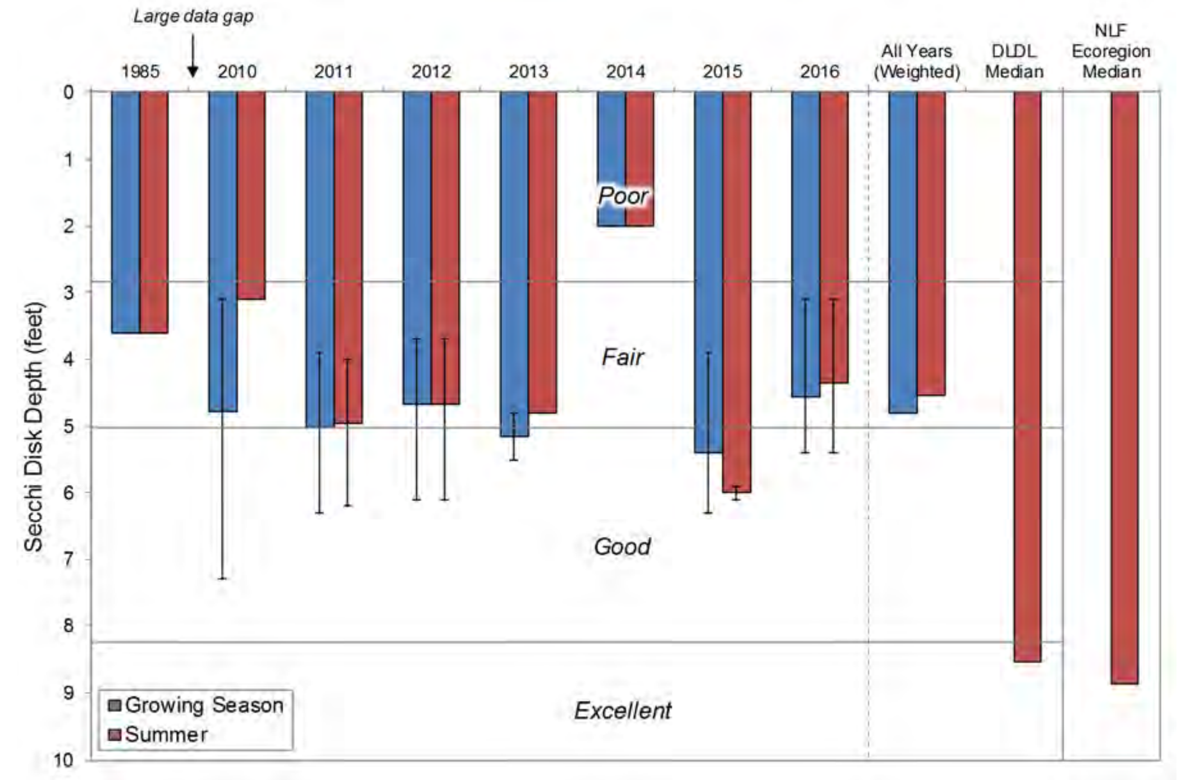


Figure 8.7.1-4. Lynx Lake annual average Secchi disk depth and median Secchi disk depths for Wisconsin deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Nutrient in Lynx Lake

As discussed in the Chain-Wide Report, in the majority of Wisconsin's lakes, phosphorus is the limiting nutrient, or the nutrient in shortest supply and is the primary nutrient regulating algal production. To determine whether phosphorus or nitrogen is the nutrient regulating algal production within a lake, the mid-summer total nitrogen (TN) to total phosphorus (TP) ratio is calculated. If the TN:TP is greater than 15, the lake is said to be phosphorus-limited. If the TN:TP is less than 10, the lake is said to be nitrogen limited. And if the TN:TP is between 10 and 15, the lake is said to be able to transition between nitrogen and phosphorus limitation.

In 2016, the mid-summer TN:TP ratio in Lynx Lake was 14:1, indicating Lynx Lake likely transitions between nitrogen and phosphorus limitation depending on the availability of either nutrient. Nitrogen concentrations measured in the Phase III lakes (Otter, Lynx, and Duck) in 2016 were lower than concentrations measured in the upstream Phase I and II lakes. It is believed that this perceived decrease in nitrogen concentration downstream is the result of collecting samples in different years. Changes in environmental conditions (e.g. precipitation) likely caused changes in nitrogen (and phosphorus) concentration between these years. As is discussed in the next subsection, chlorophyll-*a* concentrations in Lynx Lake are closely correlated with total phosphorus concentrations, indicating that phosphorus is the primary nutrient regulating algal production in Lynx Lake.

Lynx Lake Trophic State

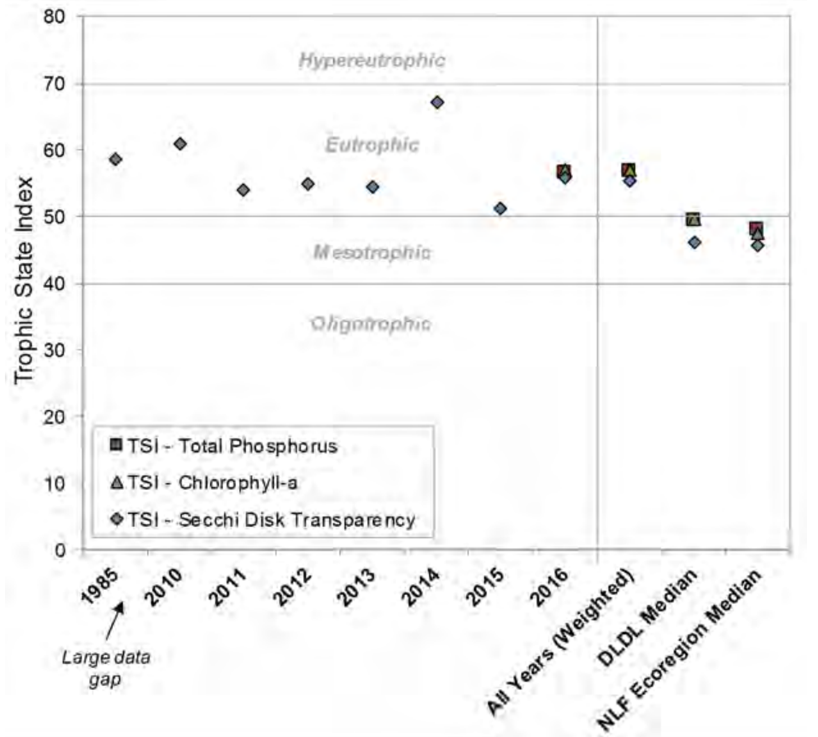


Figure 8.7.1-5. Lynx Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Figure 8.7.1-5 contains the Trophic State Index (TSI) values for Lynx Lake calculated from the data collected in 2016 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation. The TSI values for total phosphorus, chlorophyll, and Secchi disk in Lynx Lake are very similar indicating a high degree of correlation. The high degree of correlation between total phosphorus and chlorophyll-*a* indicates that while the lake may transition between phosphorus and nitrogen limitation, phosphorus is likely most often the nutrient regulating algal production within the lake. The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Lynx Lake indicate the lake is in currently in a eutrophic state. Lynx Lake is more productive when compared to other deep lowland drainage lakes in Wisconsin and other lakes within the NLF ecoregion.

Dissolved Oxygen and Temperature in Otter Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Lynx Lake by Onterra staff. Graphs of those data are displayed in Figure 8.7.1-6 for all sampling events. The temperature and dissolved oxygen data indicate that Otter Lake was beginning to thermally stratify in early-May during the first sampling event. By June, the lake had formed a distinct epilimnion, metalimnion, and hypolimnion. The hypolimnion was devoid of oxygen during the summer months, and the epilimnion was gradually eroded deeper over the course of the summer. By October, surface temperatures had cooled and temperature and dissolved oxygen were relatively uniform throughout the water column indicating fall turnover was occurring. Sampling through the ice in February of 2017 indicated the lake maintains sufficient oxygen levels under the ice and that fish-kills due to low oxygen in winter are likely not a concern on Lynx Lake.

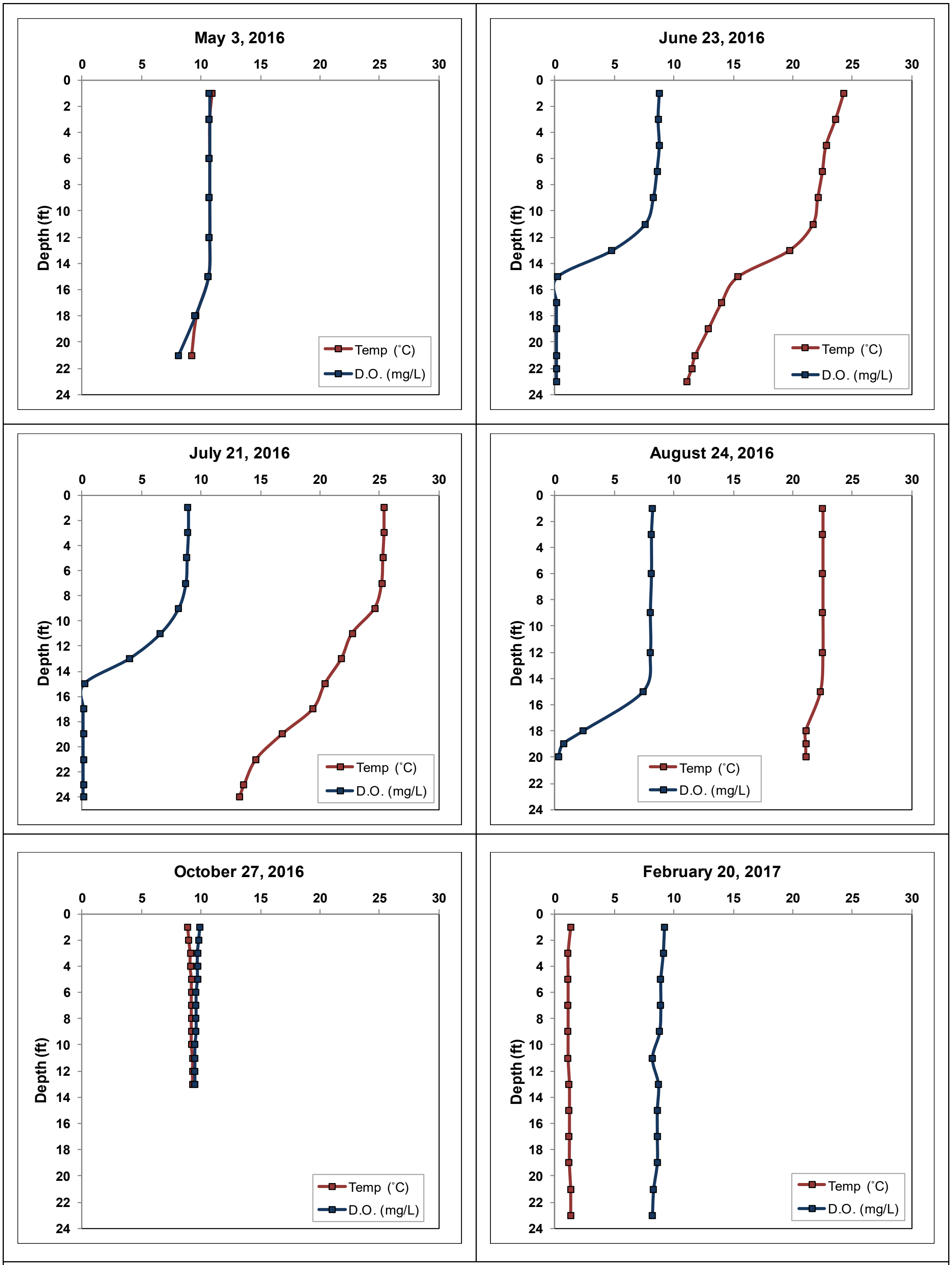


Figure 8.7.1-4. Lynx Lake 2016/2017 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Lynx Lake

The previous section is centered on parameters relating to Lynx Lake's trophic state. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Lynx 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. Lynx Lake's surface water pH was measured at roughly 7.6 during May and 7.5 during July of 2016. 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 Lynx Lake was measured at 28.7 and 31.1 mg/L as $CaCO_3$ in May and July of 2016. 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 Lynx Lake during 2016. 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 Lynx Lake's pH of 7.5 – 7.6 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 Lynx Lake was found to be 7.8 mg/L in May and 8.9 mg/L in July of 2016, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2016 and these samples were processed by the WDNR for larval zebra mussels. Their analysis was negative for the presence of zebra mussel veligers.

8.7.2 Lynx Lake Watershed Assessment

Lynx Lake's watershed is approximately 149,075 acres in size. Compared to its surface area of 30 acres, this makes for a large watershed to lake area ratio of 4,985:1.

Exact land cover calculation and modeling of nutrient input to Lynx Lake will be completed towards the end of this project (in 2016-2017). 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.

8.7.3 Lynx Lake Shoreland Condition

Shoreland Development

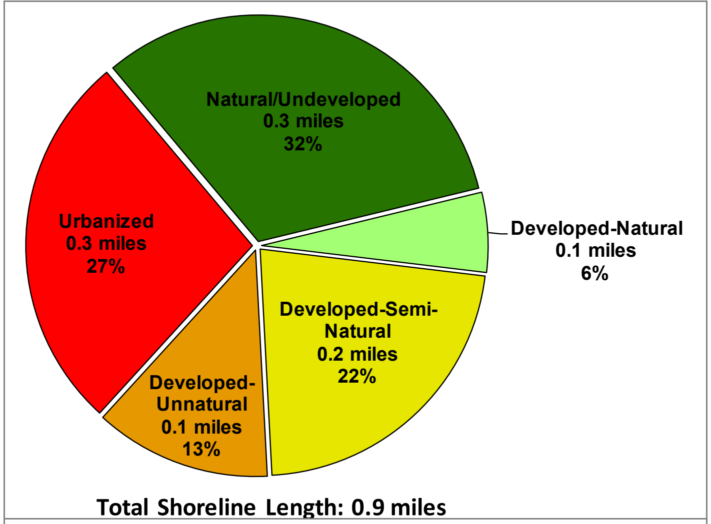


Figure 8.7.3-1. Lynx Lake shoreland categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Lynx Lake – Map 1.

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 fall of 2016, Lynx Lake's immediate shoreline was assessed in terms of its development. Lynx Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.4 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.7.3-1). This constitutes about 38% of Lynx 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, 0.4 miles of urbanized and developed–unnatural shoreline (40%) was observed. If restoration of the Lynx 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. Lynx Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

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 Eagle River 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, 24 total pieces of coarse woody habitat were observed along 0.9 miles of shoreline, which gives Lynx Lake a coarse woody habitat to shoreline mile ratio of 26:1 (Figure 8.7.3-2). Locations of coarse woody habitat are displayed on Lynx 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).

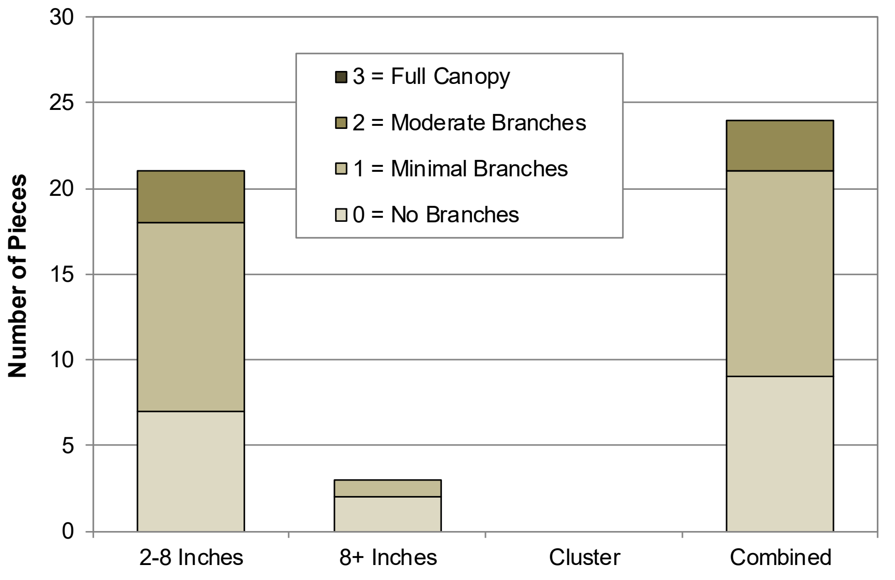


Figure 8.7.3-2. Lynx Lake coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of Lynx Lake coarse woody habitat can be found on Lynx Lake – Map 2.

8.7.4 Lynx Lake Aquatic Vegetation

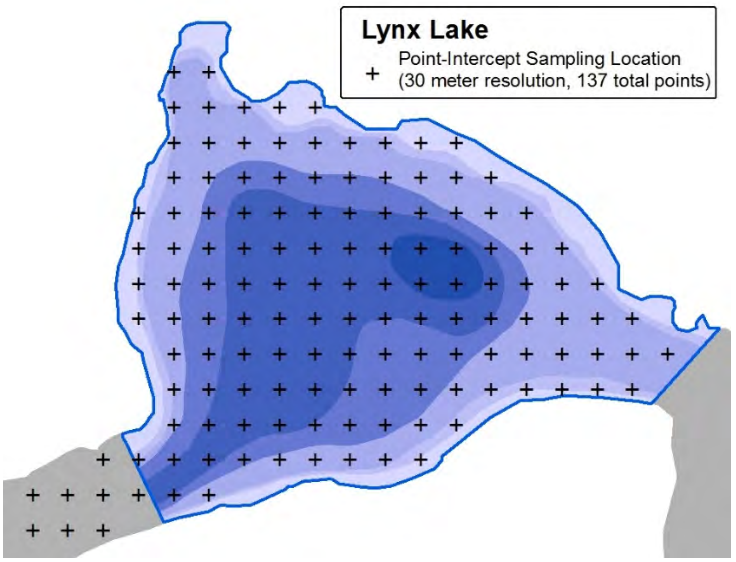


Figure 8.7.4-1. Point-intercept locations on Lynx Lake.

An early season aquatic invasive species survey was conducted on Lynx Lake on July 6, 2016. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of 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.

The whole-lake aquatic plant point-intercept survey was conducted on Lynx Lake by Onterra on August 2, 2012 (Figure 8.7.4-1), while the aquatic plant community mapping survey was conducted on July 12, 2016. During these surveys, a total of 26 aquatic plant species were located, one of which are considered to be a non-native, invasive species: Eurasian watermilfoil (Table 8.7.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 98% of the point-intercept locations within littoral areas contained sand, 2% contained fine, organic sediments (muck), and 0% contained rock. The majority of the shallow, near-shore areas contained sand, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2016 point-intercept survey, aquatic plants were found growing to a maximum depth of 11 feet, slightly deeper than a depth of 9 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered stained, or contains higher amounts of dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Of the 78 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 82% contained aquatic vegetation. This is about the same as what was found in the 2006 survey where approximately 83% of the littoral sampling locations contained aquatic vegetation. Lynx Lake Map 2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake. Twenty-three percent of the point-intercept locations had a total rake fullness rating of 1, 33% had a total rake fullness rating of 2, and 44% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.7.4-1 displays the aquatic plant species located in Lynx Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 were recorded in 2012. An additional 12 native aquatic plant species were located in Lynx Lake in 2012 that had not been recorded in 2006.

Table 8.7.4-1. Aquatic plant species located in Lynx Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012/2016 (Onterra)
E	*Carex lacustris*	Lake sedge	6		I
	Sagittaria sp. (sterile)	Arrowhead sp. (sterile)	N/A		I
	Schoenoplectus pungens	Three-square rush	5		I
	Scirpus atrocinctus	Black-girdled wool-grass	7		I
	Sparganium eurycarpum	Common bur-reed	5		X
	Typha spp.	Cattail spp.	1	X	I
FL	*Nuphar variegata*	Spatterdock	6		X
	Nymphaea odorata	White water lily	6		I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	I
	Najas flexilis	Slender naiad	6	X	X
	Nitella spp.	Stoneworts	7	X	X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton epihydrus	Ribbon-leaf pondweed	8		X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton friesii	Fries' pondweed	8		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5	X	X
	Potamogeton robbinsii	Fern pondweed	8		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
	Vallisneria americana	Wild celery	6	X	X

E = Emergent, FL = Floating Leaf
X = Located on rake during point-intercept survey; I = Incidental Species
* = Species listed as 'special concern' in Wisconsin

Of the 19 aquatic plant species recorded on the rake during the 2012 point-intercept survey, slender naiad, wild celery, spiral-fruited pondweed and small pondweed were the four-most frequently encountered (Figure 8.7.4-2). Slender naiad was the most abundant aquatic plant in Lynx Lake in

2012 with a littoral occurrence of nearly 46% and is one of three native naiads that can be found in Wisconsin. Being an annual, it produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates.

Wild celery, or tape grass, was the second-most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 41% (Figure 8.7.4-2). This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

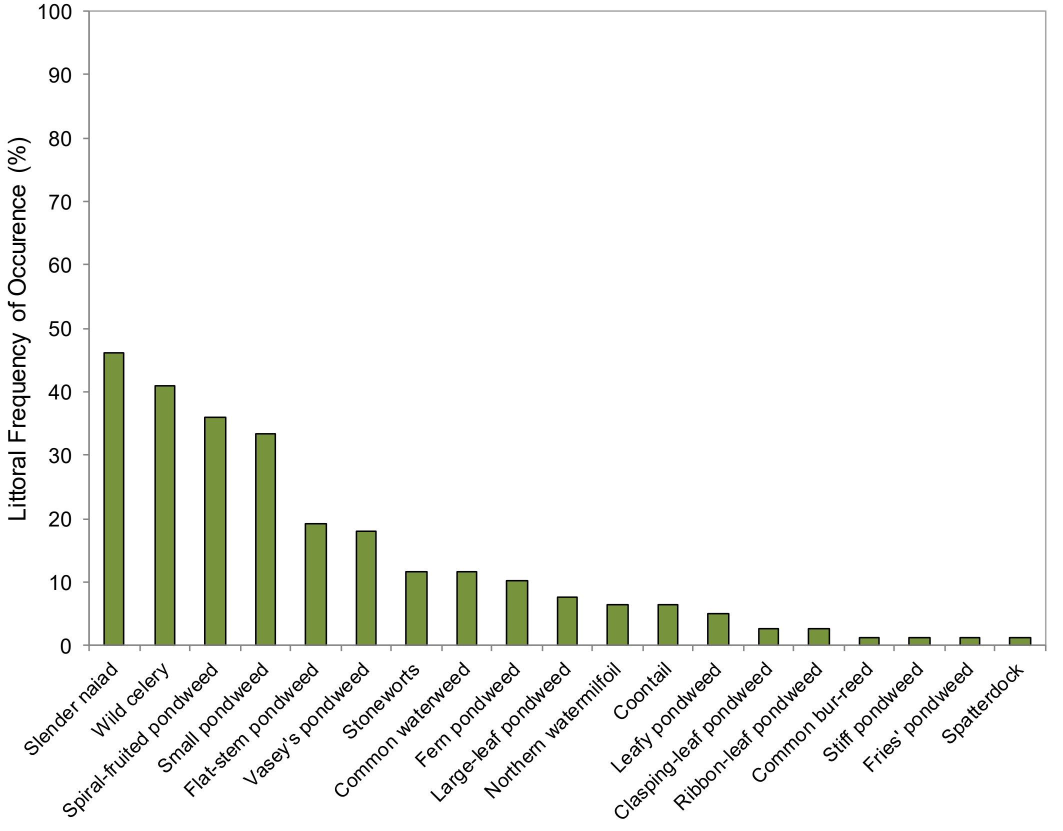


Figure 8.7.4-2. Lynx Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Spiral-fruited pondweed was the third-most abundant aquatic plant encountered in 2012, with a littoral occurrence of approximately 36%. As its name indicates, this plant produces fruit with a distinct coiled embryo and is one of several narrow-leaved pondweed species that can be found in Wisconsin. In mid-summer, the floating leaves of spiral-fruited pondweed can be observed on the surface in shallow water. The submersed leaves are long and narrow, and are usually curved. Like slender naiad, spiral-fruited pondweed is food and habitat source for wildlife.

Small pondweed was the fourth-most abundant aquatic plant encountered in Otter Lake in 2012, with a littoral occurrence of approximately 33%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Lynx Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms.

To determine if the 2008-2012 Eurasian watermilfoil control project on Lynx Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis (α = 0.05) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.7.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in lakes surrounding Lynx Lake.

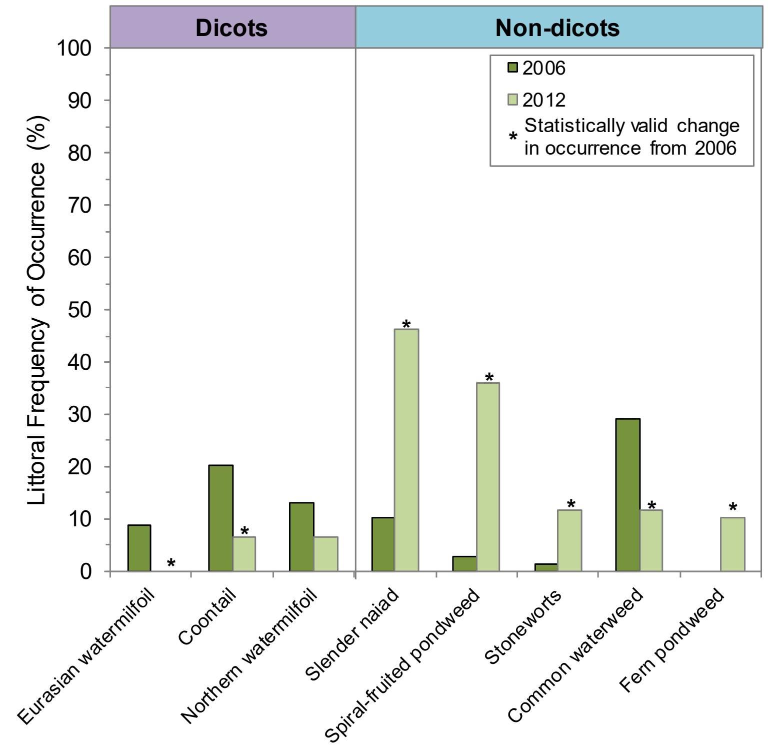


Figure 8.7.4-3. Lynx Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

In 2006, Eurasian watermilfoil had a littoral frequency of occurrence of nearly 10% in Lynx Lake. In 2012, Eurasian watermilfoil was not located at any of the sampling locations, representing a statistically valid decline in occurrence of 100% percent this time period. Six native aquatic plants exhibited statistically valid changes in their littoral occurrence in Lynx Lake between 2006 and 2012. Coontail and common waterweed exhibited statistically valid reductions in their occurrence, while slender naiad, spiral-fruited pondweed, stoneworts, and fern pondweed exhibited statistically valid increases in their occurrence. The occurrence of northern watermilfoil was not statically different between the 2006 and 2012 surveys. It is not known if the decline in the occurrences of coontail and common waterweed in Lynx Lake were the result of the herbicide treatments that have taken place on the lake or the result of natural environmental factors. Overall, it does not appear that the herbicide treatments had significant impacts to Lynx Lake's native aquatic plant community.

As discussed in the primer 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. For example, while a total of 25 native aquatic plant species were located in Lynx Lake during the 2012 and 2016 surveys, 19 were encountered on the rake during the 2012 point-intercept survey. The remaining seven species were located *incidentally*. Incidental species include those that were not encountered at any of the point-intercept sampling survey locations but were observed on the lake. Incidental species typically include emergent and floating-leaf plants which tend to grow on the margins of the lake or submersed species that are relatively rare within the community. The 19 native species and their conservatism values were used to calculate the FQI of Lynx Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.7.4-4 compares the FQI components of Lynx Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Lynx Lake's native species richness (19) is higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.5) is slightly lower than the ecoregional median but above the state median.

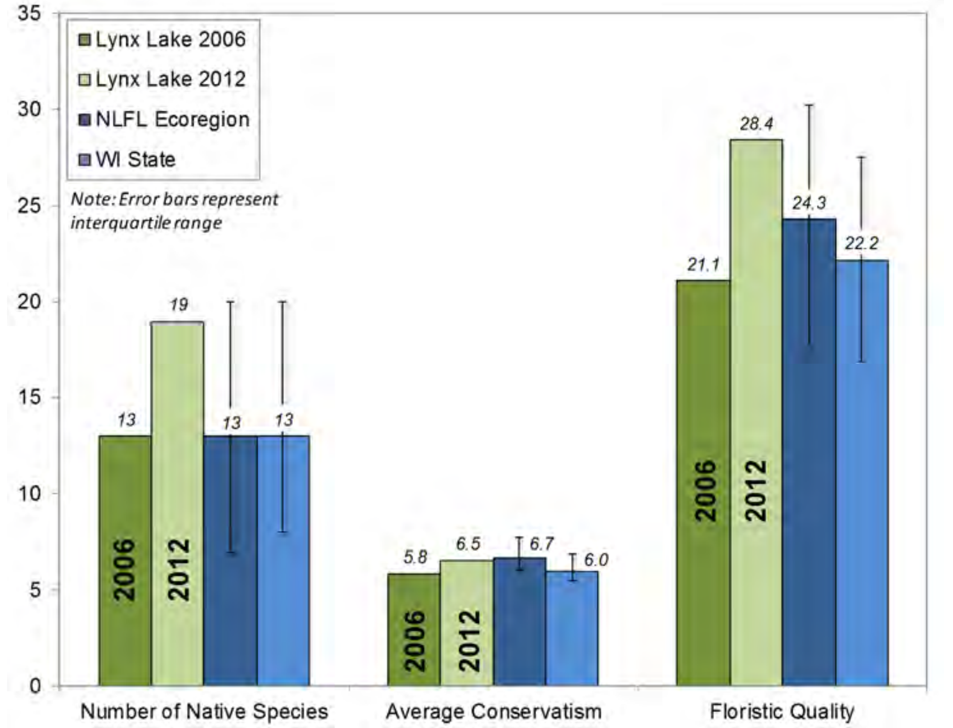


Figure 8.7.4-4. Lynx Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

Combining Lynx Lake's 2012 native species richness and average conservatism values yields a FQI value of 28.4, which is higher than the ecoregional and state median values (Figure 8.7.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in

2006, indicating that the quality of Lynx Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Lynx Lake's aquatic plant community is of slightly higher quality than the majority of lakes within the ecoregion and the entire state.

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

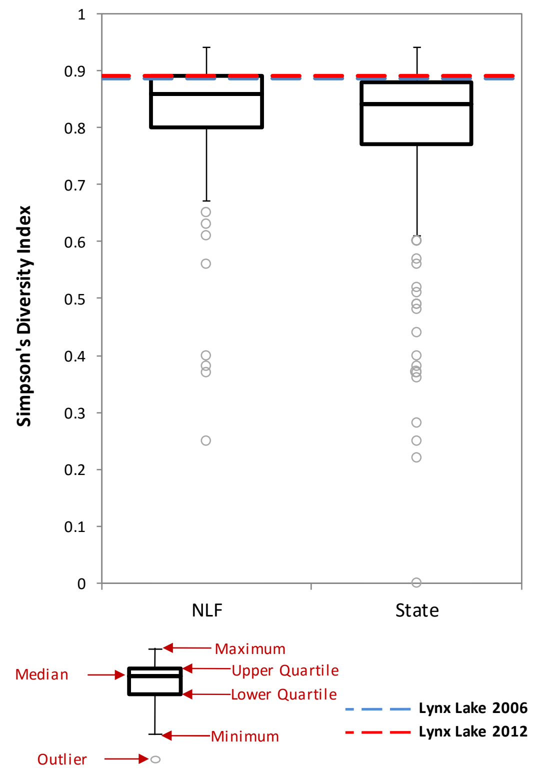


Figure 8.7.4-5. Lynx Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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 Lynx Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.7.4-5). Using the data collected from the 2012 point-intercept survey, Lynx Lake's aquatic plant community was shown to have a high species diversity with a Simpson's diversity value of 0.89, falling within and just above the upper quartile value for lakes in both the ecoregion and the state. Lynx Lake's 2012 diversity was the same diversity calculated from data collected during the 2006 point-intercept survey (0.89).

Figure 8.7.4-6 displays the relative frequency of occurrence of aquatic plant species in Lynx Lake from the 2012 point-intercept survey and illustrates the relative abundance of species within the community to one another. The aquatic plant species are relatively evenly distributed within the community, yielding higher species diversity.

The 2016 aquatic plant community mapping survey revealed that Lynx Lake contains approximately 0.4 acres of emergent and floating-leaf aquatic plant communities (Table 8.7.4-2, Lynx Lake – Map 4). Eight emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2016 (Table 8.7.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Lynx

Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

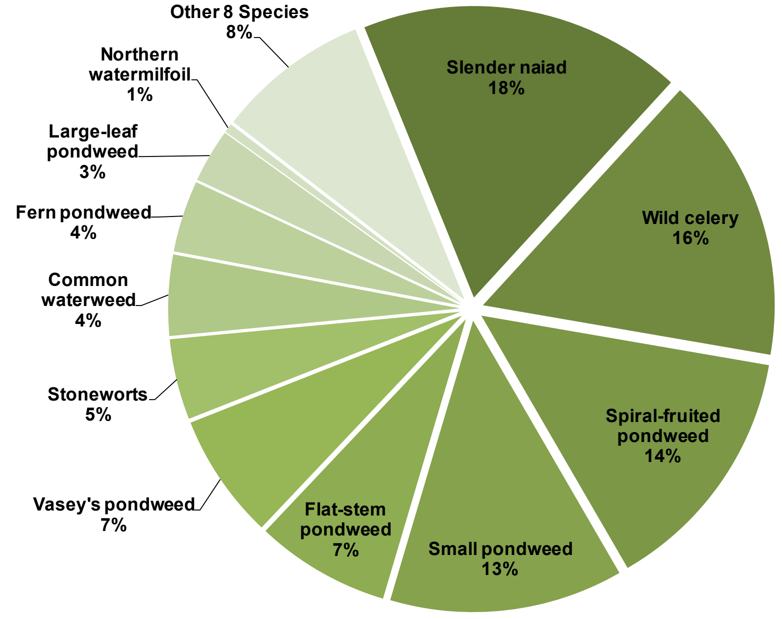


Figure 8.7.4-6. Lynx Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

Table 8.7.4-2. Acres of emergent and floating-leaf aquatic plant communities in Lynx Lake. Created using data from 2016 aquatic plant community mapping survey.

Plant Community	Acres
Emergent	0.1
Floating-Leaf	0.0
Emergent & Floating-Leaf	0.3
Total	**0.4**

8.7.4 Lynx Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Lynx Lake's Implementation Plan illustrates how Lynx Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Lynx Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Lynx Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Dave Mueller, current Lynx Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Lynx Lake have been collecting water quality data intermittently since 1992. Lynx Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Lynx Lake currently has an active volunteer (Dave Mueller) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis.

Lynx Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Dave Mueller, the current CLMN volunteer and the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers, to appoint a new monitoring volunteer as needed. Dave (or the current Lakes and Shores Committee chair) 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.

Action Steps:

1. Dave Mueller, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. Dave Mueller, current CLMN volunteer, appoints new water quality volunteer for Lynx Lake as needed.

<u>Management Action:</u> Monitor for frequency of occurrence and location of water sheet flow over Chain O'Lakes road into Otter Lake and consider collection of water quality samples from drainage ditches draining to Otter and Lynx Lake from adjacent agricultural lands.

Timeframe: Initiate in 2018

Facilitator: Dave Mueller, current CLMN volunteer (suggested)

Description: During the 2017 planning meeting with the Phase III Planning Committee, concerns were raised regarding the potential impact agricultural fields north of Chain O'Lakes Road may be having on the water quality of Otter and Lynx lakes. Property owners from these lakes indicated that they have observed water flowing from these fields over Chain O'Lakes Road and into Otter Lake during rain events. In addition, they are also concerned about water draining from these fields through ditches which eventually flow into these lakes through culverts underneath Chain O'Lakes Road. The property owners have concerns about possible contamination from herbicides and/or pesticides originating from these fields.

Analyses using Geographic Information System (GIS) Spatial Analyst software found that all the portions of the agricultural fields which lie within Lynx Lake's watershed drain to a wetland on the lake's north side prior to flowing into the lake through a culvert under Chain O'Lakes road (Figure 8.7.4-1). The eastern portion of these fields drain to Otter Lake through another culvert beneath Chain O'Lakes Road (Figure 8.7.4-1).

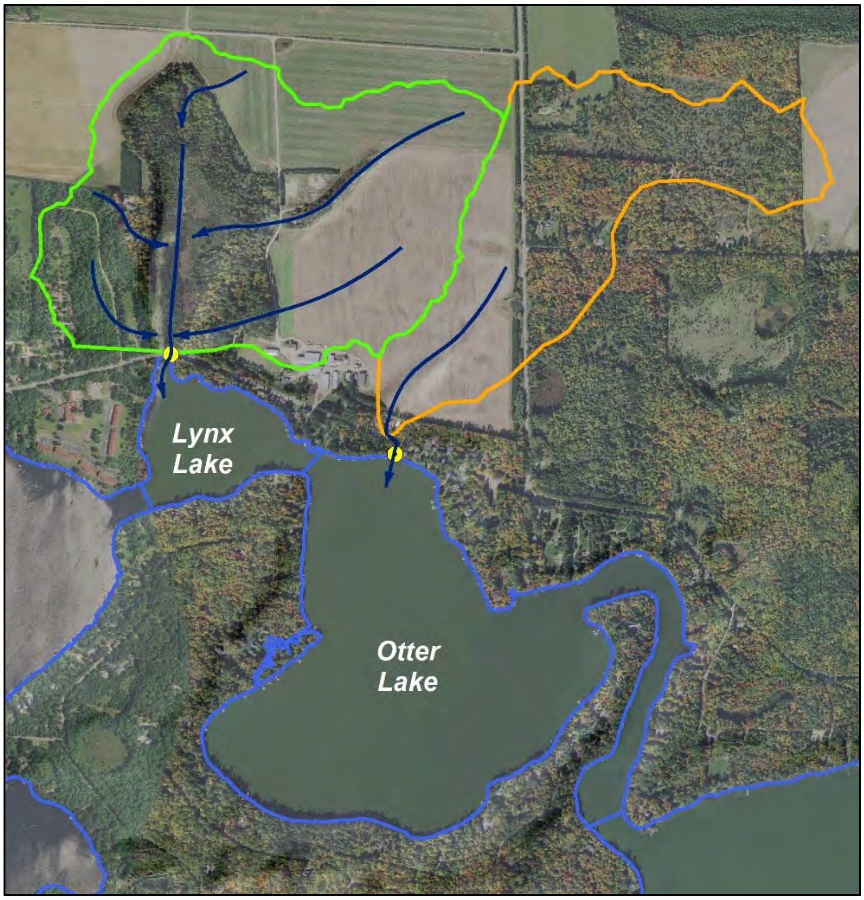


Figure 8.7.4-1. Drainage areas of concern in Otter and Lynx lakes. Area outlined in green drains through culvert in Lynx Lake and area outlined in orange drains through culvert to Otter Lake. Yellow circles indicate culvert location.

Measured phosphorus concentrations in these lakes were not significantly higher when compared to upstream lakes, indicating these fields are likely not having a detectable impact on nutrient concentrations in these lakes. Given the large watersheds of these lakes, WiLMS predicted average water residence times of 5 days and 0.7 days for Otter and Lynx lakes, respectively. With the high rate of water flow through these systems, it is believed that in-lake sampling would likely not yield detectable levels of herbicides/pesticides from these agricultural fields.

Given the concern regarding the observed flow of water over Chain O'Lakes Road, the property owners will keep a record of when and where they observe water flowing over the road and into Otter Lake in 2018. The frequency of occurrence and location of these flow events will aid in determining if samples of this water should be collected and analyzed for herbicides/pesticides.

The Lynx and Otter lake property owners also want to consider collecting water samples for analysis from the drainage ditches draining from these fields to Otter and Lynx lakes during rain events. Lake stakeholders were particular concerned about observed runoff from these fields during the spring when the ground was still frozen.

Onterra contacted the Wisconsin State Lab of Hygiene (WSLH) to inquire what types of herbicides and pesticides they are able to test for. Currently, the WSLH is only able to test for atrazine, a commonly-used broad-leaf herbicide. The WSLH recommended if any specific herbicides or pesticides apart from atrazine wanted to be tested, a private lab should be contacted. The sample results should be provided to and reviewed by local WDNR staff to determine if any detectable levels of herbicide/pesticide are within acceptable levels or not. This type of sampling and analysis would likely not be grant eligible given its small scope, and cost of analysis would have to be covered out of pocket.

Action Steps:

1. Lynx Lake volunteer, Dave Mueller, documents when and where water is observed flowing across Chain O'Lakes Road into Otter Lake in 2018.
2. If flow over the road is found to occur on a frequent basis, consider collecting samples during flow events to get tested for herbicides and/or pesticides.
3. Lynx and Otter lake property owners consider collecting water quality samples from drainage ditches draining agricultural fields north of Chain O'Lakes Road and draining through culverts into Lynx and Otter lakes.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

<u>Management Action:</u> Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Lynx Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 40% (0.4 miles) of the shoreline are in an urbanized or developed-unnatural state, 22% (0.2 miles) is in a developed-semi-natural state, and 38% (0.4 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

<u>Management Action:</u> Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 40% of Lynx Lake's shoreline is in a highly-developed state, approximately 38% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Lynx Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Lynx Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Lynx Lake property owners.

Management Action:	Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.
Description:	During the Lynx Lake shoreland assessment, approximately 26 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion. The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Lynx Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action:	Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.
Description:	Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Lynx Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Lynx Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA. Lynx Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Lynx Lake Association and ERCLA meetings. Lynx Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Lynx Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Lynx Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action:	ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.
Description:	Lynx Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Lynx Lake and its stakeholders.

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

8.8 Duck Lake

An Introduction to Duck Lake

Duck Lake, Vilas County, is a shallow, lowland drainage lake with a maximum depth of 20 feet, a mean depth of 10 feet, and a surface area of approximately 109 acres. During the 2012 and 2016 aquatic plant studies conducted by Onterra, 21 native aquatic plant species were located in the lake, of which wild celery (*Vallisneria americana*) was the most common. One non-native plant, Eurasian watermilfoil was also found growing in Duck Lake.

Photo 8.7-1. Duck Lake, Vilas County, Wisconsin.

Lake at a Glance* –Duck Lake

Morphology	
Acreage	109
Maximum Depth (ft)	20
Mean Depth (ft)	10
Volume (acre-feet)	1,009
Shoreline Complexity	1.4
Vegetation	
Curly-leaf Survey Date	July 6, 2016
Comprehensive Survey Date	August 3, 2012
Number of Native Species	21
Threatened/Special Concern Species	Vasey's pondweed (*Potamogeton vaseyi*)
Exotic Plant Species	Eurasian watermilfoil (*Myriophyllum spicatum*)
Simpson's Diversity	0.90
Average Conservatism	6.2
Water Quality	
Wisconsin Lake Classification	Shallow, Lowland Drainage
Trophic State	Eutrophic
Limiting Nutrient	Transitional between phosphorus and nitrogen
Watershed to Lake Area Ratio	1,372:1

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

8.8.1 Duck Lake Water Quality

Water quality data was collected from Duck Lake on six occasions in 2016/2017. Onterra staff sampled the lake for a variety of water quality parameters including total phosphorus, chlorophyll-*a*, and Secchi disk clarity. Please note that the data in these graphs represent were collected during the growing season (April-October), summer months (June-August) or winter (February-March)

as indicated with each dataset. In addition to sampling efforts completed in 2016/2017, any historical data was researched and are included within this report as available.

Historical total phosphorus data from Duck Lake are rather limited and are available from 1979, 1992, 2006-2010, and 2016 (Figure 8.8.1-1). Summer near-surface total phosphorus ranged from 17.0 µg/L in 2010 to 43.6 µg/L in 2016. The weighted summer average total phosphorus concentration for Duck Lake is 30.2 µg/L, which straddles the threshold between *excellent* and *good* for Wisconsin's shallow lowland drainage lakes. Duck Lake's average summer total phosphorus is slightly lower than the median concentration for other shallow lowland drainage lakes in Wisconsin (33.0 µg/L) but higher than the median concentration for lakes in the NLF ecoregion (21.0 µg/L). Given the limited data, it cannot be said if phosphorus concentrations have changed in Duck Lake over time. However, like other lakes in the chain, phosphorus concentrations measured in Duck Lake in 2016 were above average likely due to higher levels of precipitation and increased runoff to these lakes.

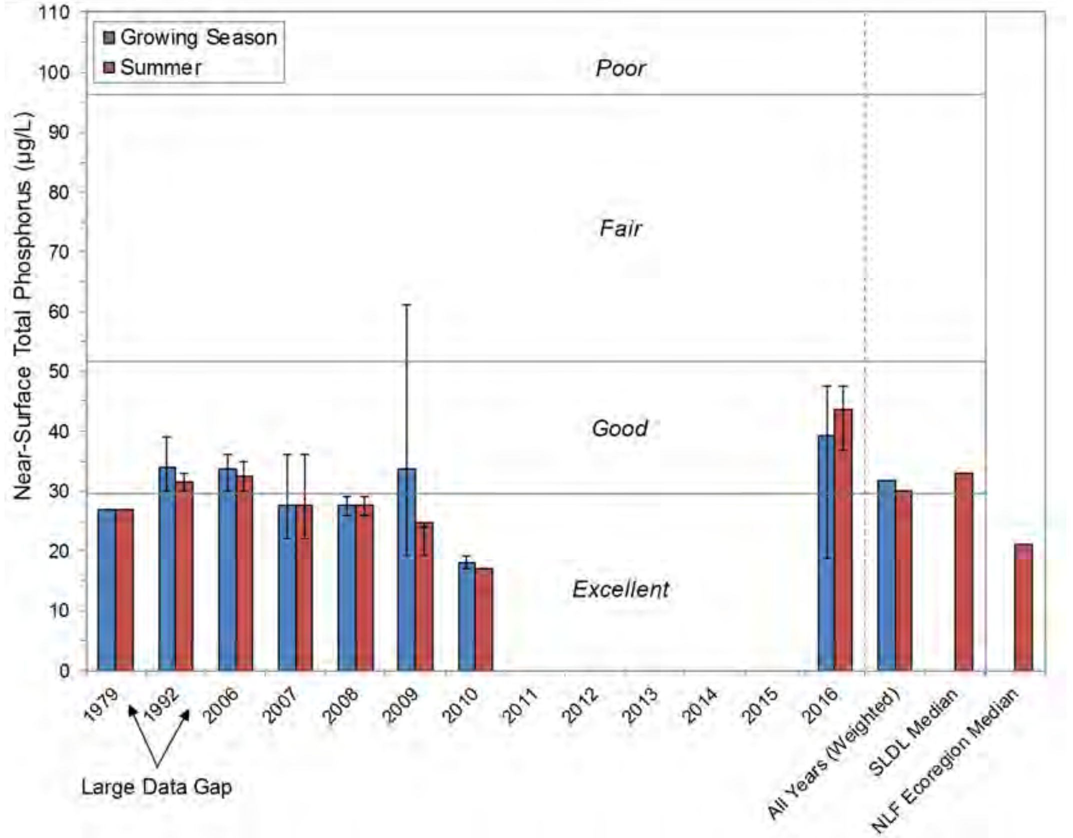


Figure 8.8.1-1. Duck Lake annual average near-surface total phosphorus and median near-surface total phosphorus concentrations for Wisconsin shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal phosphorus loading from bottom sediments is a significant source of phosphorus to Duck Lake, near-surface total phosphorus concentrations are compared to concentrations measured near the bottom. Figure 8.8.1-2 displays sampling events where both near-surface and near-bottom total phosphorus concentrations were measured. As illustrated, near-bottom total phosphorus concentrations were higher than those at the surface during the summer when the lake was thermally stratified. During stratification, water near the bottom becomes devoid of oxygen (anoxic) and phosphorus bound within the sediment gets released into the overlying water. The higher concentrations of phosphorus near the bottom in Duck Lake indicate that internal nutrient loading is occurring to some degree. However, the near-bottom concentrations of phosphorus are still relatively low and indicate that internal nutrient loading in Duck Lake is likely not a significant source of phosphorus to the lake.

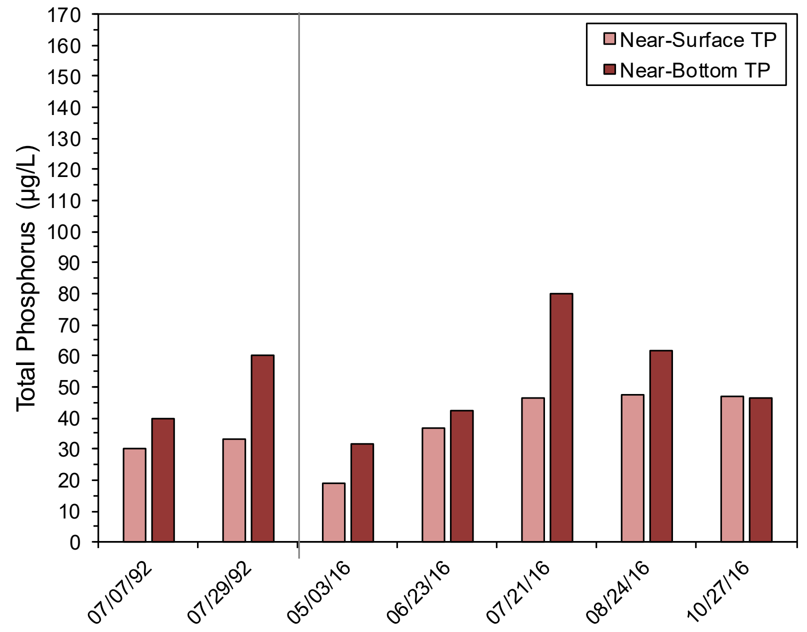


Figure 8.8.1-2. Duck Lake 2016 growing season and winter 2017 near-surface and near-bottom total phosphorus concentrations.

Like total phosphorus, chlorophyll-*a* data from Duck Lake are rather limited and are available from 1979, 1992, 2006-2010, and 2016 (Figure 8.8.1-3). Summer average chlorophyll-*a* ranged from 5.9 µg/L in 2010 to 15.7 µg/L in 2006. The weighted summer average total phosphorus concentration for Duck Lake is 12.5 µg/L, which falls into the *good* category for Wisconsin's shallow lowland drainage lakes. Average summer chlorophyll-*a* concentrations in 2016 were slightly higher than average with a concentration of 15.1 µg/L. The higher chlorophyll-*a* concentrations measured in 2016 were likely due to the higher concentrations of phosphorus as a result of increased precipitation. The average summer chlorophyll-*a* concentration in Duck Lake is higher than the median concentration for other shallow lowland drainage lakes in Wisconsin (9.4 µg/L) and higher than the median concentration for lakes in the NLF ecoregion (5.6 µg/L). Given the limited data, it cannot be said if chlorophyll-*a* concentrations have changed over time in Duck Lake.

While total phosphorus and chlorophyll-*a* data are limited from Duck Lake, Secchi disk transparency data are available from 1979, 1992-1998, 2002-2010, and 2015-2016 (Figure 8.8.1-4). Average summer Secchi disk depth ranged from 3.3 feet in 1992 to 6.5 feet in 1993. The weighted summer average Secchi disk depth in Duck Lake is 5.4 feet, straddling the threshold between *excellent* and *good* for Wisconsin's shallow lowland drainage lakes. The average summer Secchi disk depth in 2016 was below average with a depth of 4.0 feet. The below-average water clarity in 2016 was likely due to increased nutrients, algae, and tannins as a result of above-average precipitation. The available Secchi disk data do not indicate any trends (positive or negative) in water clarity have occurred in Duck Lake. Overall, Duck Lake's Secchi disk depth is similar to the median depth for other shallow lowland drainage lakes in Wisconsin (5.6 feet) but lower than the median depth for lakes within the NLF ecoregion (8.9 feet).

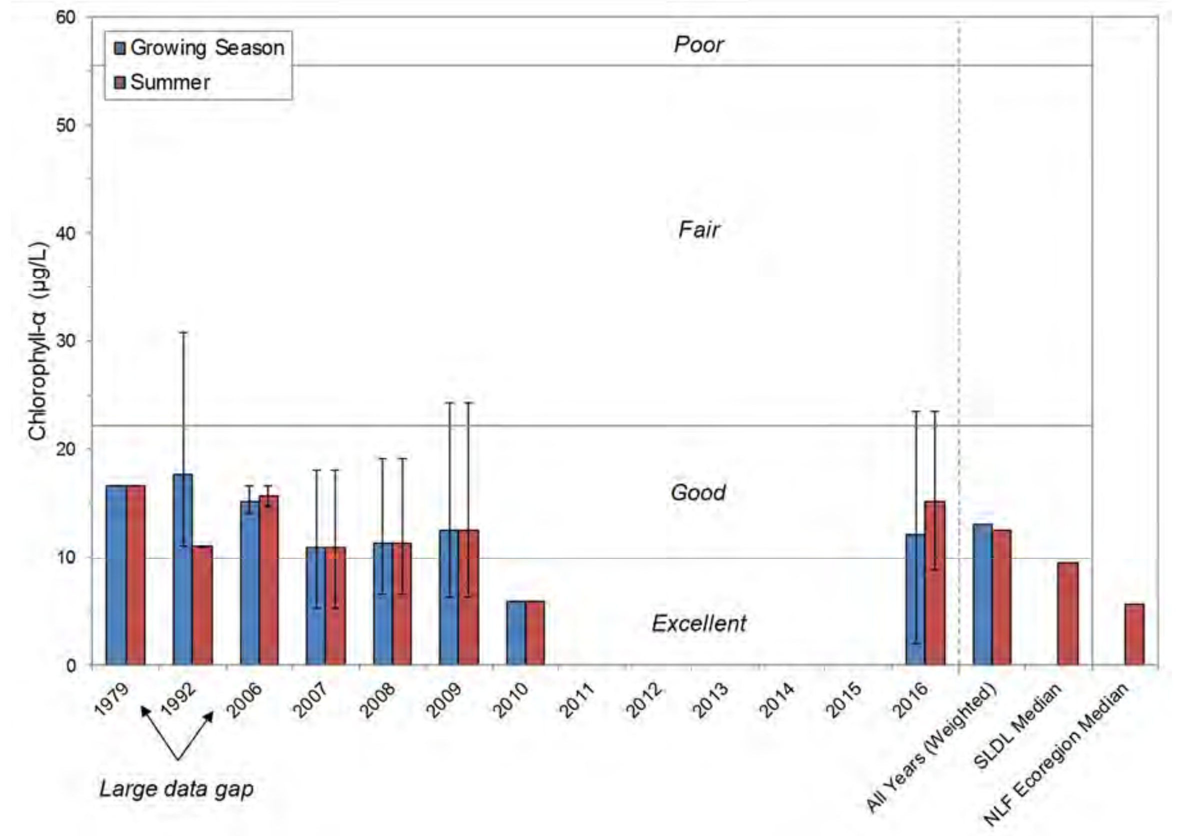


Figure 8.8.1-3. Duck Lake annual average chlorophyll-α and median chlorophyll-α concentrations for Wisconsin shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Abiotic suspended particulates, such as sediment, also influence a lake's water clarity. *Total suspended solids*, a measure of both biotic (plankton) and abiotic suspended particles within the water were relatively low in Duck Lake in 2016. Apart from suspended particles, water clarity can also be influenced by dissolved compounds within the water. Many lakes in the northern region of Wisconsin contain higher concentrations of dissolved organic acids (tannins) that originate from decomposing plant material within wetlands in the lake's watershed. In higher concentrations, these dissolved organic compounds give the water a tea-like color or staining and decrease water clarity. A measure of water clarity once all of the suspended material (i.e. plankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color values measured from Duck Lake in 2016 averaged 40 SU (standard units), indicating the lake's water is *tea-colored*. The higher concentrations of dissolved organic acids in the lake reduce the water's clarity. It is important to note that the tea-colored water in Duck Lake and the rest of the chain is natural, and is not an indication of degraded conditions

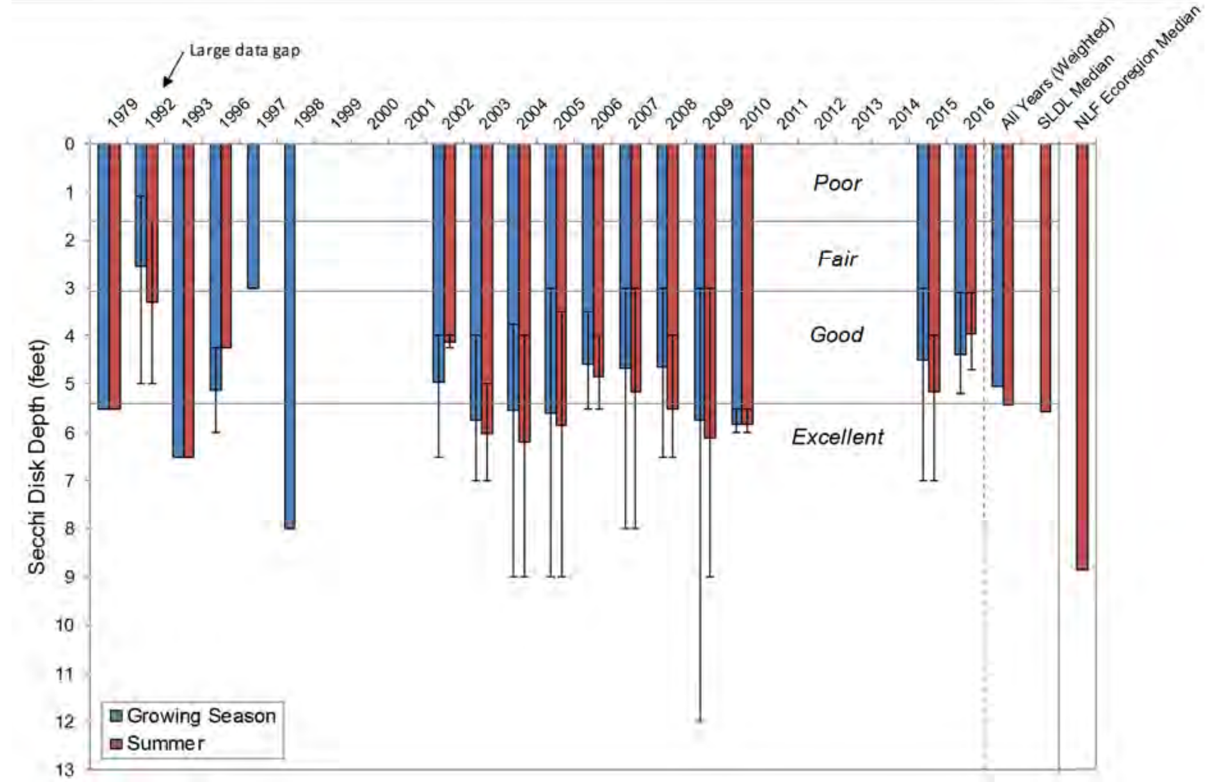


Figure 8.8.1-4. Duck Lake annual average Secchi disk depth and median Secchi disk depth for Wisconsin shallow lowland drainage lakes (SLDL) and Northern Lakes and Forests (NLF) lakes. Error bars indicate minimum and maximum values. Water Quality Index values adapted from WDNR PUB WT-913.

Limiting Nutrient in Duck Lake

As discussed in the Chain-Wide Report, in the majority of Wisconsin's lakes, phosphorus is the limiting nutrient, or the nutrient in shortest supply and is the primary nutrient regulating algal production. To determine whether phosphorus or nitrogen is the nutrient regulating algal production within a lake, the mid-summer total nitrogen (TN) to total phosphorus (TP) ratio is calculated. If the TN:TP is greater than 15, the lake is said to be phosphorus-limited. If the TN:TP is less than 10, the lake is said to be nitrogen limited. And if the TN:TP is between 10 and 15, the lake is said to be able to transition between nitrogen and phosphorus limitation.

In 2016, the mid-summer TN:TP ratio in Duck Lake was 11:1, indicating Duck Lake likely transitions between nitrogen and phosphorus limitation depending on the availability of either nutrient. Nitrogen concentrations measured in the Phase III lakes (Otter, Lynx, and Duck) in 2016 were lower than concentrations measured in the upstream Phase I and II lakes. It is believed that this perceived decrease in nitrogen concentration downstream is the result of collecting samples in different years. Changes in environmental conditions (e.g. precipitation) likely caused changes in nitrogen (and phosphorus) concentration between these years. As is discussed in the next subsection, chlorophyll-*a* concentrations in Duck Lake are closely correlated with total phosphorus concentrations, indicating that phosphorus is the primary nutrient regulating algal production in Duck Lake.

Duck Lake Trophic State

Figure 8.8.1-5 contains the Trophic State Index (TSI) values for Duck Lake calculated from the data collected in 2016 along with historical data. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by other factors other than phytoplankton such as dissolved organic compounds. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation. The TSI values for total phosphorus, chlorophyll, and Secchi disk in Duck Lake are very similar indicating a high degree of correlation. The high degree of correlation between total phosphorus and chlorophyll-*a* indicates that while the lake may transition between phosphorus and nitrogen limitation, phosphorus is likely most often the nutrient regulating algal production within the lake. The weighted TSI values for total phosphorus and chlorophyll-*a* (and Secchi disk depth) in Duck Lake indicate the lake is in currently in a eutrophic state. Duck Lake is more productive when compared to other deep lowland drainage lakes in Wisconsin and other lakes within the NLF ecoregion.

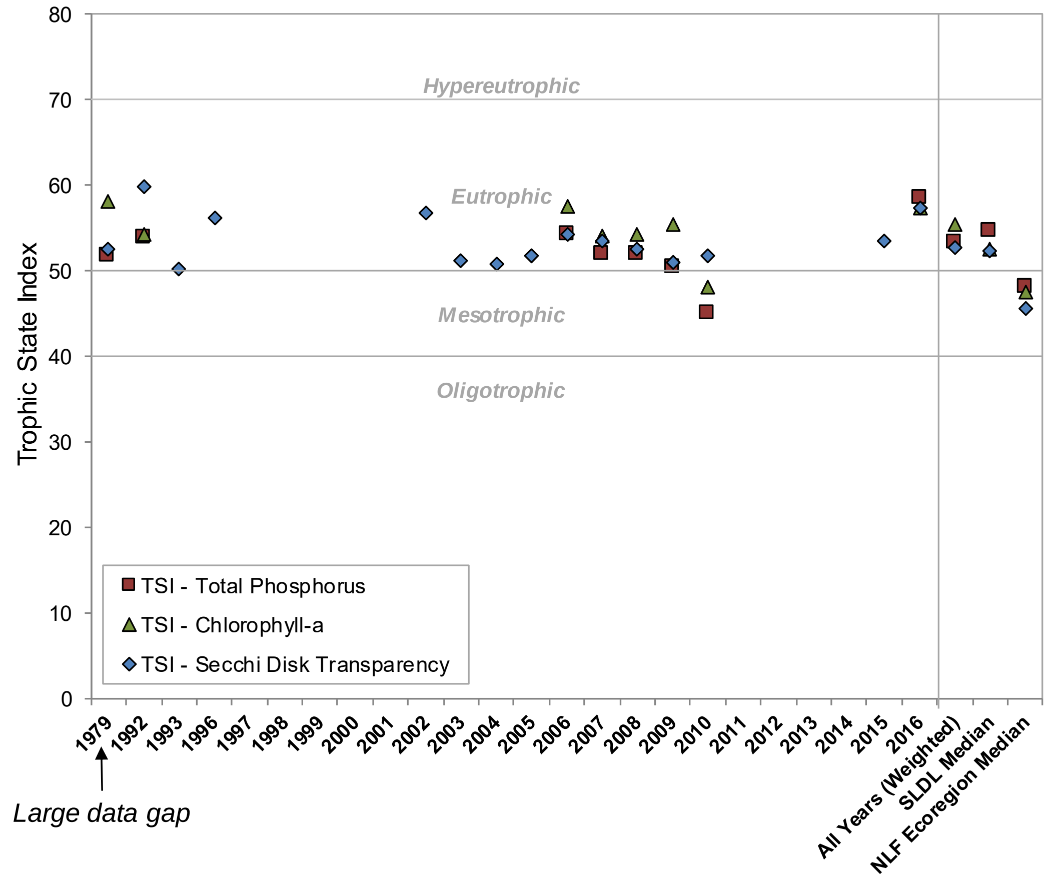
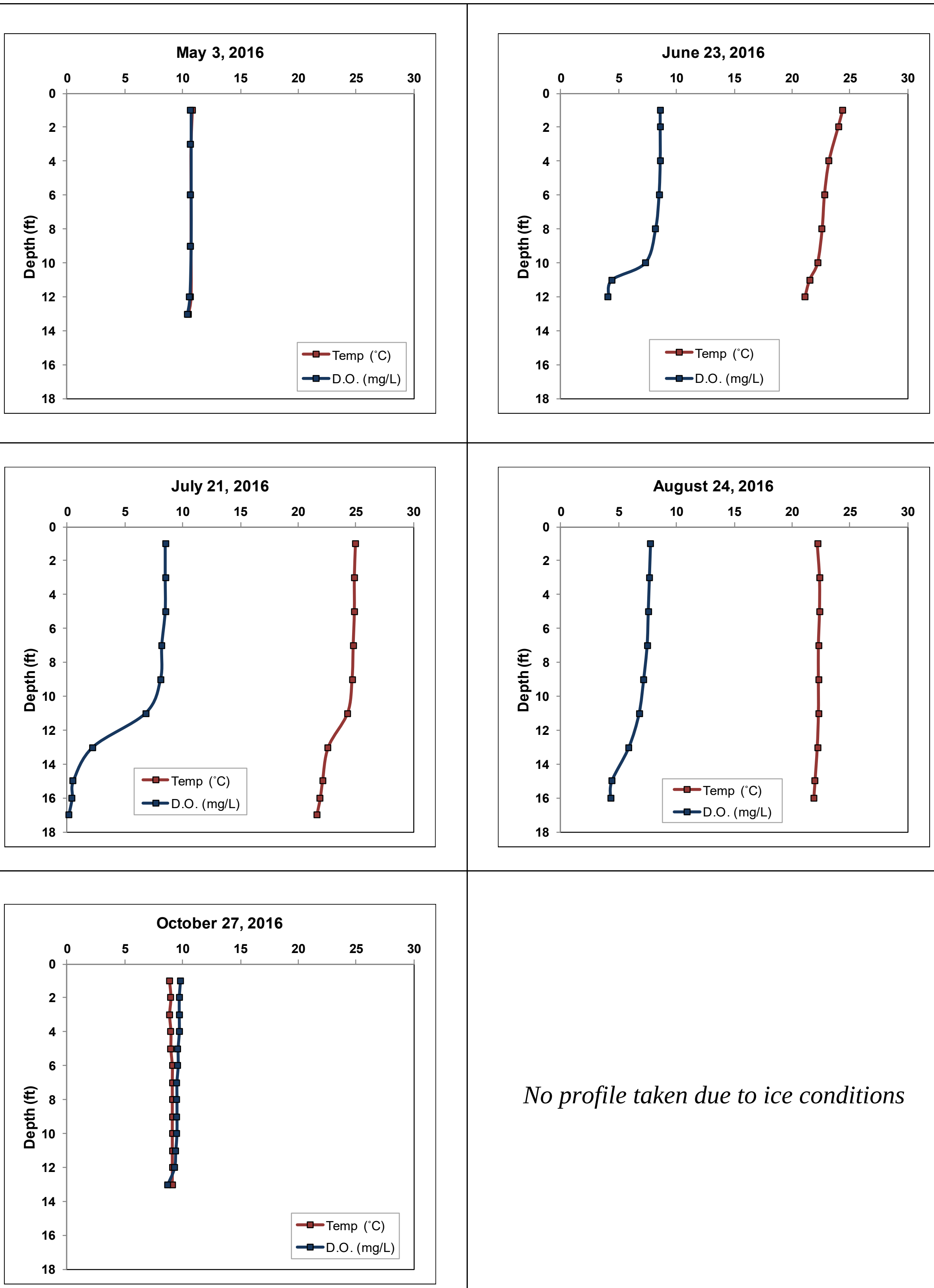


Figure 8.8.1-5. Duck Lake, statewide deep lowland drainage lakes (DLDL), and Northern Lakes and Forests (NLF) ecoregion lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Duck Lake

Dissolved oxygen and temperature profiles were created during each water quality sampling trip made to Duck Lake by Onterra staff. Graphs of those data are displayed in Figure 8.8.1-6 for all sampling events. An attempt to sample Duck Lake during the winter was made in February 2017, but the sampling did not occur due to unsafe ice conditions. The temperature and dissolved oxygen data indicate that Duck Lake was well mixed in early-May and stratified weakly in June and July. In August, the lake was again completely mixed and likely remained mixed into the fall.



No profile taken due to ice conditions

Figure 8.8.1-4. Duck Lake 2016/2017 dissolved oxygen and temperature profiles.

Additional Water Quality Data Collected at Duck 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 Duck 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. Duck Lake's surface water pH was measured at roughly 7.7 during May and 7.3 during July of 2016. 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 Duck Lake was measured at 29.0 and 31.0 mg/L as $CaCO_3$ in May and July of 2016. 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 Duck Lake during 2016. 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 Duck Lake's pH of 7.5 - 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 Duck Lake was found to be 8.1 mg/L in May and 8.6 mg/L in July of 2016, which are below the optimal range for zebra mussels. Plankton tows were completed by Onterra staff during the summer of 2016 and these samples were processed by the WDNR for larval zebra mussels. Their analysis was negative for the presence of zebra mussel veligers.

8.8.2 Duck Lake Watershed Assessment

Duck Lake's watershed is approximately 149,705 acres in size. Compared to its surface area of 109 acres, this makes for a large watershed to lake area ratio of 1,372:1.

Exact land cover calculation and modeling of nutrient input to Duck Lake will be completed towards the end of this project (in 2016-2017). 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.

8.8.3 Duck 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 fall of 2016, Duck Lake's immediate shoreline was assessed in terms of its development. Duck Lake has stretches of shoreland that fit all of the five shoreland assessment categories. In all, 0.5 miles of natural/undeveloped and developed-natural shoreline were observed during the survey (Figure 8.8.3-1). This constitutes about 30% of Duck 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, 0.8 miles of urbanized and developed–unnatural shoreline (51%) was observed. If restoration of the Duck 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. Duck Lake – Map 1 displays the location of these shoreline lengths around the entire lake.

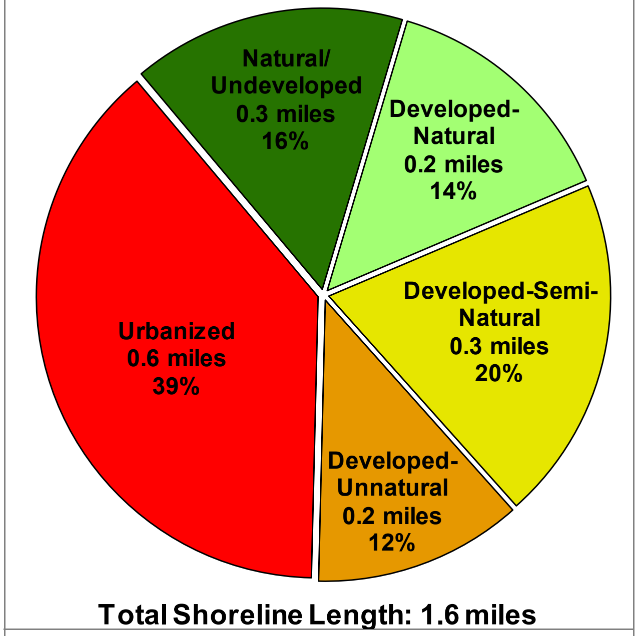


Figure 8.8.3-1. Duck Lake shoreland categories and total lengths. Based upon a fall 2016 survey. Locations of these categorized shorelands can be found on Duck Lake – Map 1.

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 Eagle River 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.

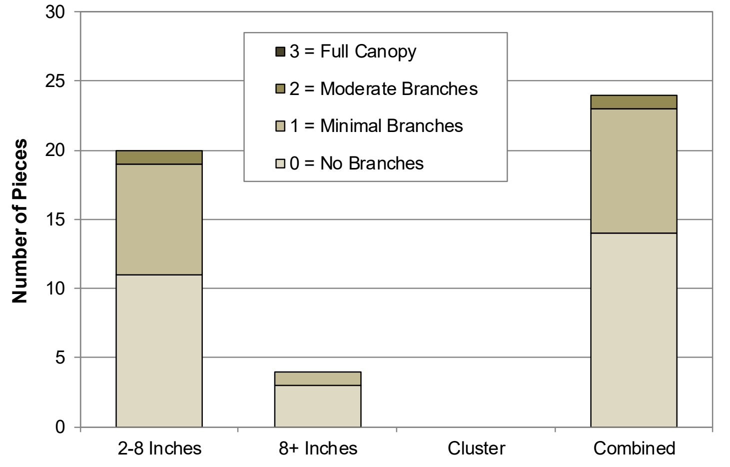


Figure 8.8.3-2. Duck Lake coarse woody habitat survey results. Based upon a fall 2016 survey. Locations of Duck Lake coarse woody habitat can be found on Duck Lake – Map 2.

During this survey, 24 total pieces of coarse woody habitat were observed along 1.6 miles of shoreline, which gives Duck Lake a coarse woody habitat to shoreline mile ratio of 15:1 (Figure 8.8.3-2). Locations of coarse woody habitat are displayed on Duck 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).

8.8.4 Duck Lake Aquatic Vegetation

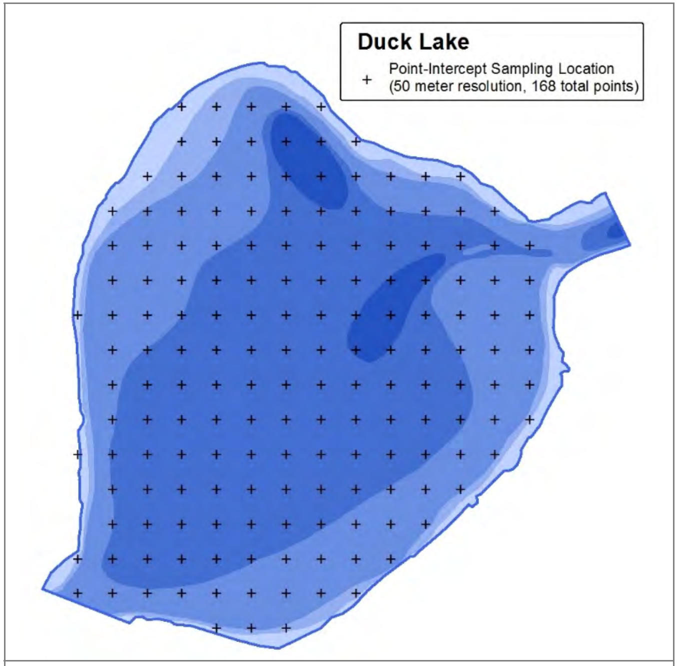


Figure 8.8.4-1. Point-intercept locations on Duck Lake.

An early season aquatic invasive species survey was conducted on Lynx Lake on July 6, 2016. While the intent of this survey is to locate any potential non-native species within the lake, the primary focus is to locate occurrences of 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.

The whole-lake aquatic plant point-intercept survey was conducted on Duck Lake by Onterra on August 3, 2012 (Figure 8.8.4-1), while the aquatic plant community mapping survey was conducted on July 12, 2016. During these surveys, a total of 22 aquatic plant species were located, one of which are considered to be a non-native, invasive species: Eurasian watermilfoil (Table 8.8.4-1). One native plant species located, Vasey's pondweed (*Potamogeton vaseyi*), is listed by the Wisconsin Natural Heritage Inventory Program as a species of 'special concern' because it is rare or uncommon in Wisconsin and there is uncertainty regarding its abundance and distribution within the state.

As discussed in the primer section, sediment data were collected at each sampling location within the littoral zone during the point-intercept survey. Approximately 36% of the point-intercept locations within littoral areas contained sand, 64% contained fine, organic sediments (muck), and 0% contained rock. The majority of the shallow, near-shore areas contained sand and/or rock, while the deeper areas of the littoral zone were comprised of muck. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in mucky substrates, others only in sandy areas, and some can be found growing in either. Lakes that have varying substrate types generally support a higher number of plant species because the different habitat types that are available.

During the 2016 point-intercept survey, aquatic plants were found growing to a maximum depth of 12 feet, deeper than the depth of 9 feet recorded in 2006. The water within the Lower Eagle River Chain of Lakes is considered 'stained,' or contains higher amounts of dissolved organic compounds which gives the water a tea-like color. These compounds scatter light and limit the amount that can penetrate vertically into the water column. Thus, the growth of aquatic plants within the chain's lakes is restricted to shallower areas where they can receive enough light to photosynthesize.

Of the 144 point-intercept sampling locations that fell at or below the maximum depth of plant growth in 2012, approximately 22% contained aquatic vegetation. This is much lower than what was found in the 2006 survey where approximately 66% of the littoral sampling locations contained aquatic vegetation. Map Duck Lake-2 displays the point-intercept locations that contained aquatic vegetation in 2012, and the total rake fullness (TRF) ratings at those locations. Most of the aquatic vegetation in 2012 was located within shallower areas of the lake. Twenty-eight percent of the point-intercept locations had a total rake fullness rating of 1, 41% had a total rake fullness rating of 2, and 31% had the highest total rake fullness rating of 3. Total rake fullness ratings were not recorded during the 2006 survey, so a comparison cannot be made.

Table 8.8.4-1 displays the aquatic plant species located in Duck Lake during the 2006 Northern Environmental, Inc. (NEI) and Onterra 2012 point-intercept surveys. All of the species recorded in 2006 were recorded in 2012. An additional 11 native aquatic plant species were located in Duck Lake in 2012 that had not been recorded in 2006.

Table 8.8.4-1. Aquatic plant species located in Duck Lake during 2006 and 2012 point-intercept surveys.

Growth Form	Scientifc Name	Common Name	Coefficient of Conservatism (C)	2006 (NEI)	2012 (Onterra)
E	*Carex utriculata*	Common yellow lake sedge	7		I
	Pontederia cordata	Pickerelweed	9		X
	Schoenoplectus tabernaemontani	Softstem bulrush	4		I
	Typha spp.	Cattail spp.	1		I
FL	*Nymphaea odorata*	White water lily	6	X	X
	Nuphar variegata	Spatterdock	6		X
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9		I
Submergent	*Ceratophyllum demersum*	Coontail	3	X	X
	Elodea canadensis	Common waterweed	3	X	X
	Myriophyllum sibiricum	Northern watermilfoil	7	X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Exotic	X	X
	Najas flexilis	Slender naiad	6		X
	Nitella spp.	Stoneworts	7		X
	Potamogeton amplifolius	Large-leaf pondweed	7	X	X
	Potamogeton foliosus	Leafy pondweed	6		X
	Potamogeton pusillus	Small pondweed	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	5		X
	Potamogeton robbinsii	Fern pondweed	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	8		X
	*Potamogeton vaseyi**	Vasey's pondweed	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	6	X	X
	Vallisneria americana	Wild celery	6	X	X

E = Emergent, FL = Floating-leaf, FL/E = Floating Leaf and Emergent
X = Located on rake during point-intercept survey; I = Incidental Species
** = Species listed as special concern in Wisconsin*

Of the 18 aquatic plant species recorded on the rake during the 2012 point-intercept survey, wild celery, flat-stem pondweed, small pondweed, and Vasey's pondweed were the four-most frequently encountered (Figure 8.8.4-2). Wild celery, or tape grass, was the most abundant aquatic plant encountered in 2012 with a littoral occurrence of approximately 12.5%. This species has bundles of long submersed leaves that are flat and ribbon-like which emerge from a basil rosette and provide excellent structural habitat for aquatic organisms. Spreading rapidly via rhizomes, wild celery is often found growing in large colonies where their extensive root systems stabilize bottom sediments. In mid- to late-summer, the coiled flower stalks of wild celery can be observed at or near the surface, and following pollination, large banana-shaped seed pods can also be seen. These seed pods have been shown to be an important food source for waterfowl (Borman et al. 1997).

Flat-stem pondweed was the second-most frequently encountered aquatic plant in Duck Lake in 2012 with a littoral frequency of occurrence of 11% (Figure 8.8.4-2). As its name indicates, flat-stem pondweed possesses a conspicuously flattened stem. Able to tolerate low-light conditions, flat-stem pondweed is usually found in more productive lakes, and provides valuable structural habitat and sources of food for wildlife. Small pondweed was the third-most abundant aquatic plant encountered in Duck Lake in 2012, with a littoral occurrence of approximately 9%. Small pondweed is one of several narrow-leaved pondweed species that can be found in Wisconsin. In Duck Lake, it was observed growing in tall, dense stands, which provide excellent structural habitat for aquatic organisms.

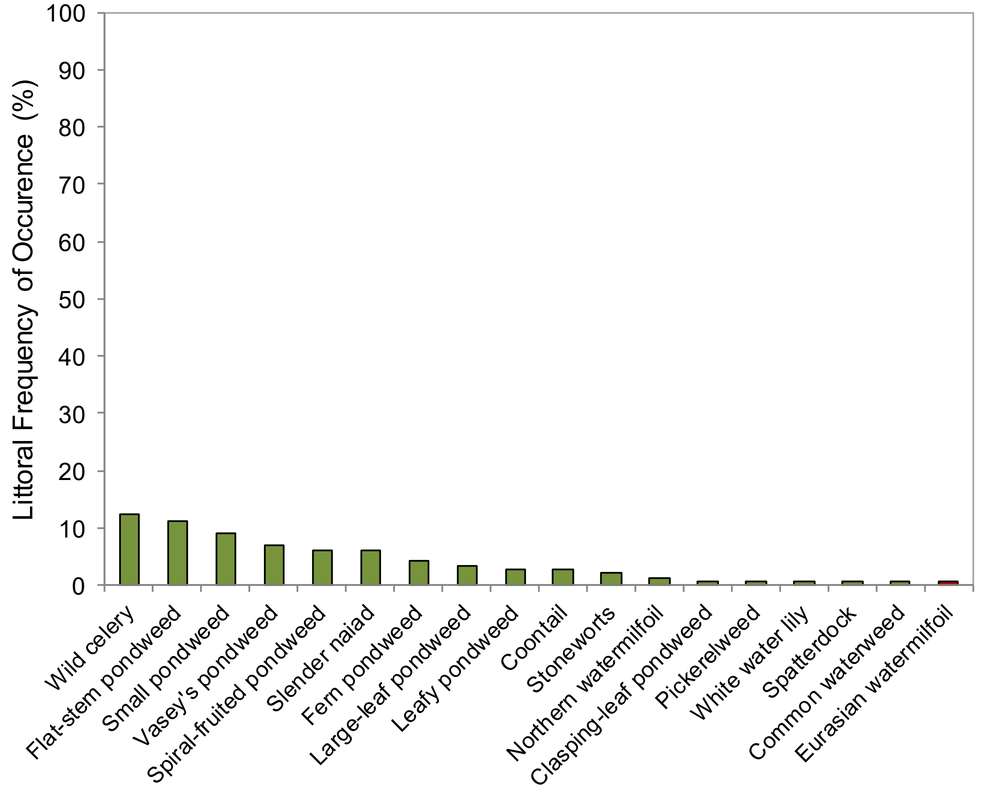


Figure 8.8.4-2. Duck Lake 2012 aquatic plant littoral frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey. Non-native species are indicated in red.

Vasey's pondweed was the fourth-most frequently encountered aquatic plant species in 2012. As mentioned previously, Vasey's pondweed is listed as a special concern species due to its rarity and uncertainty regarding its abundance in Wisconsin. Like small pondweed, Vasey's pondweed is a narrow-leaf pondweed, but its leaves are much finer. Vasey's pondweed also produces floating leaves, which can be seen at the surface in shallow water. The occurrence of Vasey's pondweed within Duck Lake is an indicator of a high-quality environment.

To determine if the 2008-2012 Eurasian watermilfoil control project on Duck Lake had any detectable impacts to the native aquatic plant community, and to determine if the control project was successful at reducing the Eurasian watermilfoil population, Chi-square distribution analysis ($\alpha = 0.05$) was used to determine if there were any statistically valid changes in the occurrences of aquatic plant species from 2006 to 2012. Figure 8.8.4-3 displays the littoral occurrences of Eurasian watermilfoil and native aquatic plant species that had a littoral occurrence of at least 5% in one of the two surveys. The figure divides the plants into dicots and non-dicots, as dicots are thought to be more susceptible to the 2,4-D herbicide treatments that were occurring in Duck Lake.

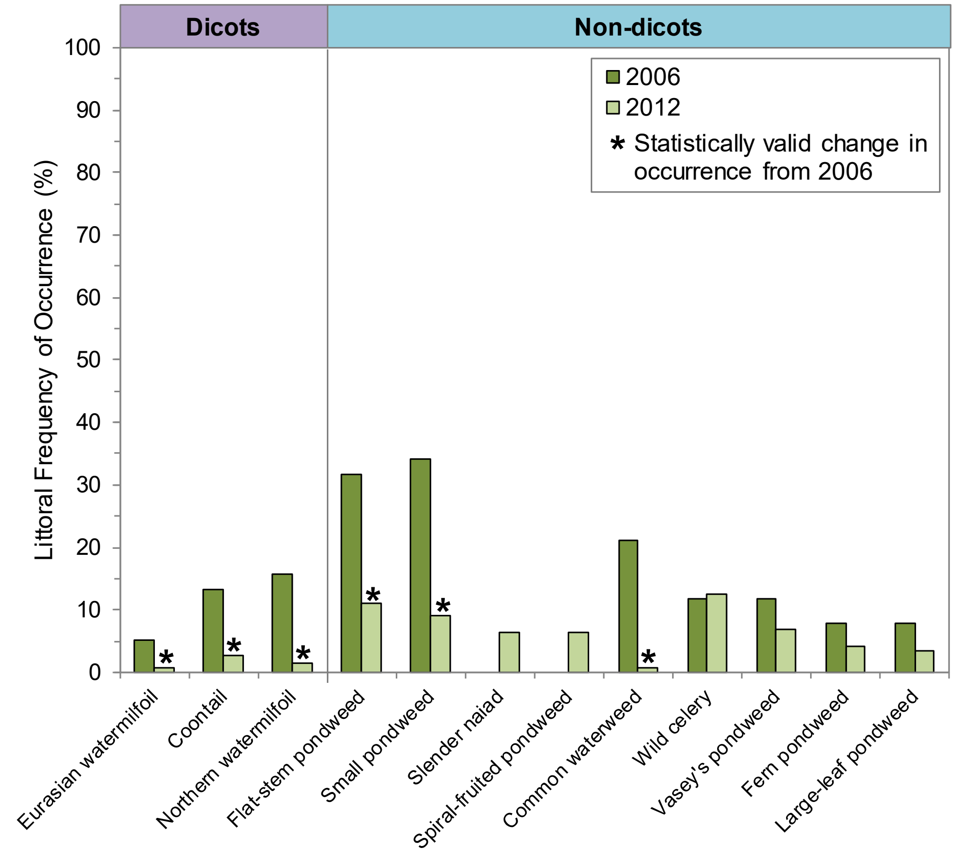


Figure 8.8.4-3. Duck Lake littoral frequency of occurrence of select aquatic plant species from 2006 and 2012 point-intercept surveys. Please note that only those native species with an occurrence of at least 5% in one of the two surveys are displayed. Created using data from 2006 and 2012 point-intercept surveys.

The littoral occurrence of Eurasian watermilfoil in Duck Lake in 2006 was approximately 5%, and in 2012 its occurrence was found to have declined to 0.7% (Figure 8.8.4-3). Five native aquatic plant species including coontail, northern watermilfoil, flat-stem pondweed, small pondweed, and common waterweed also exhibited statistically valid reductions in their occurrence from 2006-2012 in Duck Lake. Two native aquatic plant species, slender naiad and spiral-fruited pondweed, exhibited statistically valid increases in their littoral occurrence from 2006 to 2012. It is possible that the declines observed in some native aquatic plants in Duck Lake were due to the herbicide treatments that took place on the lake between this period. A point-intercept survey is scheduled to take place on Duck Lake in 2017 to reassess its plant community, and data collected from this survey will reveal if the occurrence of these native plant species has increased.

As discussed in the primer 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. For example, while a total of 21 native aquatic plant species were located in Duck Lake during the 2012 and 2016 surveys, 17 were encountered on the rake during the 2012 point-intercept survey. The remaining four species were located *incidentally*. Incidental species include those that were not encountered at any of the point-intercept sampling survey locations but were observed on the lake. Incidental species typically include emergent and floating-leaf plants which tend to grow on the margins of the lake or submersed species that are relatively rare within the community. The 17 native species and their conservatism values were used to calculate the FQI of Duck Lake's aquatic plant community in 2012 (equation shown below). The FQI was also calculated based on the species located during the 2006 survey.

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

Figure 8.8.4-4 compares the FQI components of Duck Lake from the 2006 and 2012 point-intercept surveys to median values of lakes within the Northern Lakes and Forests Lakes (NLFL) Ecoregion as well as the entire State of Wisconsin. In 2012, Duck Lake's native species richness (17) is higher than the median values for lakes within the ecoregion and the state. The average conservatism value in 2012 (6.5) is slightly lower than the ecoregional median but above the state median.

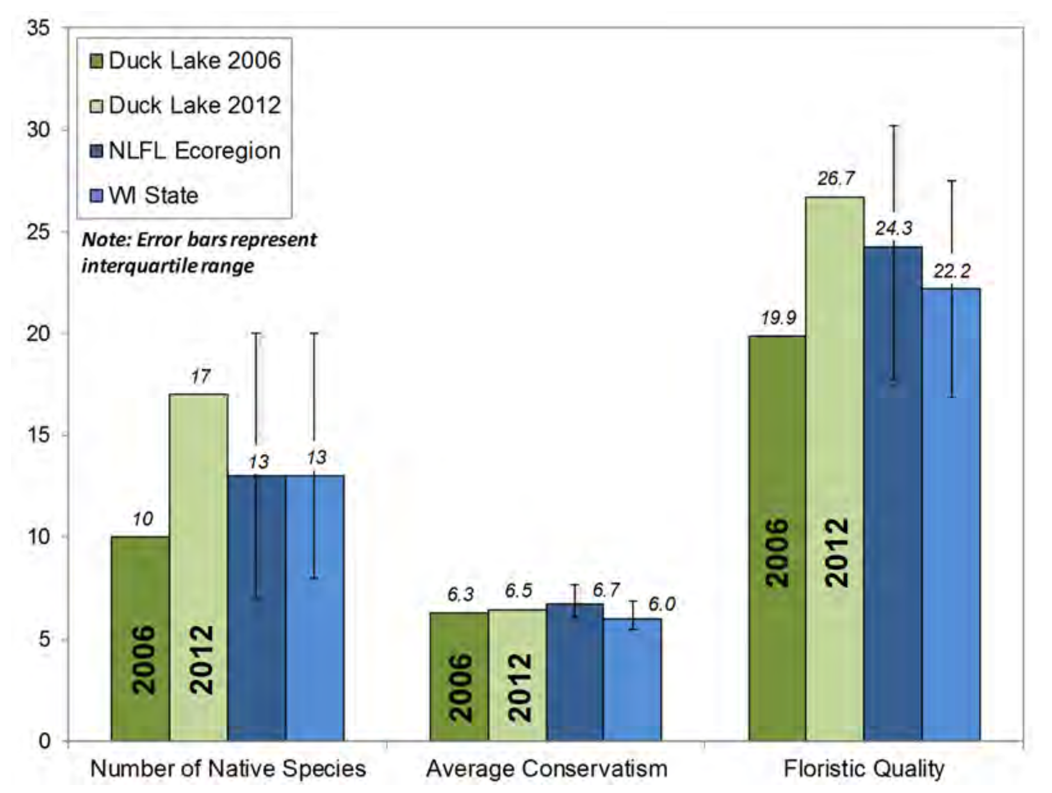


Figure 8.8.4-4. Duck Lake Floristic Quality Index values. Created using data from 2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLFL = Northern Lakes and Forests Lakes Ecoregion.

Combining Duck Lake's 2012 native species richness and average conservatism values yields a FQI value of 26.7, which is higher than the ecoregional and state median values (Figure 8.8.4-4). The FQI values from 2012 are also higher than those calculated from point-intercept survey in 2006, indicating that the quality of Duck Lake's aquatic plant community has not been degraded by the Eurasian watermilfoil control project. This analysis indicates that Duck Lake's aquatic plant community is of slightly higher quality than the majority of lakes within the ecoregion and the entire state.

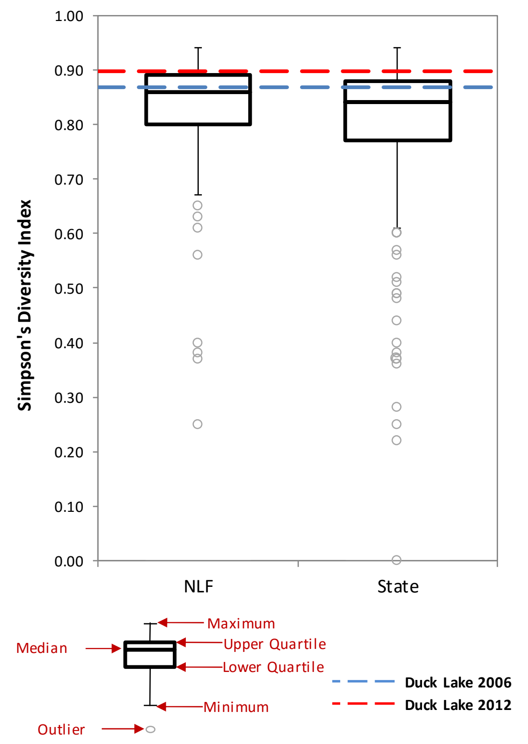


Figure 8.8.4-5. Duck Lake species diversity index. Created using data from 2006 and 2012 point-intercept surveys. Ecoregion data provided by WDNR Science Services.

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

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Duck Lake's diversity value ranks. Using data obtained from WDNR Science Services, quartiles were calculated for 109 lakes within the NLF Ecoregion (Figure 8.8.4-5). Using the data collected from the 2012 point-intercept survey, Duck Lake's aquatic plant community was shown to have a high species diversity with a Simpson's diversity value of 0.90, falling just above the upper quartile value for lakes in both the ecoregion and the state. Duck Lake's 2012 diversity was higher than the diversity calculated from data collected during the 2006 point-intercept survey (0.87).

Figure 8.8.4-6 displays the relative frequency of occurrence of aquatic plant species in Duck Lake from the 2012 point-intercept survey and illustrates relative abundance of species within the community to one another; the aquatic plant community is not overly dominated by a single or few species, which would create a less-diverse community.

The 2016 aquatic plant community mapping survey revealed that Duck Lake contains and floating-leaf aquatic plant communities but none of the areas were large enough to create a determinable acreage (Duck Lake – Map 4). Eight emergent and floating-leaf aquatic plant species were located in the lake in 2012 and 2016 (Table 8.7.4-2). These plant communities provide valuable fish and wildlife habitat important to the ecosystem of the lake. The community map represents a 'snapshot' of the important emergent and floating-leaf plant communities, and a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within Duck Lake. This is important, because these communities are often negatively affected by recreational use and shoreland development.

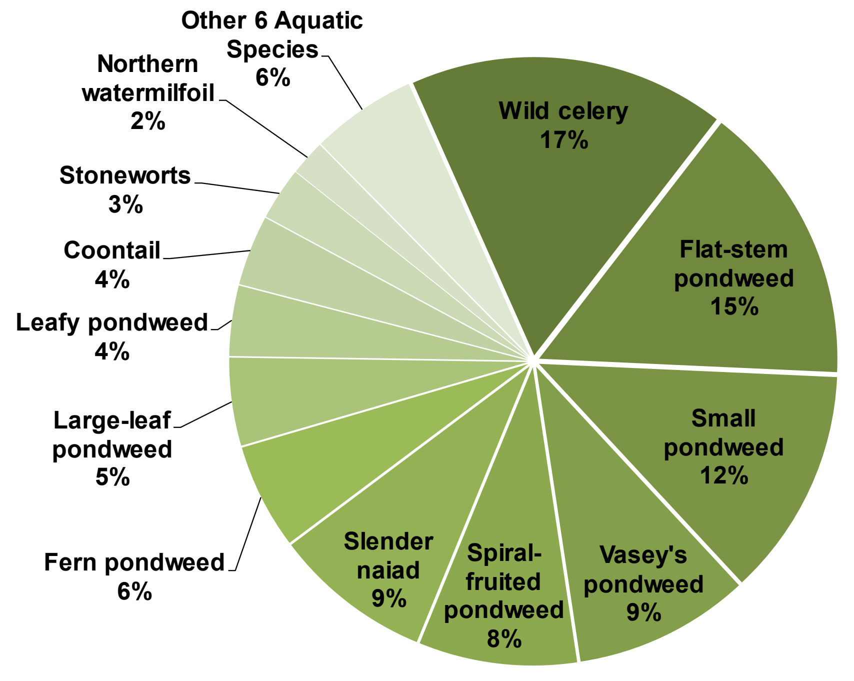


Figure 8.8.4-6. Duck Lake 2012 aquatic plant relative frequency of occurrence. Created using data from 2012 aquatic plant point-intercept survey.

8.8.4 Duck Lake Implementation Plan

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

While the lakes within the Lower Eagle River Chain of Lakes are relatively similar in terms of their water quality and aquatic plant communities, each lake possesses its own unique attributes. This uniqueness leads to the need to create individual plans aimed at managing the specific needs of each individual lake. Some of the lakes within the Lower Eagle River Chain (i.e. Scattering Rice Lake) have more complicated management needs than others, but in general most lakes' needs center on protecting the current quality of the lake and restoring/protecting immediate shoreland areas. The Chain-wide Implementation Plan will serve each of the project lakes well in terms of protecting their current condition as a chain. Duck Lake's Implementation Plan illustrates how Duck Lake stakeholders should proceed in implementing applicable portions of the Chain-wide Implementation Plan for their lake.

Chain-wide Implementation Plan – Specific to Duck Lake

Chain-wide Management Goal 1: Maintain Current Water Quality Conditions

Management Action:	Continue water clarity monitoring in Duck Lake through the WDNR Citizen Lake Monitoring Network (CLMN).
Timeframe:	Continuation of current effort
Facilitator:	Marc Groth, current Duck Lake CLMN volunteer
Description:	Monitoring water quality is an important aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. 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 WDNR 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 annually. If funding 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).

Volunteers from Duck Lake have been collecting water quality data intermittently since 1992. Duck Lake is not currently enrolled in the advanced water program and is currently collecting water clarity data. As is discussed within the Chain-Wide Implementation Plan, if additional funding should become available to include additional lakes within the chain in the advanced monitoring program, Scattering Rice Lake and Watersmeet have been given priority due to their positions within the chain. Duck Lake currently has an active volunteer (Dave Mueller) who collects and enters water quality data into the WDNR's SWIMS database on an annual basis.

Duck Lake (and ERCLA) recognizes the importance of continuing this effort which will supply them and resource managers with valuable data about their lake. Moving forward, it is the responsibility of Marc Groth, the current CLMN volunteer, to report to the current chair of the ERCLA Lakes and Shores Committee and coordinator of the chain's CLMN volunteers to appoint a new monitoring volunteer as needed. The current Lakes and Shores Committee chair 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.

Action Steps:

1. Marc Groth, current CLMN volunteer, continues to collect water quality data and enter data into WDNR SWIMS database.
2. Marc Groth, current CLMN volunteer, contacts ERCLA Lakes and Shores Committee chair when new volunteer is needed.

Chain-wide Management Goal 2: Lessen the Impact of Shoreline Development on the Eagle River Chain of Lakes

Management Action: Investigate restoring highly developed shoreland areas on the Eagle River Chain of Lakes.

Description: As part of the planning project, the entire shoreline of Duck Lake was categorized based on the amount of development present. The results of this survey revealed that approximately 51% (0.8 miles) of the shoreline are in an urbanized or developed-unnatural state, 20% (0.3 miles) is in a developed-semi-natural state, and 30% (0.5 miles) is in a developed-natural or natural/undeveloped state. Continuing research indicates that the shoreland zone is a critical component of a lake's ecology through providing both pollutant buffering and wildlife habitat. In addition, natural shoreland areas also increase the lake's aesthetic appeal.

ERCLA's Shores Subcommittee will be working with Quita Sheehan from the Vilas County Land and Water Department to gather information on initiating and conducting shoreland restoration projects. The Shores Subcommittee will serve as a contact point for

property owners who are interested in pursuing shoreland restoration on their property. Interested property owners may contact ERCLA for more information on shoreland restoration plans, financial assistance, and benefits of implementation.

Management Action: Preserve natural shoreland areas on the Eagle River Chain of Lakes.

Description: While approximately 51% of Duck Lake's shoreline is in a highly-developed state, approximately 30% of the shoreline contains little to no development. Preservation of these natural areas is very important for the lake's overall health, and owners of these properties should be educated on the benefits their shoreland is providing to Duck Lake and to the entire chain.

The shoreland areas delineated as Natural and Developed-Natural should be prioritized for education initiatives and physical preservation. The ERCLA Shores Subcommittee will work with appropriate entities to research grant programs and other pertinent information that will aid ERCLA in preserving the Eagle River Chain's shoreland. This would be accomplished through education of property owners, or direct preservation of land through implementation of conservation easements or land trusts that the property owner would approve of. Duck Lake stakeholders may assist in this management action by attending educational events held by ERCLA and by aiding in distributing ERCLA materials to Duck Lake property owners.

Management Action: Investigate with WDNR and private landowners to expand coarse woody habitat in the Eagle River Chain of Lakes.

Description: During the Duck Lake shoreland assessment, approximately 15 pieces of coarse woody habitat (CWH) per shoreline mile were observed. Often, property owners will remove downed trees, stumps, etc. from a shoreland area because these items may impede watercraft navigation shore-fishing or swimming. However, these naturally occurring woody pieces serve as crucial habitat for a variety of aquatic organisms, particularly fish, and also aid in reducing shoreline erosion.

The ERCLA Shores Subcommittee will encourage its membership to implement coarse woody habitat projects along their shoreland properties. Habitat design and location placement would be determined in accordance with the WDNR fisheries biologist. Duck Lake stakeholders interested in implementing a coarse woody habitat project along their property or who have questions about the benefits of coarse woody habitat should contact ERCLA.

Chain-wide Management Goal 3: Actively Manage Existing and Reduce the Likelihood of Further Aquatic Invasive Species Establishment within the Eagle River Chain of Lakes

Management Action: Continue annual monitoring of aquatic invasive species on the Lower Eagle River Chain of Lakes.

Description: Of the aquatic invasive species currently present in the Lower Eagle River Chain of Lakes, Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife are currently being actively managed. Duck Lake stakeholders may participate in a variety of ways to aid in managing aquatic invasive species in Duck Lake and throughout the chain. Those who are interested in participating in aquatic invasive species monitoring and management should contact ERCLA.

Duck Lake stakeholders can keep themselves up to date on aquatic invasive species matters through attending WDNR training sessions, media releases, or participating in Duck Lake Association and ERCLA meetings. Duck Lake stakeholders can also participate in the active annual monitoring of Eurasian watermilfoil, purple loosestrife, pale-yellow iris, and garden yellow loosestrife on Duck Lake and/or volunteer to conduct watercraft inspections at designated boat landings in accordance with the Clean Boats Clean Waters Program. Additionally, Duck Lake stakeholders can also report sightings of aquatic invasive species to ERCLA and remove occurrences of purple loosestrife, pale-yellow iris, and/or garden yellow loosestrife on their property in accordance with methods determined by ERCLA and the Vilas County Invasive Species Coordinator.

Management Goal 4: Continue and Expand Awareness and Education of Lake Management and Stewardship Matters to Eagle River Chain of Lakes Riparians and the General Public

Management Action: ERCLA will continue to promote stakeholder involvement and inform stakeholders of various lake issues as well as the quality of life on the Eagle River Chain of Lakes.

Description: Duck Lake stakeholders can assist in the implementation of this action by actively participating in ERCLA-associated educational initiatives. Participation may include attending presentations and trainings of educational topics, volunteering at local and regional events, participating in ERCLA committees, or simply notifying ERCLA of concerns regarding Duck Lake and its stakeholders.