DRAFT

Eagle River Chain of Lakes
Vilas & Oneida Counties, Wisconsin

Comprehensive Management Plan
August 2016

Created by: Brenton Butterfield, Tim Hoyman, and Eddie Heath
Onterra, LLC
De Pere, WI

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

Wisconsin Dept. of Natural Resources

Kevin Gauthier

DRAFT

TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

MAPS

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

APPENDICES

Will be included in final draft.

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 water milfoil (*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 water milfoil 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 I and Phase II 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 water milfoil) 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.

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 Brenton Butterfield met with representatives from Phase I and Phase II lakes in 2014 and 2015, 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 in November of 2015.

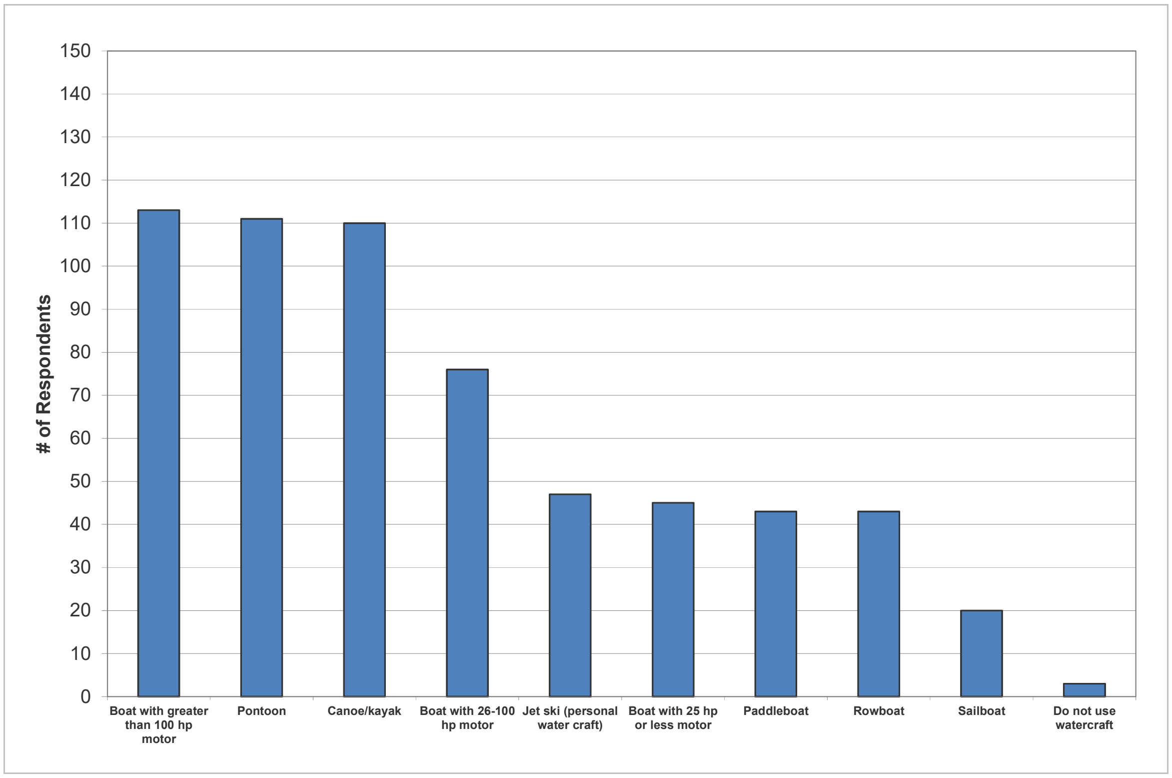
Stakeholder Survey

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.

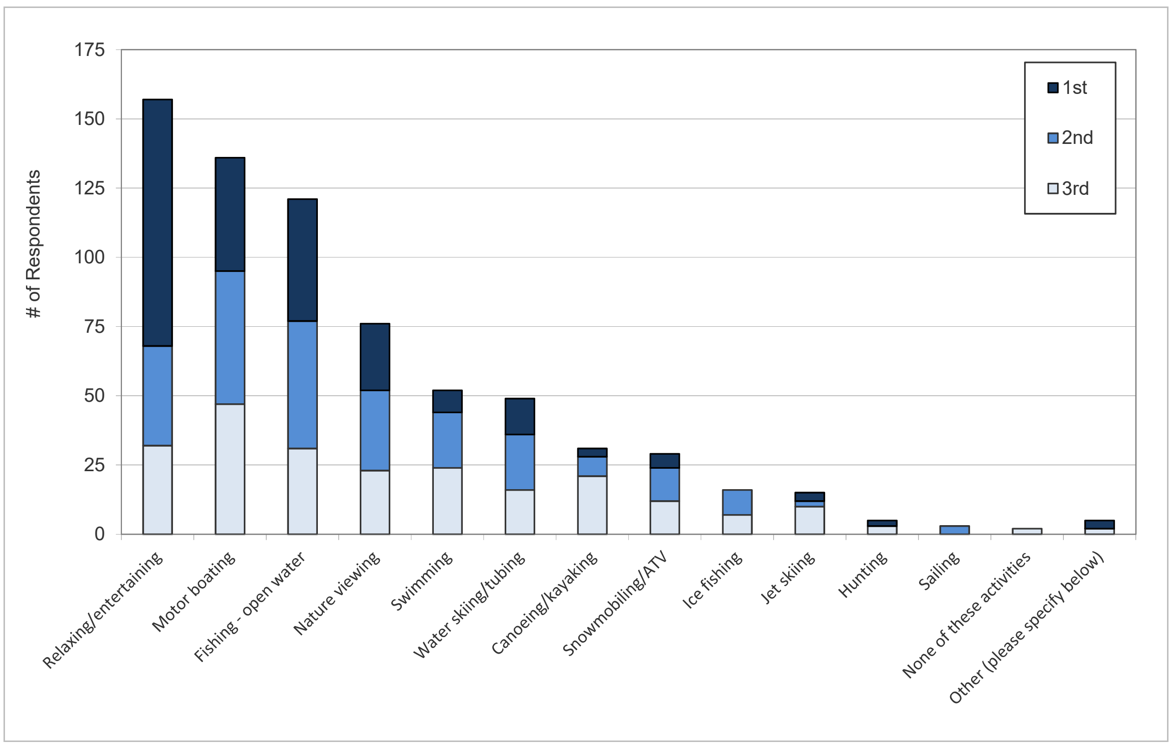


Figure 2.0-1. Select survey responses from the Eagle River Chain Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

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

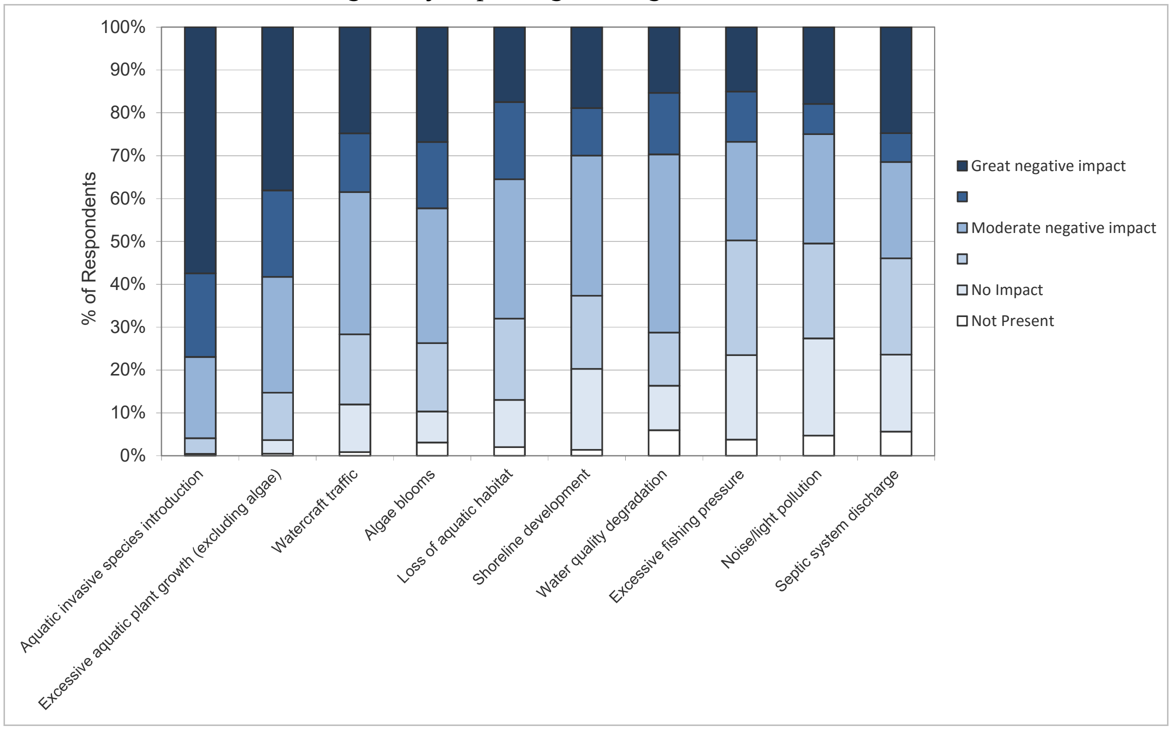


Figure 2.0-1. Select survey responses from the Eagle River Chain Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

Lower Eagle River Chain of Lakes Stakeholder AIS Concerns

As with most Wisconsin lake stakeholders, there is great concern among Lower Eagle River Chain of Lakes stakeholders regarding aquatic invasive species (AIS). ERCLA has put forth much effort to educate chain stakeholders and visitors about AIS and the threats they pose to the chain's ecology and recreation. Table 2.0-1 provides a list of the AIS that have been confirmed to be present within the lakes in the Lower Eagle River Chain of Lakes.

While no reasonable and efficient control strategy exists for several of the species on Table 2.0-1 (banded and Chinese mystery snails and rusty crayfish), several effective methods have been utilized for control of Eurasian water milfoil and purple loosestrife. The AIS present within the chain and current control strategies being implemented are discussed within the Chain-Wide Aquatic Plant Section (Section 3.4) and the Chain-Wide Implementation Plan (Section 5.0).

Table 2.0-1. Aquatic Invasive Species located on the Lower Eagle River Chain of Lakes. Information obtained from WDNR Surface water data viewer - http://dnrmaps.wi.gov/sl/?Viewer=SWDV.

Lake	Aquatic Invasive Species & Year Confirmed
Cranberry Lake	Chinese Mystery Snail (NA); Eurasian water milfoil (2001); Rusty Crayfish (1960); Purple loosestrife (NA); Garden Yellow Loosestrife (2013); Pale-yellow Iris (NA)
Catfish Lake	Chinese Mystery Snail (NA); Eurasian water milfoil (1995); Rusty Crayfish (1992); Purple Loosestrife (NA); Garden Yellow Loosestrife (2013); Pale-yellow Iris (NA)
Voyageur Lake	Eurasian water milfoil (1994); Rusty Crayfish (2002); Pale-yellow Iris (NA)
Eagle Lake	Banded Mystery Snail (2012); Chinese Mystery Snail (2009); Eurasian water milfoil (1992); Rusty Crayfish (NA); Pale-yellow Iris (NA)
Scattering Rice Lake	Banded Mystery Snail (2006); Chinese Mystery Snail (2006); Eurasian water milfoil (1992); Rusty Crayfish (2002); Purple Loosestrife (2014); Garden Yellow Loosestrife (2014); Pale-yellow Iris (NA)
Otter Lake	Banded Mystery Snail (2006); Chinese Mystery Snail (2006); Eurasian water milfoil (1992); Rusty Crayfish (2002)
Lynx Lake	Banded Mystery Snail (2006); Chinese Mystery Snail (2006); Eurasian water milfoil (1992); Rusty Crayfish (2002)
Duck Lake	Banded Mystery Snail (2006); Chinese Mystery Snail (2006); Eurasian water milfoil (1992); Rusty Crayfish (2002); Pale-yellow Iris (NA)
Yellow Birch Lake	Eurasian water milfoil (1992); Rusty Crayfish (2002); Purple Loosestrife (NA); Pale-yellow Iris (NA)
Watersmeet Lake	Chinese Mystery Snail (2005); Eurasian water milfoil (1992); Rusty Crayfish (2002); Purple Loosestrife (NA); Pale-yellow Iris (NA)

NA = Confirmation year not available

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 (vascular plants). Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.
>
> **Chlorophyll-*a*** is the green pigment in plants used during photosynthesis. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.
>
> **Secchi disk transparency** is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

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

Trophic State

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

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

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

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

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

Internal Nutrient Loading

In lakes that support strong stratification, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algae blooms decades after external sources are controlled. The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to screen non-candidate and candidate lakes following the general guidelines below:

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2014 Consolidated Assessment and Listing Methodology* (WDNR 2013A) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of 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 three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by Lathrop and Lillie (1980) which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

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

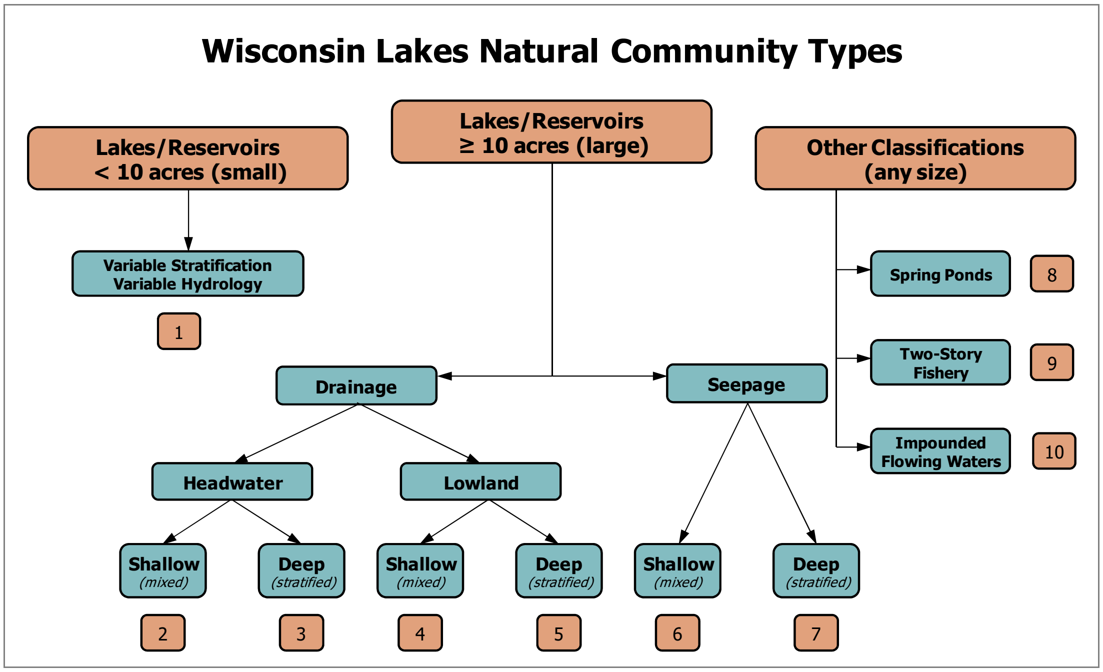


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2013A.

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.

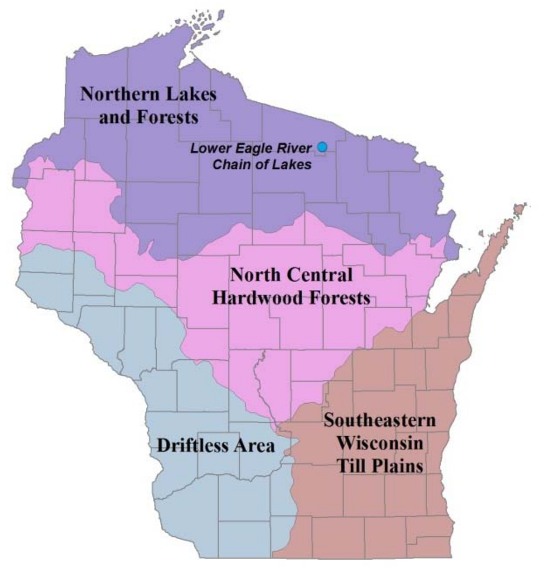


Figure 3.1-2. Location of the Lower Eagle River Chain of Lakes within the ecoregions of Wisconsin. After Nichols 1999.

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 scheduled for 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 and II lakes which have been sampled to date, average summer near-surface total phosphorus concentrations range from 43.0 µg/L in Scattering Rice Lake to 22.4 µg/L in Catfish Lake (Figure 3.1-3). With the exception of Scattering Rice Lake, the total phosphorus concentrations for the other Phase I and Phase II lakes fall near or below the statewide median value for their respective lake type. Scattering Rice Lake's total phosphorus concentration exceeds the statewide median value for shallow, lowland drainage lakes by 10 µg/L.

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 individual lake sections, 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.

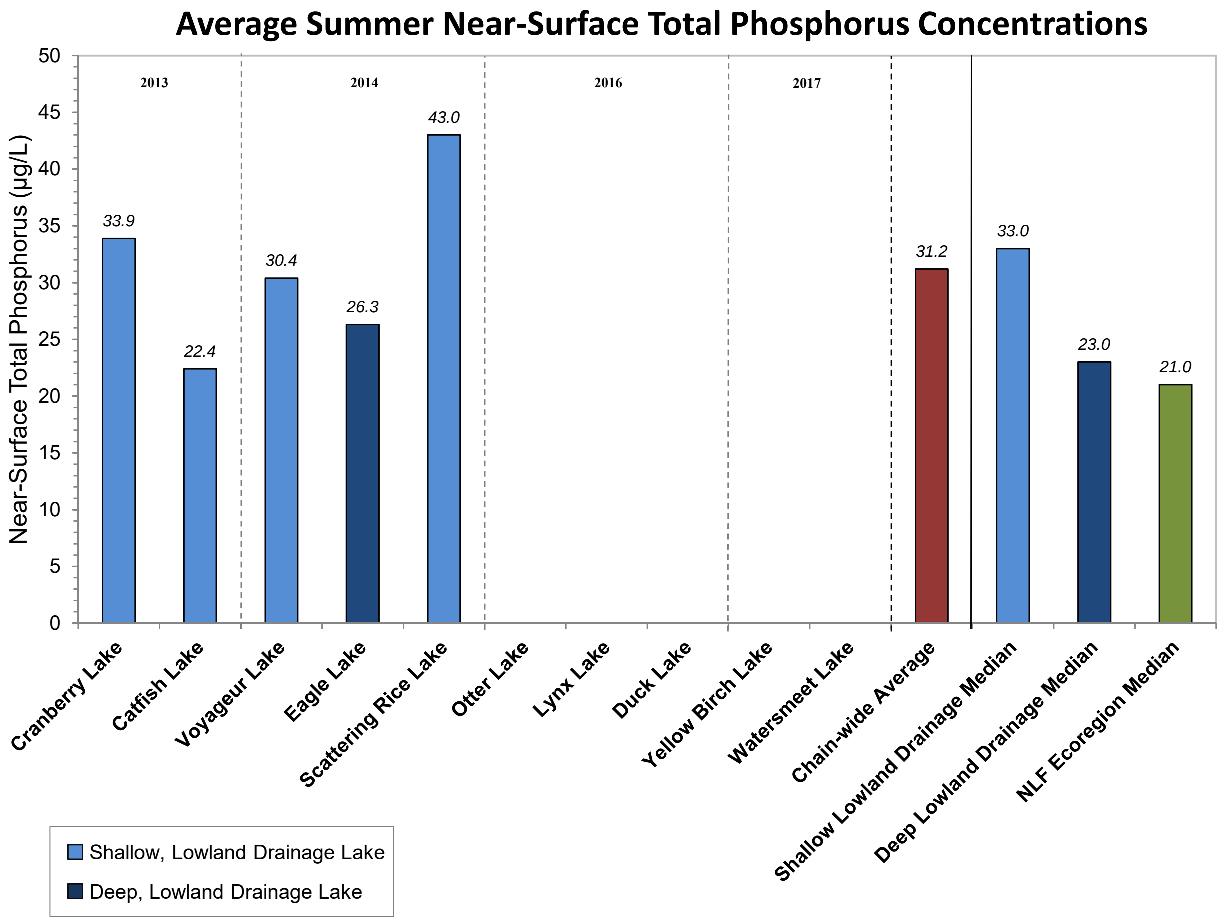


Figure 3.1-3. Lower Eagle River Chain of Lakes average summer near-surface total phosphorus concentrations and median total phosphorus concentrations from comparable lakes. Values calculated with summer month surface data and methodology using WDNR 2013. Comparisons indicated through color-coding on 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 and II lakes, with summer averages ranging from 25.8 µg/L in Scattering Rice Lake to 15.7 in Voyageur Lake. All of the chlorophyll-*a* concentrations within the Phase I and II 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 and Phase II 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 phenomena 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 >20 µg/L, periodic perceptible algae blooms may occur.

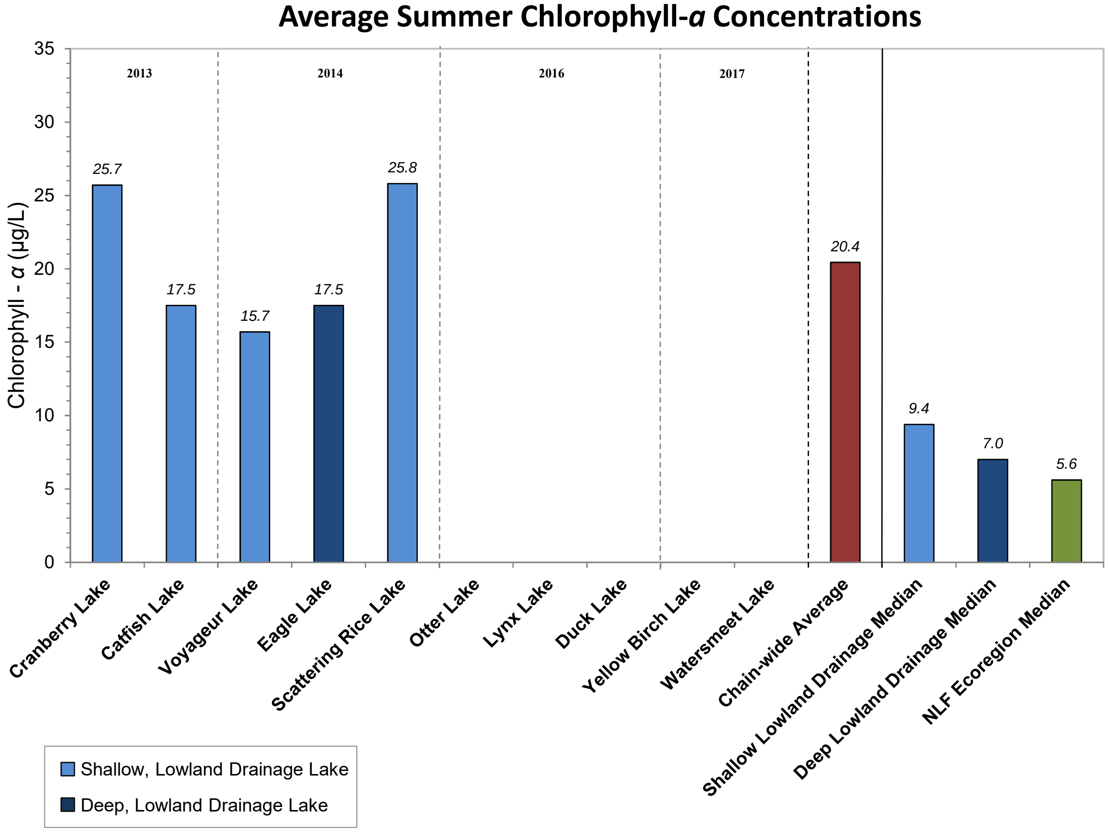


Figure 3.1-4. Lower Eagle River Chain of Lakes average summer chlorophyll-α concentrations and median chlorophyll-α concentrations for comparable lakes. Values created with summer month surface data and methodology follows WDNR 2013. Comparisons indicated through color-coding on similar natural community 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 and Phase II lakes, and ranged from 4.8 feet in Cranberry and Voyageur Lake to 3.8 feet in Scattering Rice Lake (Figure 3.1-5). Average Secchi disk clarity for the Phase I and Phase II lakes falls below 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.

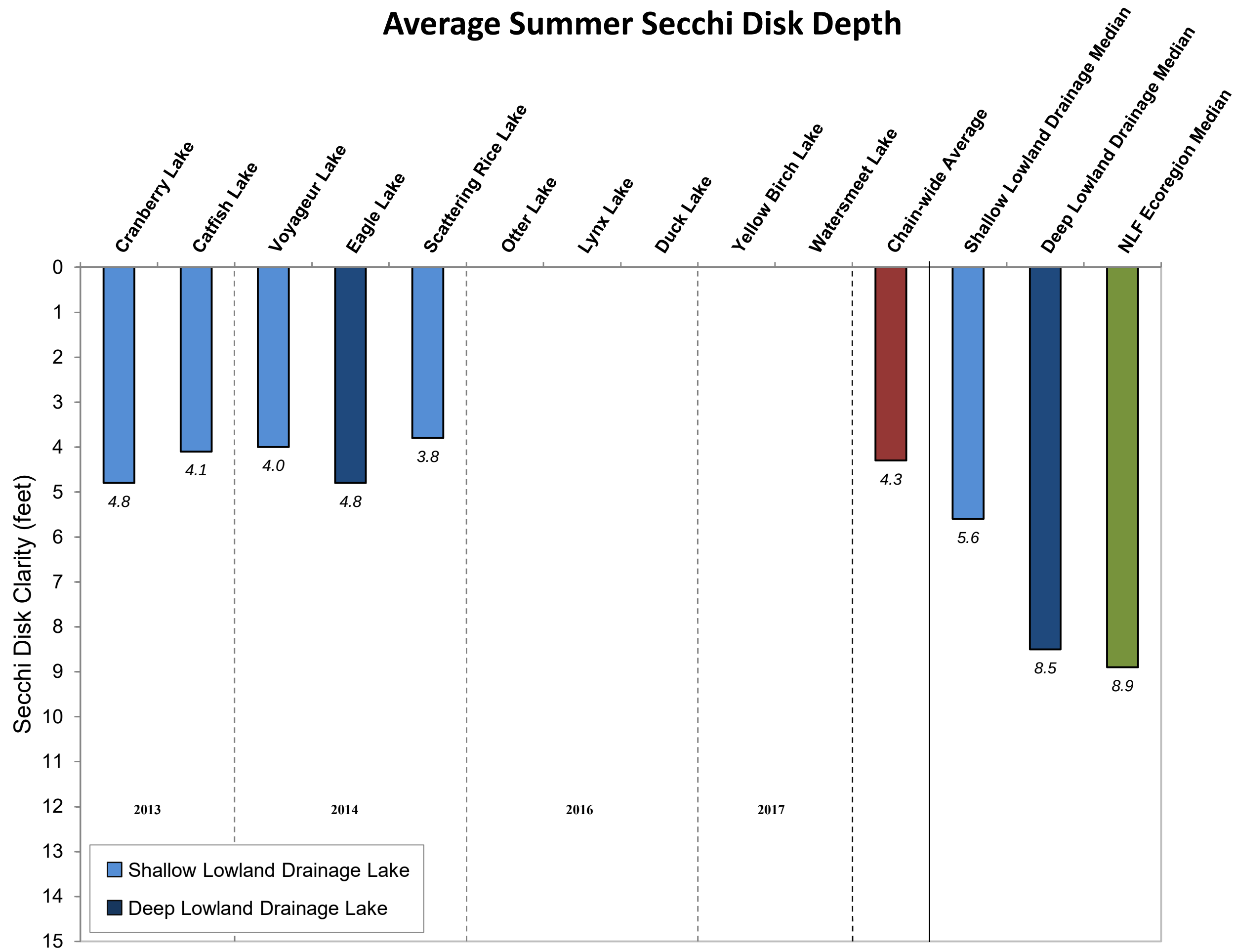


Figure 3.1-5. Lower Eagle River Chain of Lakes average summer Secchi disk transparency and median Secchi disk transparency values for comparable lakes. Methodology follows WDNR 2013. Comparisons indicated through color-coding on similar natural community lakes (Figure 3.1-1) and to the Northern Lakes 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 lakes except Scattering Rice indicate that phosphorus is the limiting nutrient and the nutrient driving algae growth within these lakes. The lower nitrogen to phosphorus ration in Scattering Rice 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			
	Lynx Lake			
	Duck Lake			
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.

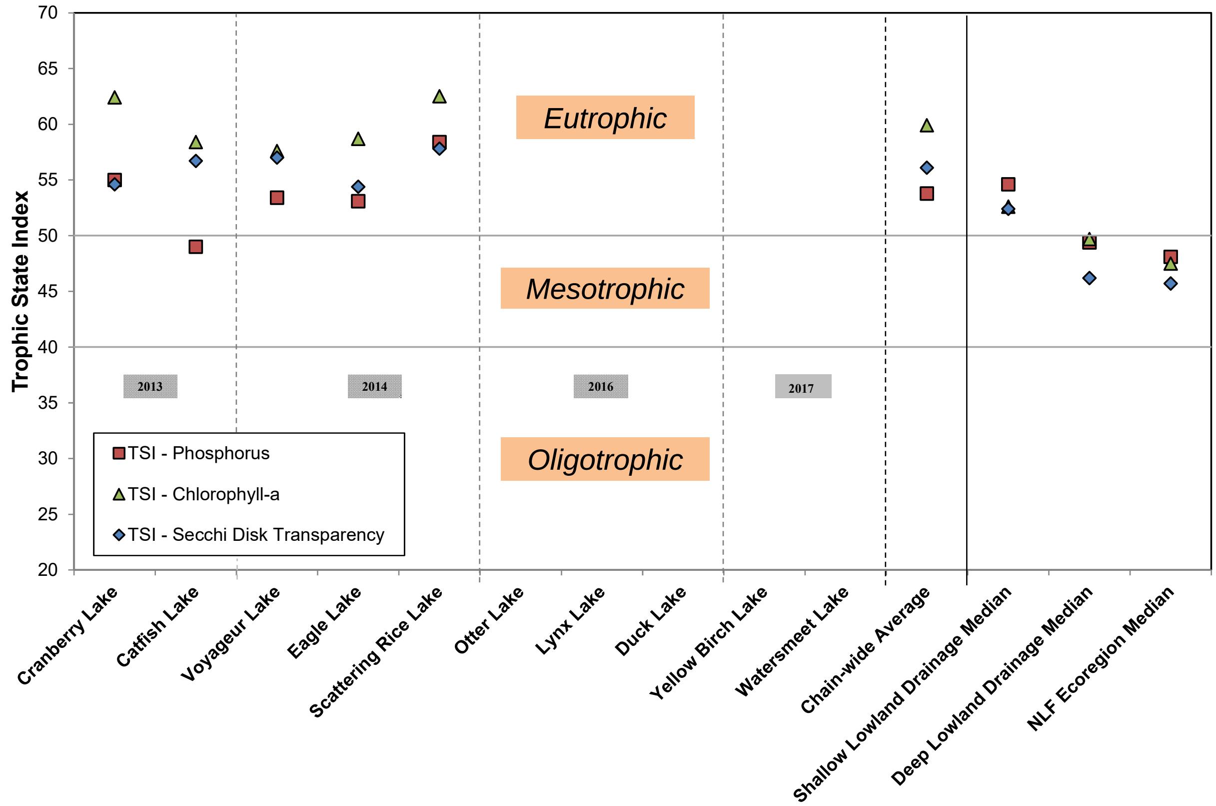


Figure 3.1-6. Lower Eagle River Chain of Lakes and comparable lakes Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

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.

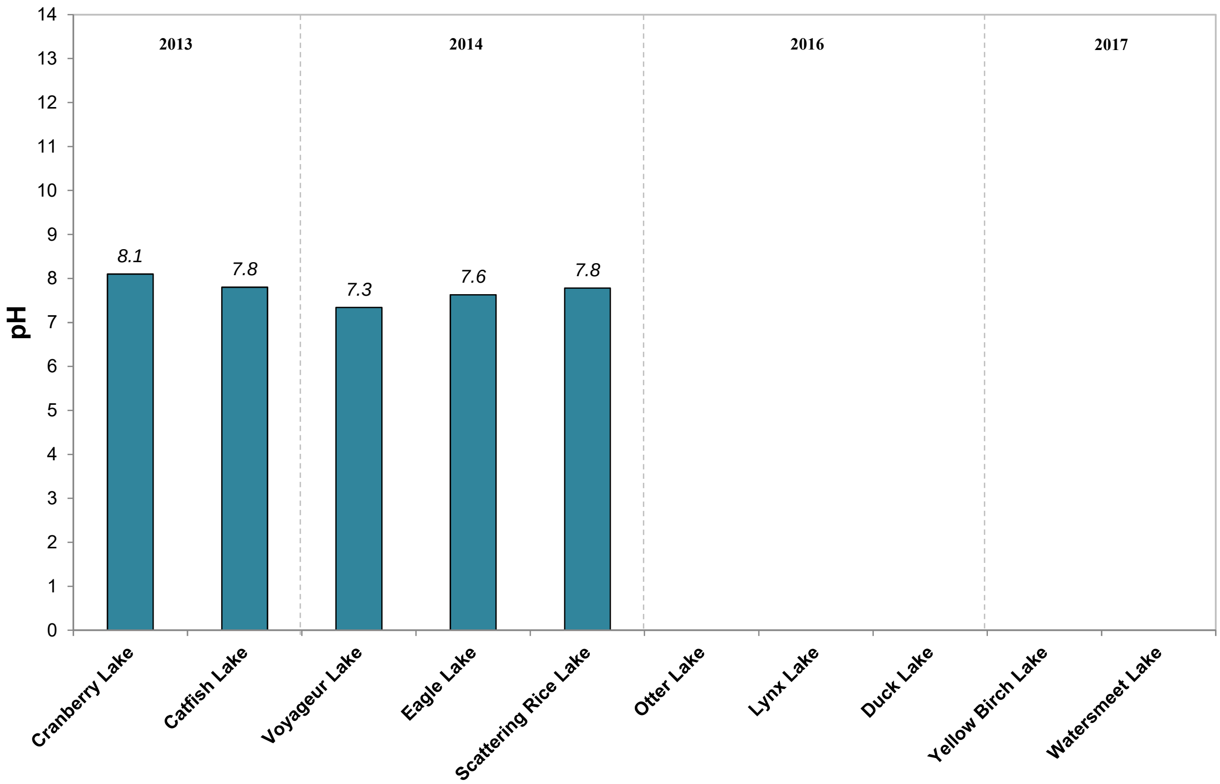


Figure 3.1-7. Lower Eagle River Chain of Lakes mid-summer pH values. Data collected from mid-summer month surface samples.

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 and Phase II lakes, alkalinity ranged from 44.1 mg/L as $CaCO_3$ in Scattering Rice Lake to 27.7 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.

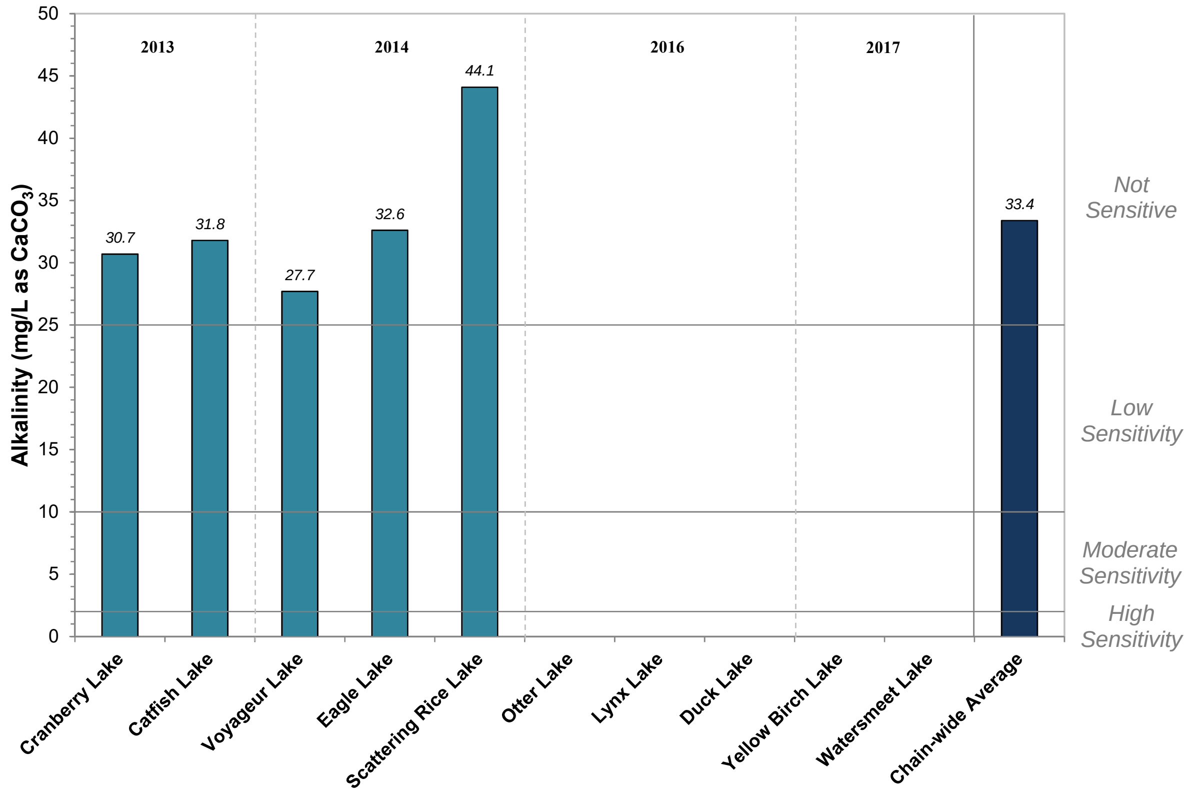


Figure 3.1-8. Lower Eagle River Chain of Lakes alkalinity values and acid rain sensitivity ranges. Data collected from mid-summer surface samples.

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 and Phase II lakes, calcium concentrations ranged from 10.4 mg/L in Scattering Rice Lake to 7.2 mg/L in Cranberry Lake (Figure 3.1-9). The calcium concentrations within the Phase I and Phase II lakes are within the *very low susceptibility* category for zebra mussel suitability.

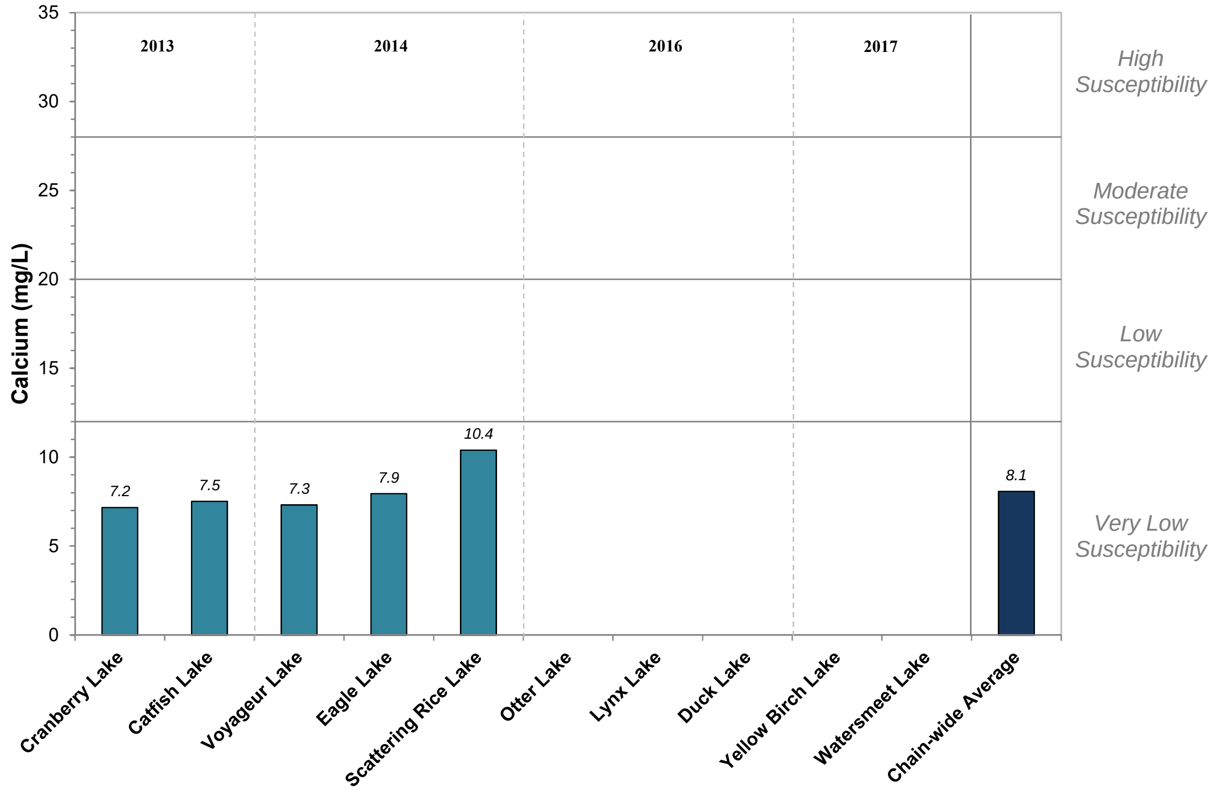


Figure 3.1-9. Lower Eagle River Chain of Lakes susceptibility to zebra mussel survivability and establishment based on calcium concentration. Created using surface calcium. Calcium susceptibility range adapted from Whittier et al. 2008.

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 and Phase II lakes, water color varied from 30.0 SU in Catfish Lake to 50.0 SU in Scattering Rice Lake (Figure 3.1-10). The average color value for the Phase I and Phase II lakes falls near the median value for drainage lakes throughout Wisconsin. These values indicate that the water of the Phase I and Phase II 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.

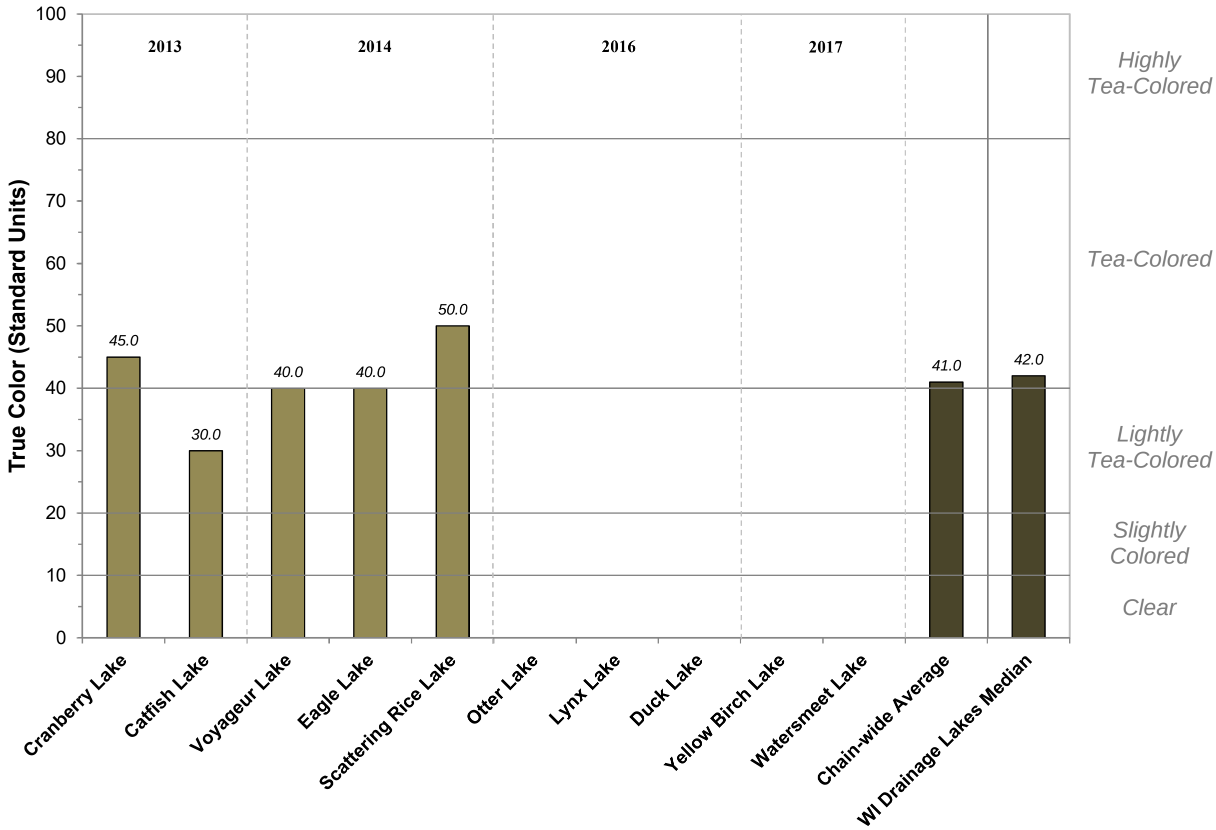


Figure 3.1-10. Lower Eagle River Chain of Lakes true color values. Created using spring and summer near-surface samples. Color range adapted from UNH Center for Freshwater Biology (2014).

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

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

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

As discussed above, the size of the watershed in relation to the size of the lake can have a considerable impact on the lake's water quality. There is high variation in the amount of land draining to each of the 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.

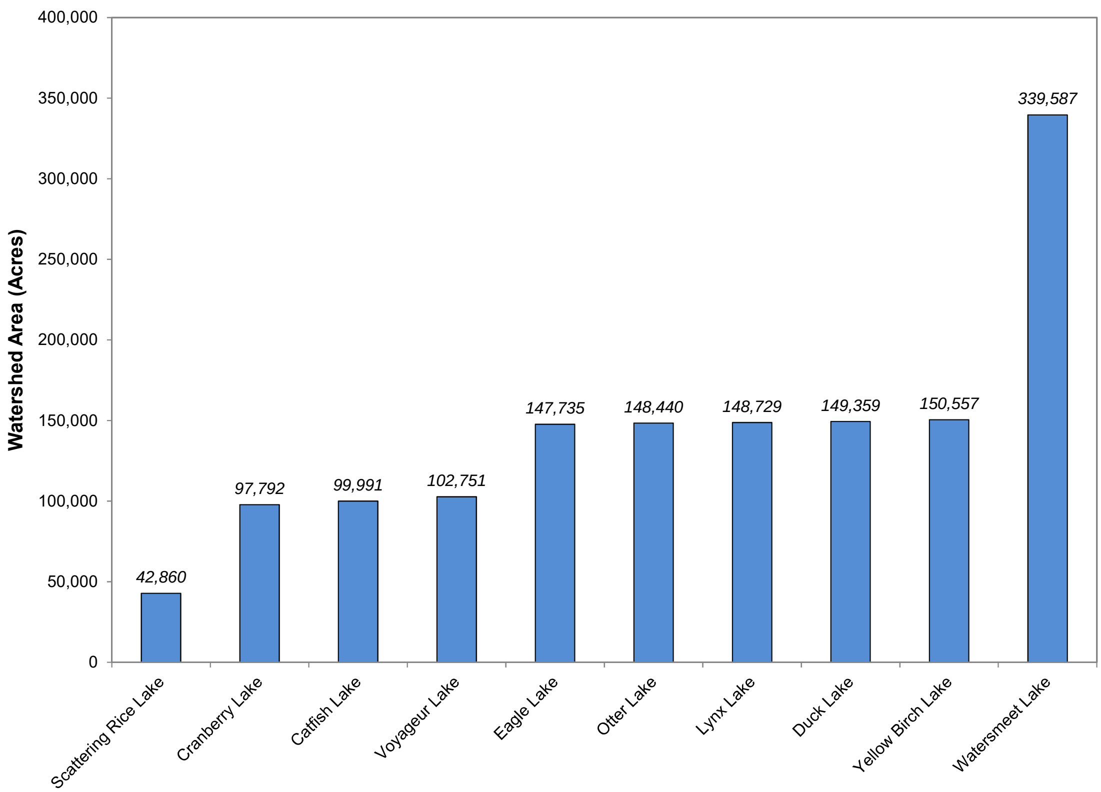


Figure 3.2-1. Lower Eagle River Chain of Lakes' watershed sizes in acres.

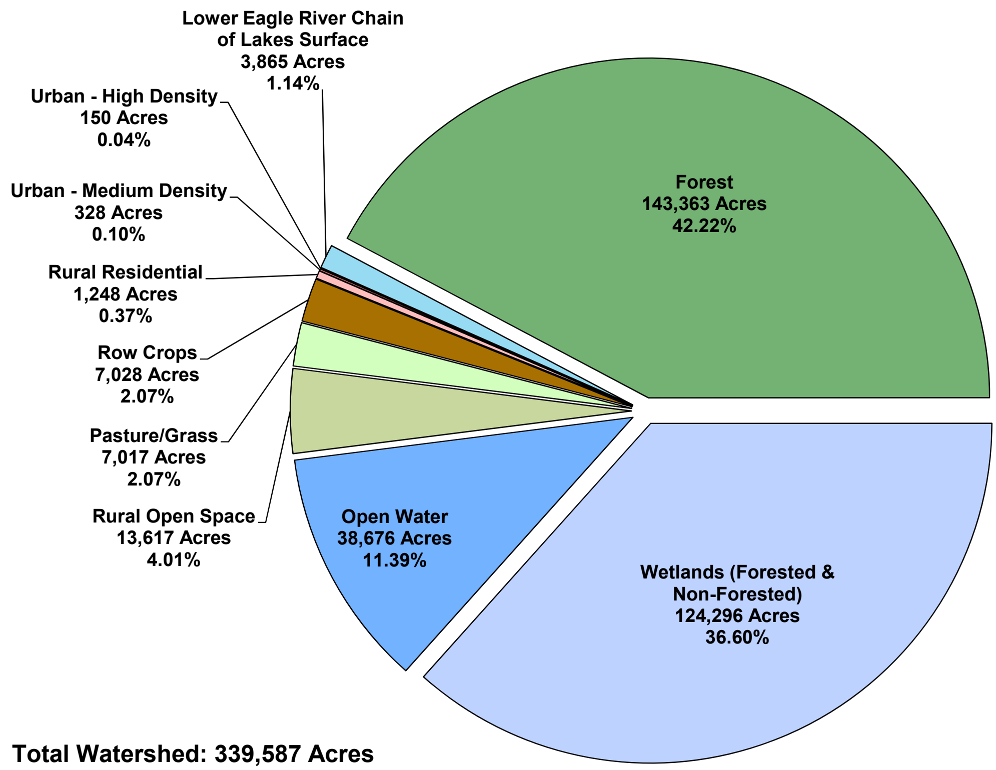


Figure 3.2-2. Lower Eagle River Chain of Lakes watershed land cover types in acres. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

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 Assessment

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

- 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 the lesser of 30 percent of the shoreline frontage), invasive species removal, or damaged, diseased, or dying vegetation. No permit is required for removal of vegetation that meets any of the above criteria. Vegetation removed must be replaced by replanting in the same area (native species only).

- Impervious surface standards: The amount of impervious surface is restricted to 15% of the total lot size, on lots that are entirely within 300 feet of the ordinary high-water mark of the waterbody. A county may allow more than 15% impervious surface on a residential lot provided that the county issues a permit and that an approved mitigation plan is implemented by the property owner. Counties may develop an ordinance, providing higher impervious surface standards, for highly developed shorelines.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. New language in NR-115 allows construction projects on structures within 75 feet with the following caveats:
    - No expansion or complete reconstruction within 0-35 feet of shoreline
    - Re-construction may occur if no other build-able location exists within 35-75 feet, dependent on the county.
    - Construction may occur if mitigation measures are included either within the footprint or beyond 75 feet.
    - Vertical expansion cannot exceed 35 feet

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

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

Wisconsin Act 31

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

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 regular fertilizer application lawns was twice that of lawns with non-phosphorus or no fertilizer. Dissolved phosphorus is a form in which the phosphorus molecule is not bound to a particle of any kind; in this respect, it is readily available to algae.

Therefore, these studies show us that it is a developed shoreland that is continuously maintained in an unnatural manner (receiving phosphorus rich fertilizer) that impacts lakes the greatest. This understanding led former Governor Jim Doyle into passing the Wisconsin Zero-Phosphorus Fertilizer Law (Wis Statue 94.643), which restricts the use, sale and display of lawn and turf fertilizer which contains phosphorus. Certain exceptions apply, but after April 1, 2010, use of this type of fertilizer was prohibited on lawns and turf in Wisconsin. The goal of this action is to reduce the impact of developed lawns, and is particularly helpful to developed lawns situated near Wisconsin waterbodies.

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

Emerging research in Wisconsin has shown that coarse woody habitat (sometimes called "coarse woody debris"), often stemming from natural or undeveloped shorelands, provides many ecosystem benefits in a lake. Coarse woody habitat describes habitat consisting of trees, limbs, branches, roots and wood fragments at least four inches in diameter that enter a lake by natural or human means. Coarse woody habitat provides shoreland erosion control, a carbon source for the lake, prevents suspension of sediments and provides a surface for algal growth which is important for aquatic macroinvertebrates (Sass 2009). While it affects these aspects considerably, one of the greatest benefits coarse woody habitat provides is habitat for fish species.

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

Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen et al. 1996). With development of a lake's shoreland zone, much of the coarse woody debris that was once found in Wisconsin lakes has disappeared. Prior to human establishment and development on lakes (mid to late 1800's), and due to logging practices, the amount of coarse woody habitat in lakes was likely greater than under completely natural conditions. However, with changes in the logging industry and increasing development along lake shorelands, coarse woody habitat has decreased substantially. Shoreland residents are removing woody debris to improve aesthetics or for recreational opportunities (boating, swimming, and, ironically, fishing). However, with continued education and lake stewardship in-lake habitat can be restored to Wisconsin lakes.

National Lakes Assessment

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

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

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

Native Species Enhancement

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

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

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

Cost

The cost of native, aquatic, and shoreland plant restorations is highly variable and depends on the size of the restoration area, the depth of buffer zone required to be restored, the existing plant density, the planting density required, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other sites may require erosion control stabilization measures, which could be as simple as using erosion control blankets and plants and/or seeds or more extensive techniques such as geotextile bags (vegetated retaining walls), geogrids (vegetated soil lifts), or bio-logs (see above picture). Some of these erosion control techniques may reduce the need for rip-rap or seawalls which are sterile environments that do not allow for plant growth or natural shorelines. Questions about rip-rap or seawalls should be directed to the local Wisconsin DNR Water Resources Management Specialist. Other measures possibly required include protective measures used to guard newly planted areas from wildlife predation, wave-action, and erosion, such as fencing, erosion control matting, and animal deterrent sprays. One of the most important aspects of planting is maintaining moisture levels. This is done by watering regularly for the first two years until plants establish themselves, using soil amendments (i.e., peat, compost) while planting, and using mulch to help retain moisture.

Most restoration work can be completed by the landowners themselves. To decrease costs further, bare-root forms of trees and shrubs should be purchased in early spring. If additional assistance is needed, the lakefront property owner could contact an experienced landscaper. For properties with erosion issues, owners should contact their local county conservation office to discuss cost-share options.

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

- Spring-planting time frame.
- 100’ of shoreline.
- An upland buffer zone depth of 35’.
- An access and viewing corridor 30’ x 35’ free of planting (recreation area).
- Planting area of upland buffer zones: two 35’ x 35’ areas
- Site is assumed to need little invasive species removal prior to restoration.
- Site has only turf grass (no existing trees or shrubs), a moderate slope, sandy-loam soils, and partial shade.
- Trees and shrubs planted at a density of 1 tree/100 sq. ft; and 2 shrubs/100 sq. ft, therefore, 24 native trees and 48 native shrubs would need to be planted.
- Turf grass would be removed by hand.
- A native seed mix is used in bare areas of the upland buffer zone.
- An aquatic zone with shallow-water 2 - 5’ x 35’ areas.
- Plant spacing for the aquatic zone would be 3 feet.
- Each site would need 70’ of erosion control fabric to protect plants and sediment near the shoreland (the remainder of the site would be mulched).
- Soil amendment (peat, compost) would be needed during planting.
- There is no hard-armor (riprap or seawall) that would need to be removed.
- The property owner would maintain the site for weed control and watering.

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

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

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

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

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

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

Figure 3.3-1. Shoreline assessment category descriptions.

On each of 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 five lakes in Phase I and Phase II of the project, approximately 42% (16.3 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 32% (12.6 miles) of the shoreline is comprised of urbanized and developed–unnatural shorelines. Figure 3.3-3 provides a breakdown of the Phase I and Phase II 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.

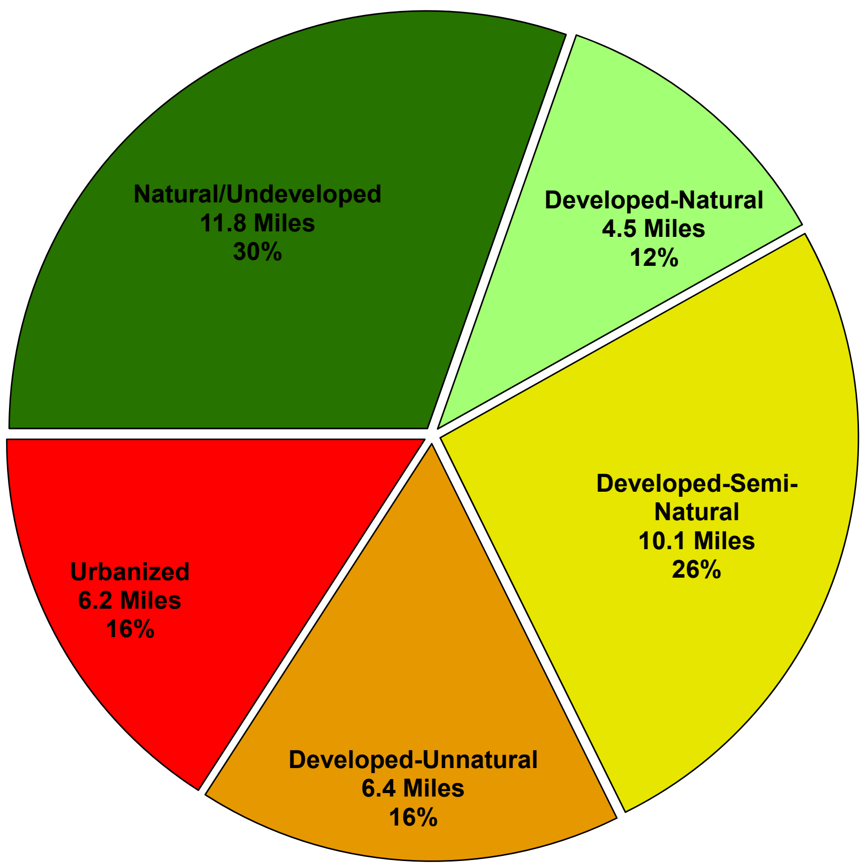


Figure 3.3-2. Combined shoreland conditions from the Lower Eagle River Chain of Lakes Phase I and Phase II Lakes. Based upon field surveys conducted in late summer 2013 (Phase I) and late summer 2014 (Phase II). Locations of these categorized shorelands can be found on maps within each individual lake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

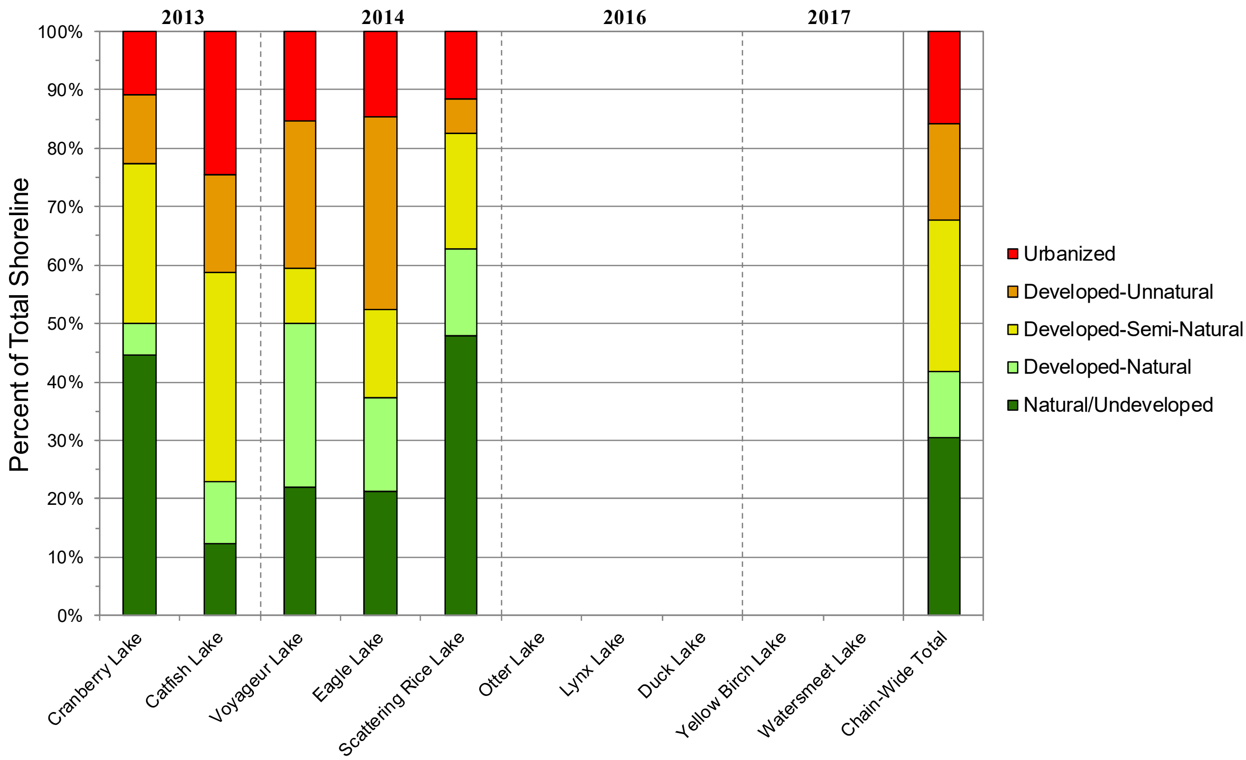


Figure 3.3-3. Lower Eagle River Chain of Lakes shoreland condition by lake. Created using data from late summer surveys. Locations of these categorized shorelands can be found on maps within each individual lake section.

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.

Each individual lake report examines the coarse woody habitat availability within the respective lake. Figure 3.3-4 displays results from the Phase I and Phase II lakes combined. A total of 802 coarse woody habitat pieces were identified along 39 miles of shoreline, yielding approximately 21 pieces per every mile of shoreline. Of the Phase I and II lakes assessed so far, Scattering Rice Lake had the highest number of coarse woody habitat pieces per shoreline mile with 36, while Cranberry Lake had the least with 16 (Figure 3.3-5). Although this may seem to be a considerable amount, WDNR studies have identified as much as 300-400 pieces per mile of shoreline on completely undeveloped lakes (Christensen et al. 1996). In addition to structural related habitat projects, refraining from removing woody elements and other natural features from a shoreland area is the best way to increase availability of coarse woody habitat in a lake.

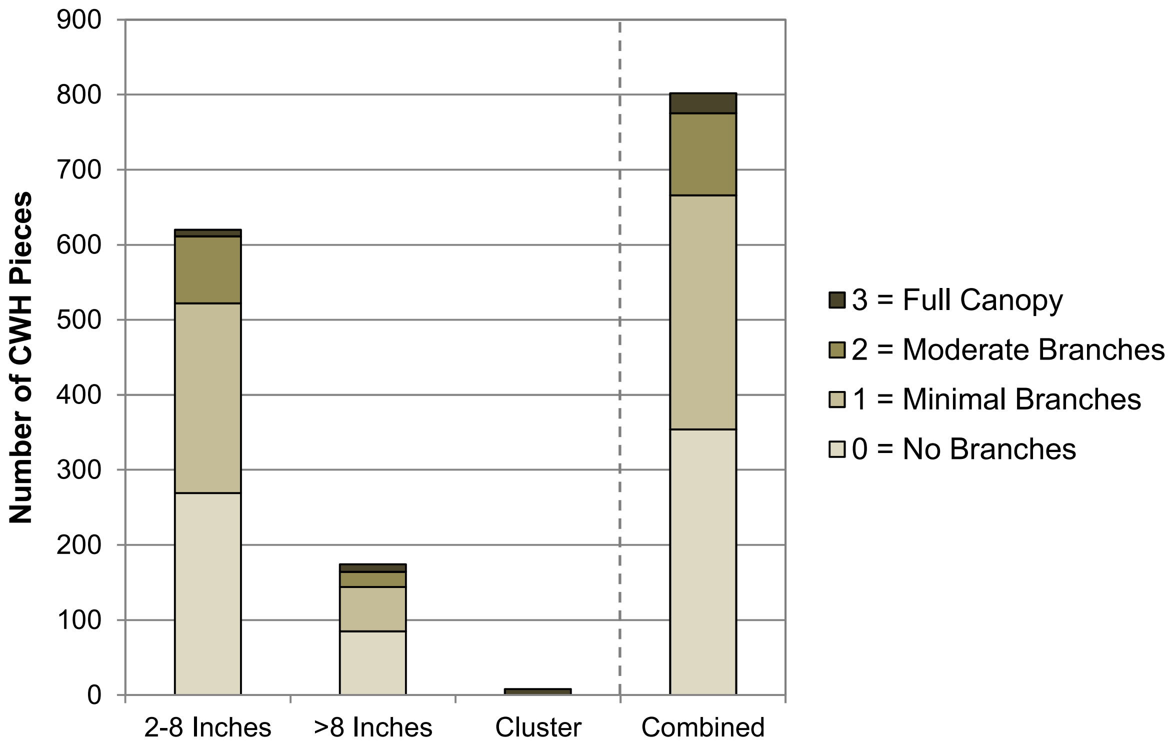


Figure 3.3-4. Lower Eagle River Chain of Lakes combined coarse woody habitat survey results. Created using data from late summer 2013 (Phase I) and late summer 2014 (Phase II) surveys.

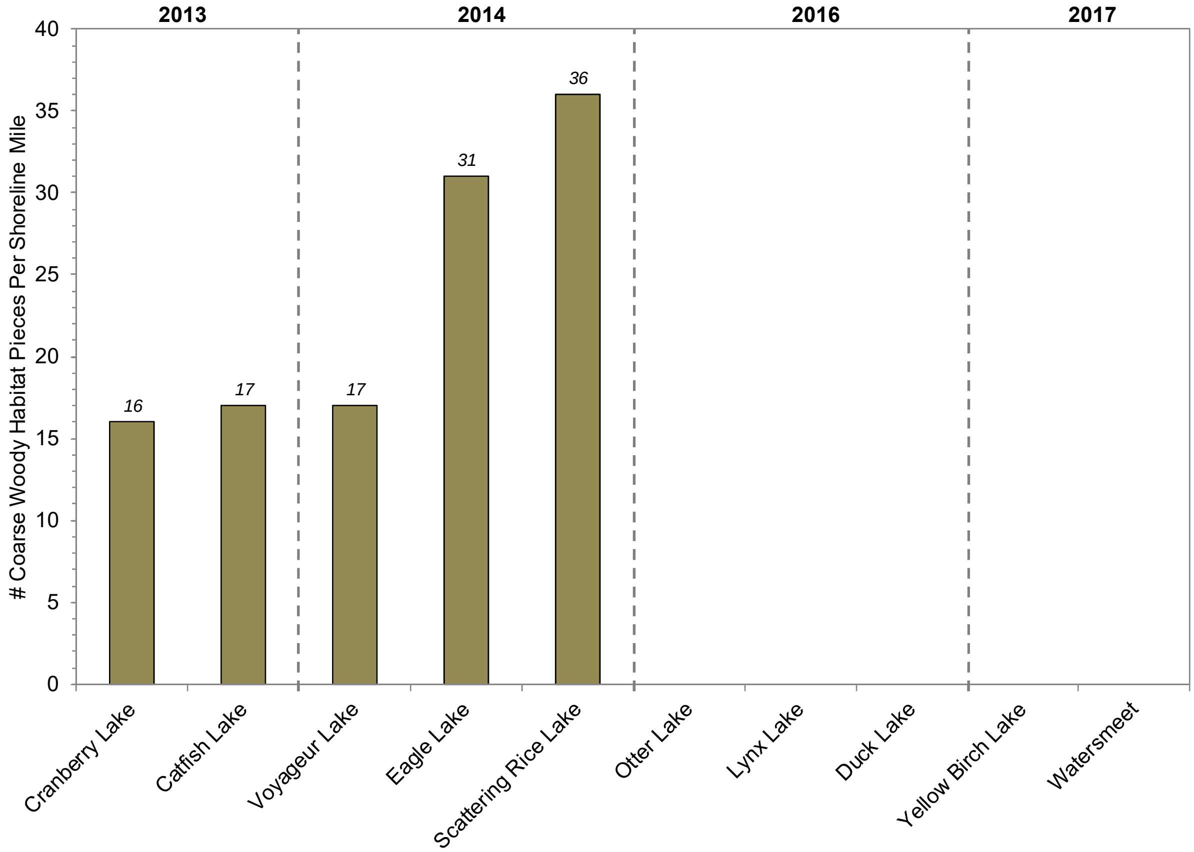


Figure 3.3-5. Lower Eagle River Chain of Lakes number of coarse woody habitat pieces per shoreline mile. Created using data from late summer 2013 (Phase I) and late summer 2014 (Phase II) surveys.

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.

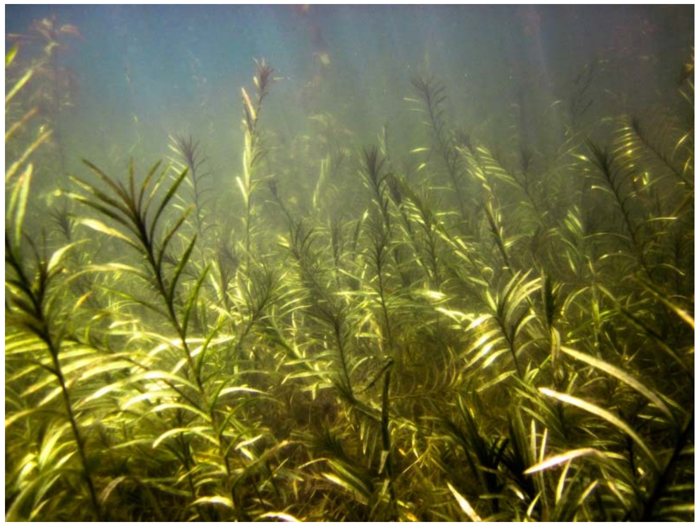


Photo 3.4-1. Native aquatic plant community. Fern pondweed (*Potamogeton robbinsii*).

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife (Photo 2.1-1). 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 water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing native plants and reducing species diversity. These invasive plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

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

Aquatic Plant Management and Protection

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 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.

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

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Water Level Drawdown

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

Cost

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

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

Mechanical Harvesting

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

Cost

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

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

Herbicide Treatment

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

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

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

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

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

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

General Mode of Action		Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		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 water-milfoil. • Some herbicides can be used effectively in spot treatments. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g. mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as water hyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively.

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

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

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

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

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

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on 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 water milfoil. 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

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.

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.

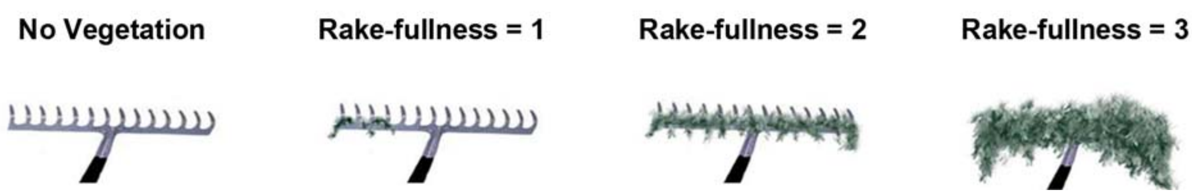


Figure 3.4-1. Aquatic plant rake fullness ratings. Adapted from Hauxwell et al (2010).

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. Between 2005 and 2009, WDNR Science Services conducted point-intercept surveys on 252 lakes within the state. In the absence of comparative data from Nichols (1999), the Simpson's Diversity Index values of the lakes within the WDNR Science Services dataset will be compared to 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.

Community Mapping

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

Exotic Plants

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

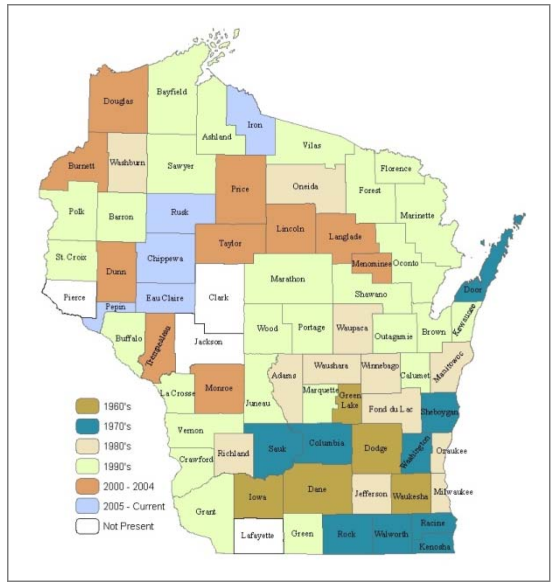


Figure 3.4-2. Spread of Eurasian water milfoil within WI counties. WDNR Data 2011 mapped by Onterra.

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

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

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

Aquatic Plant Survey Results

Photo 3.4-2. Close-up of floating leaves and flower spikes of state-listed special concern species Vasey's pondweed (*Potamogeton vaseyi*).

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 67 aquatic plant species were located within the chain, four of which are considered to be a non-native, invasive species: Eurasian water milfoil, 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 (Photo 3.4-2). 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 67 plant species were located in all 10 lakes in 2012, and include: coontail, common waterweed, slender naiad, stoneworts, wild celery, Eurasian water milfoil, northern water milfoil, clasping-leaf pondweed, fern pondweed, flat-stem pondweed, small pondweed, and Vasey's pondweed.

Photo 3.4-3. Alpine pondweed (*Potamogeton alpinus*) located in Cranberry, Voyageur, and Scattering Rice Lakes.

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 (Photo 3.4-3), 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 community mapping surveys. Note: community mapping surveys have not yet occurred on Phase III and 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										
Emergent	*Carex comosa*	Bristle sedge	5	I										
Emergent	*Carex crinita*	Fringed sedge	6	I										
Emergent	*Carex utriculata*	Common yellow lake sedge	7	I	I									
Emergent	*Decodon verticillatus*	Water willow	7	I										
Emergent	*Dulichium arundinaceum*	Three-way sedge	9	I										
Emergent	*Eleocharis palustris*	Creeping spikerush	6	I			X						X	X
Emergent	*Equisetum fluviatile*	Water horsetail	7	I	I								X	
Emergent	*Iris pseudacorus*	Pale-yellow iris	Exotic	I	I									
Emergent	*Iris versicolor*	Northern blue flag	5	I										
Emergent	*Lysimachia vulgaris*	Garden yellow loosestrife	Exotic	I										
Emergent	*Lythrum salicaria*	Purple loosestrife	Exotic	I	I									
Emergent	*Pontederia cordata*	Pickerelweed	9	X	I			X			X		X	X
Emergent	*Sagittaria latifolia*	Common arrowhead	3	I									X	
Emergent	*Sagittaria rigida*	Stiff arrowhead	8	I	I									
Emergent	*Sagittaria sp. (sterile)*	Arrowhead sp. (sterile)	N/A	I										
Emergent	*Schoenoplectus acutus*	Hardstem bulrush	5		I									
Emergent	*Schoenoplectus tabernaemontani*	Softstem bulrush	4	I	X		X						X	X
Emergent	*Typha spp.*	Cattail spp.	1	I	I								X	
Emergent	*Zizania palustris*	Northern wild rice	8										X	X
FL	*Brasenia schreberi*	Watershield	7	X	I								X	X
FL	*Nuphar variegata*	Spatterdock	6	X	X	X	X	X		X	X	X	X	X
FL	*Nymphaea odorata*	White water lily	6	X	X	X		X			X	X	X	X
FL/E	*Sparganium americanum*	Eastern bur-reed	8	I										
FL/E	*Sparganium androcladum*	Shining bur-reed	8	X				X						
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	X	X									X
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8	I			X							X
FL/E	*Sparganium eurycarpum*	Common bur-reed	5	I	I					X				
FL/E	*Sparganium fluctuans*	Floating-leaf bur-reed	10	X	I	X								

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 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 water milfoil	7	X	X	X	X	X	X	X	X	X	X	X
	Myriophyllum spicatum	Eurasian water milfoil	Exotic	X	X	X	X	I	X	I	X	X	X	X
	Myriophyllum verticillatum	Whorled water milfoil	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	X										
	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
	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 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 water milfoil had a chain-wide littoral occurrence of 1.7% in 2012. To determine if the 2008-2012 Eurasian water milfoil 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 water milfoil, spatterdock is a dicot and may be susceptible to herbicide treatments that have been occurring since 2008. Unlike Eurasian water milfoil, 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.

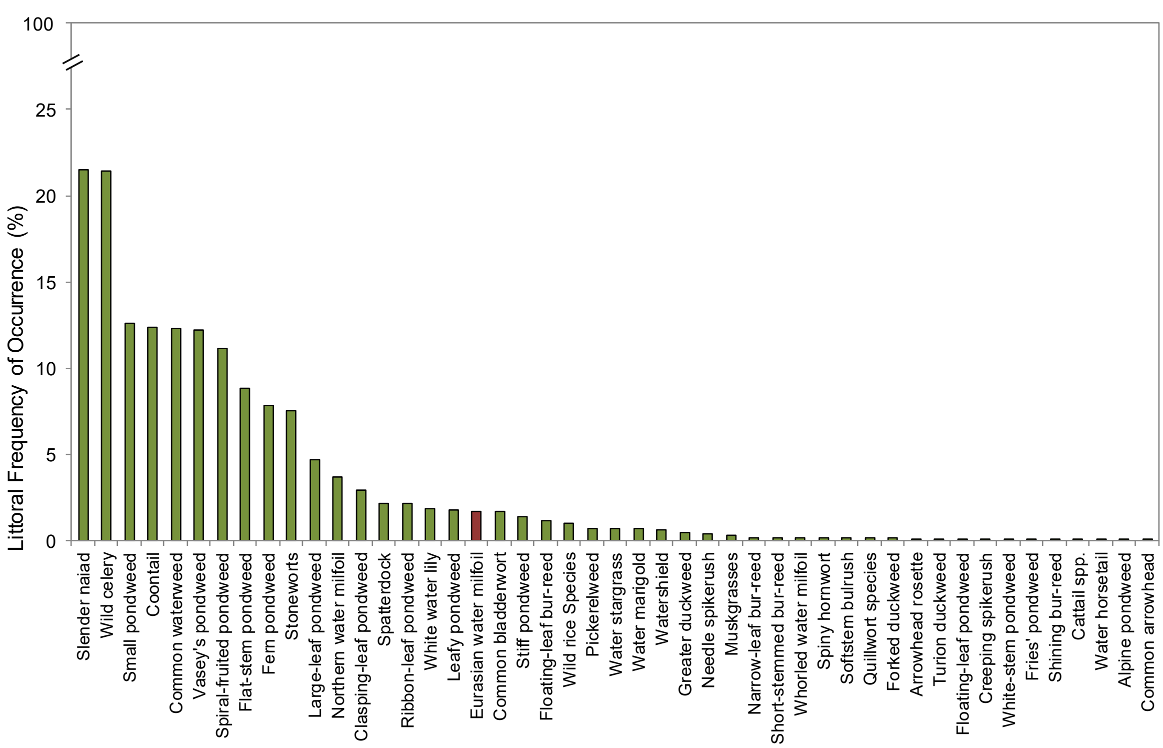


Figure 3.4-3. Littoral frequency of occurrence of aquatic plant species in the Lower Eagle River Chain of Lakes in 2012. Non-native species indicated with red. Created using data from 2012 point-intercept survey.

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 water milfoil, 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).

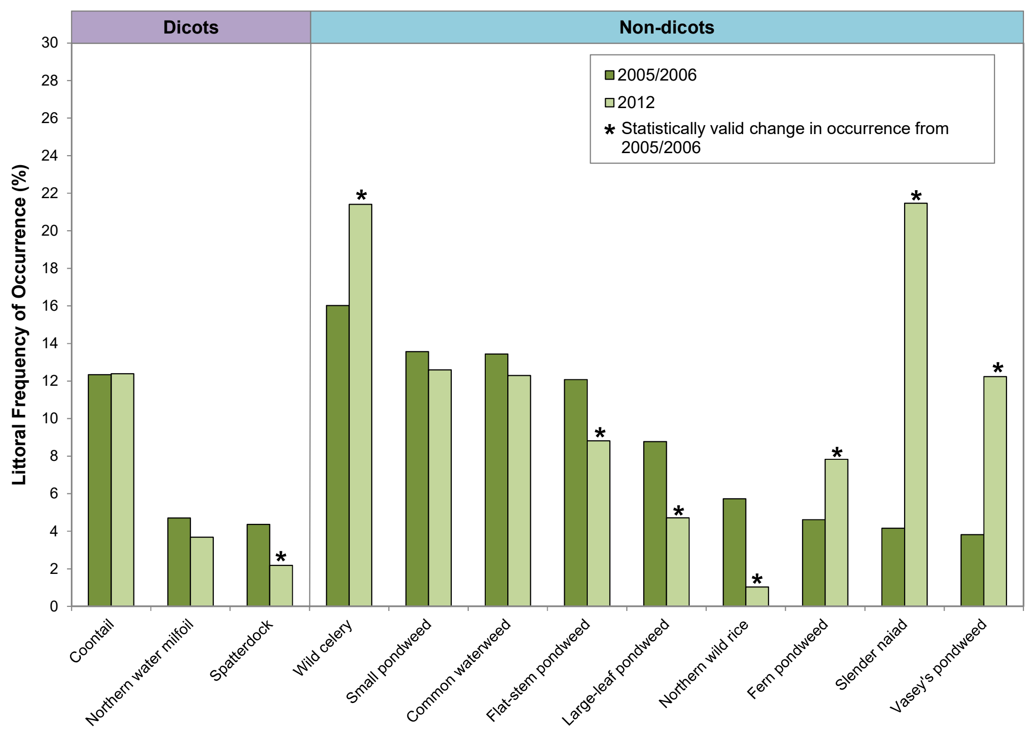


Figure 3.4-4. Lower Eagle River Chain of Lakes littoral occurrence of native aquatic plant species from 2005/2006 and 2012 point-intercept surveys. Please note that only those species with an occurrence of at least 4% in either survey are displayed. Created using data from 2005/2006 and 2012 point-intercept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

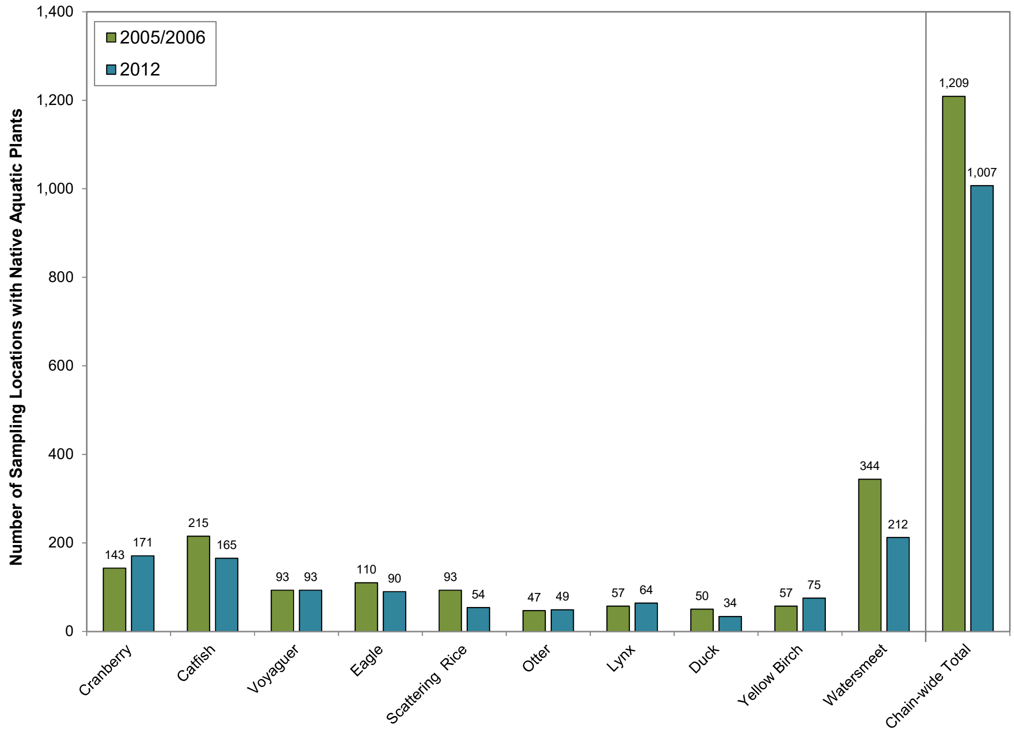


Figure 3.4-5. Number of point-intercept sampling locations containing native aquatic vegetation in 2005/2006 and 2012 point-intercept surveys. Created using data from 2005/2006 and 2012 point-intercept surveys.

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.

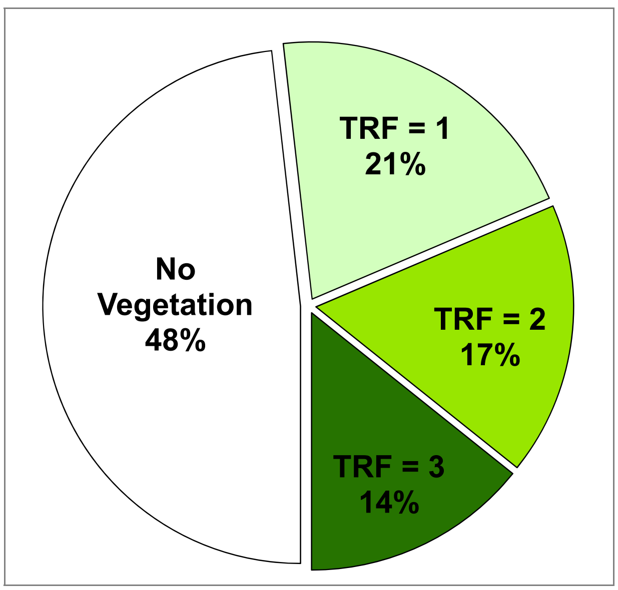


Figure 3.4-6. Lower Eagle River Chain of Lakes total rake fullness ratings of aquatic vegetation from the 2012 point-intercept surveys. Created using data from 2012 point-intercept surveys.

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.

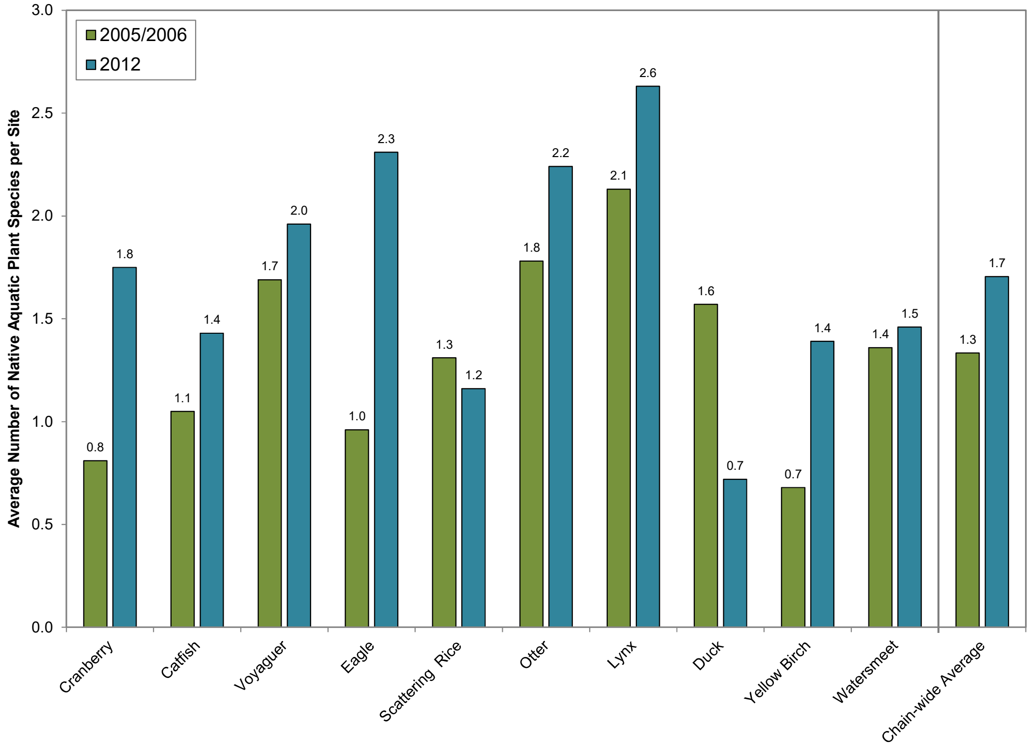


Figure 3.4-7. Lower Eagle River Chain of Lakes average number of native aquatic plant species per site. Created using data from 2005/2006 and 2012 point-intercept surveys.

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.

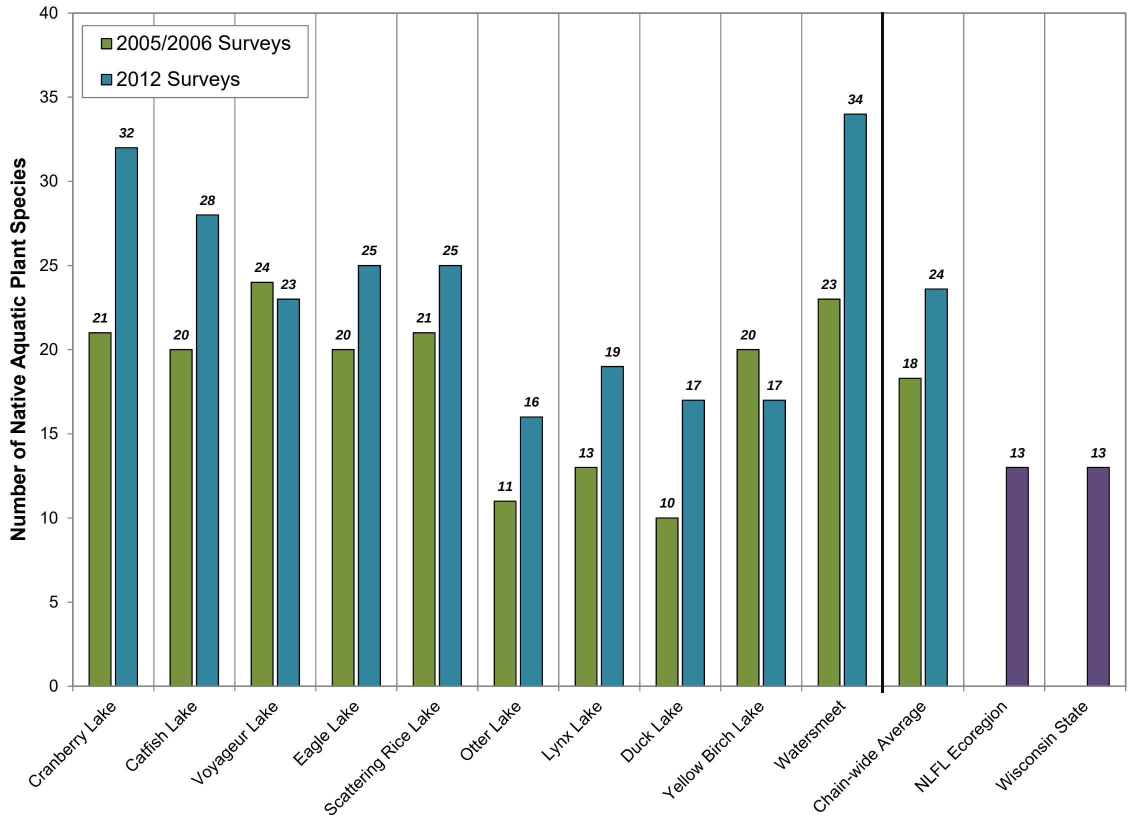


Figure 3.4-8. Lower Eagle River Chain of Lakes 2005/2006 and 2012 native species richness. Created using data from 2005/2006 and 2012 point-intercept surveys.

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).

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

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.

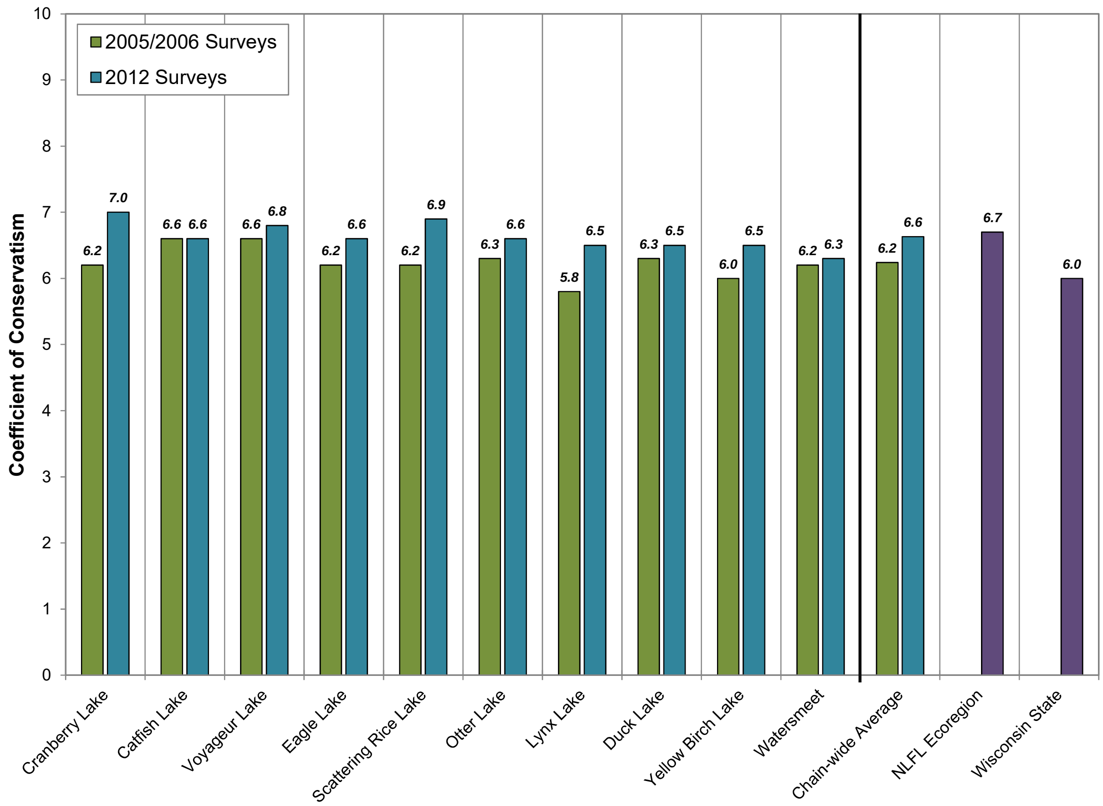


Figure 3.4-9. Lower Eagle River Chain of Lakes average coefficients of conservatism. Created using data from 2005/2006 and 2012 point-intercept surveys.

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.

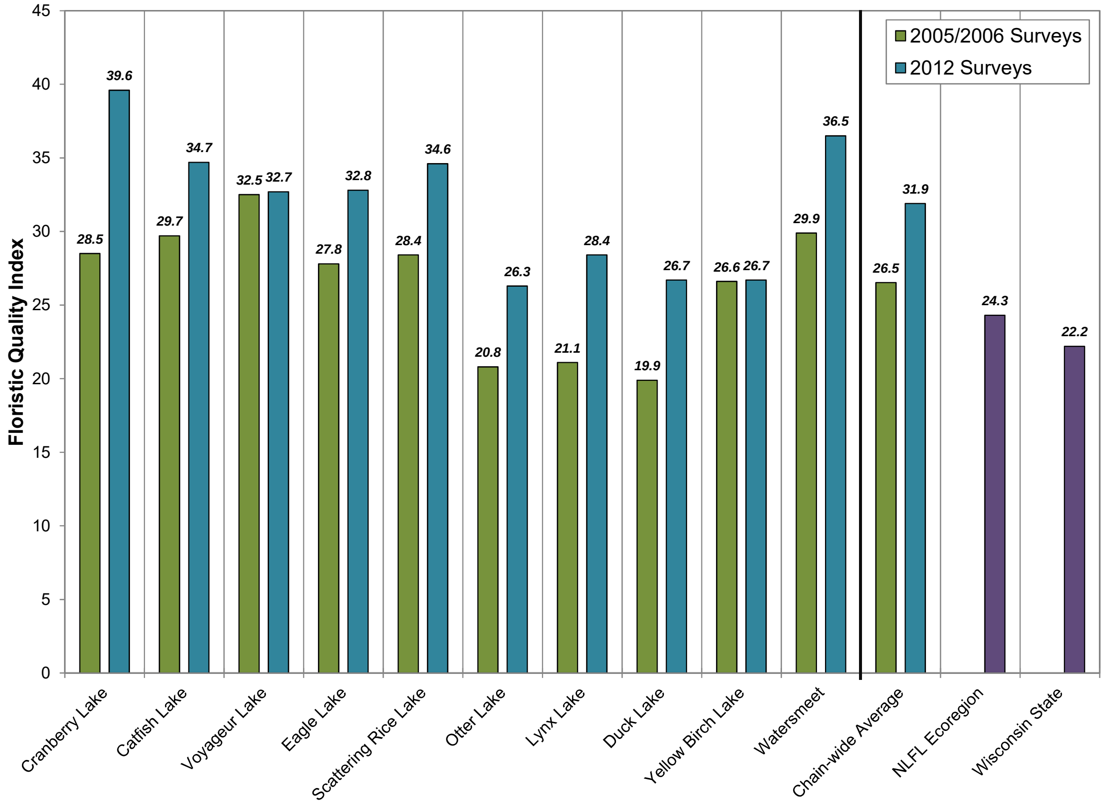


Figure 3.4-10. Lower Eagle River Chain of Lakes Floristic Quality Index values. Created using data from 2005/2006 and 2012 point-intercept surveys. Analysis follows Nichols (1999) where NLF = Northern Lakes and Forests Ecoregion.

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 water milfoil throughout many areas within the chain may be one of the reasons why diversity was shown to have increased in 2012.

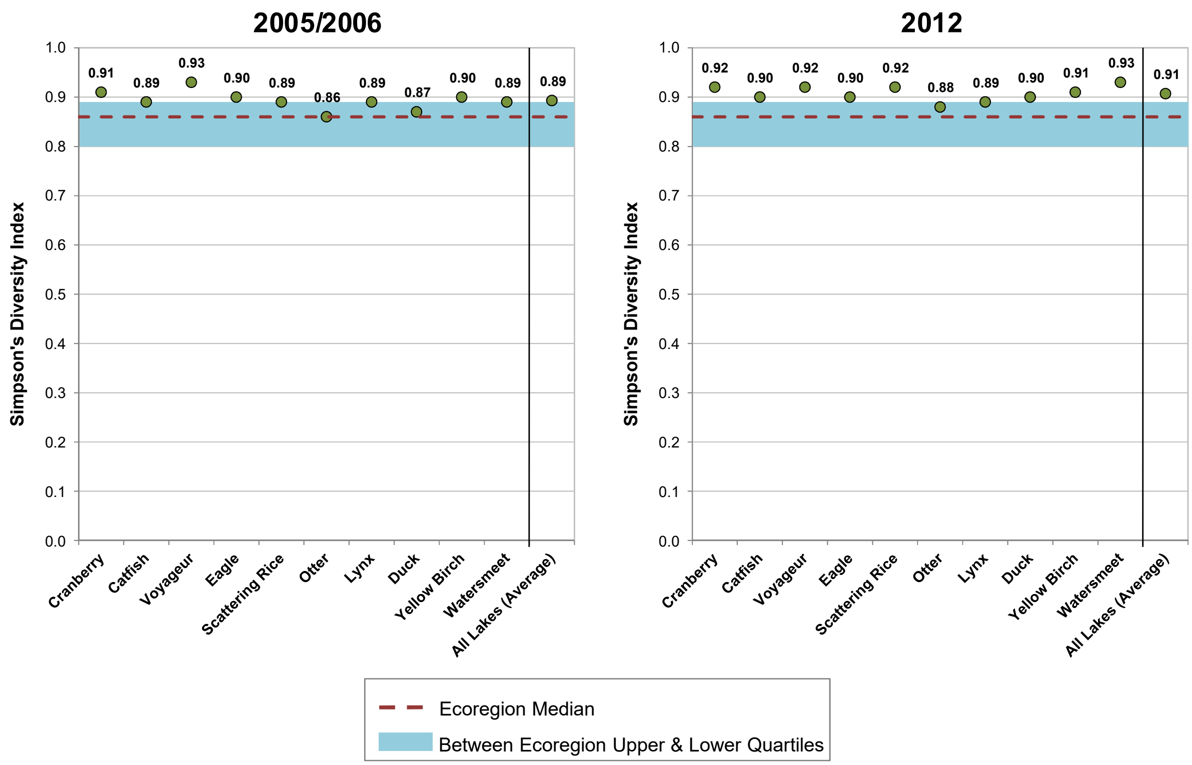


Figure 3.4-11. Lower Eagle River Chain of Lakes Simpson's Diversity Index. Created using data from 2005/2006 and 2012 point-intercept surveys.

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

Eurasian water milfoil

Eurasian water milfoil (*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 water milfoil. 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 water milfoil acreage has been reduced from the 278 acres in 2007 to approximately 12 acres in 2015 (Figure 3.4-12). In addition, the majority of EWM in 2007 was comprised of *dominant*, *highly dominant*, and *surface-matted* EWM, while the majority the acreage in 2014 is comprised of *scattered* and *highly scattered* EWM.

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 3.4-13 illustrates, seven of the 10 lakes saw a statistically valid reduction in the littoral occurrence of EWM from 2005/2006 to 2012 (Chi-square $\alpha = 0.05$). 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 been reduced by a statistically valid 82% since 2005/2006.

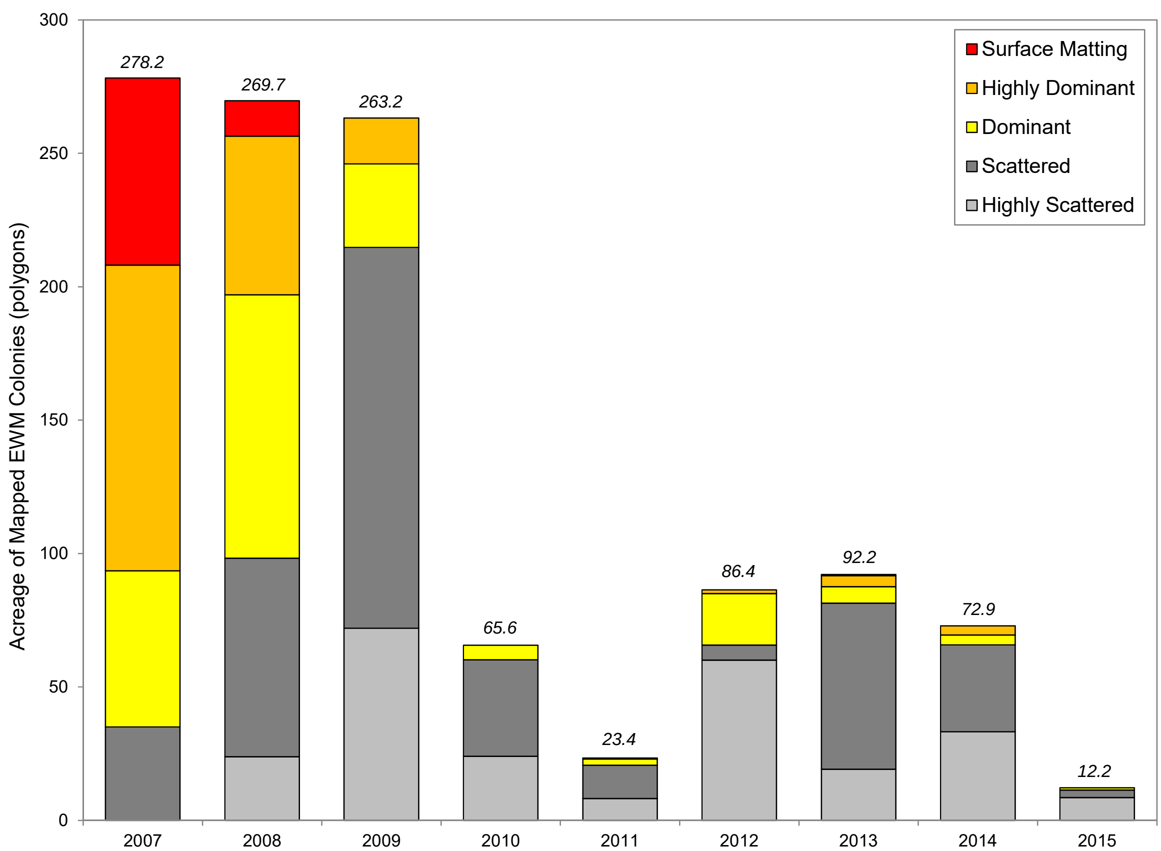


Figure 3.4-12. Acreage of mapped EWM colonies within the Lower Eagle River Chain of Lakes from 2007-2015.

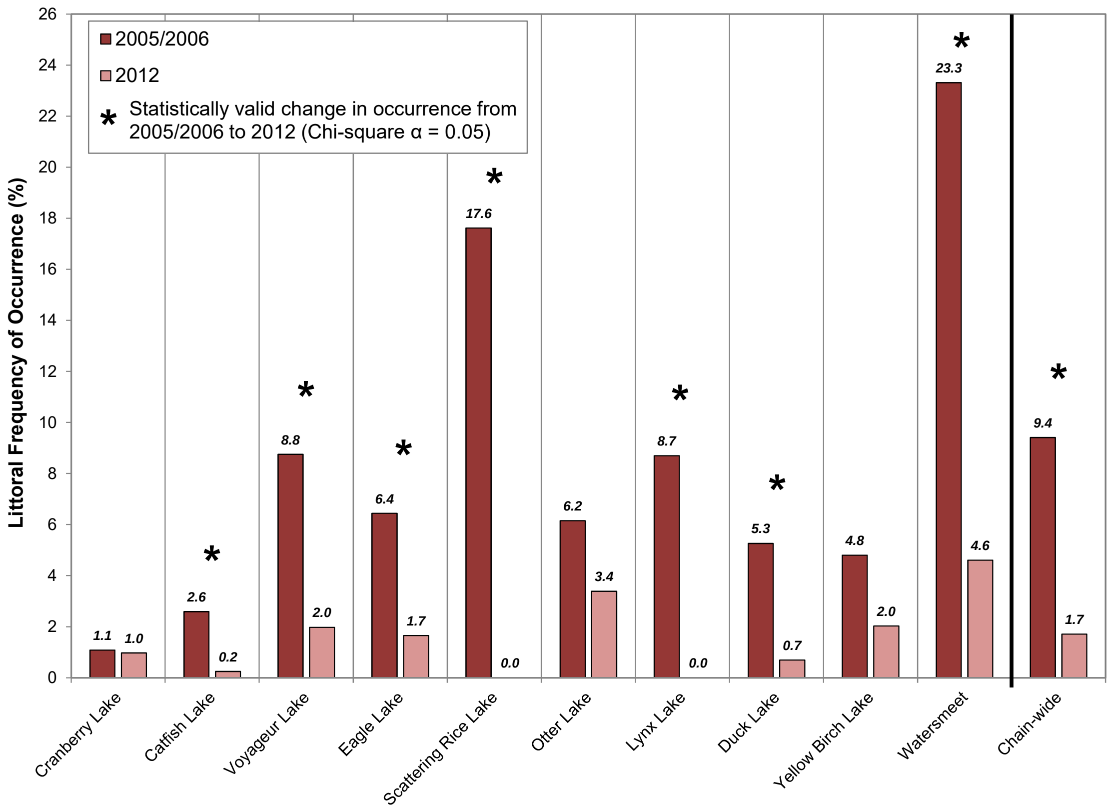


Figure 3.4-13. Lower Eagle River Chain of Lakes EWM littoral occurrence from 2005/2006 to 2012. Created using data from 2005/2006 and 2012 point-intercept surveys.

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 Lake in 2013 (Cranberry 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.

3.5 Fisheries Data Integration

This section will be included in Phase III.

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, we 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 and Phase II 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 hypolimnetic delivery of phosphorus to the epilimnion during the growing season. Scattering Rice Lake's shallow nature makes it prone to mixing and breaking stratification during wind events throughout the summer. To investigate Scattering Rice Lake's water quality further, additional water quality sampling is scheduled to take place on the lake during the Phase III studies in 2016. This additional monitoring will allow for a more detailed understanding of nutrient, algae, and thermal dynamics in Scattering Rice Lake.

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 and Phase II 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 is scheduled to be completed in 2017. 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 and II 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.

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 water milfoil (EWM) population.

Timeframe: Continuation of current effort.

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

Description: While Eurasian water milfoil 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 2016. 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 water milfoil active management strategy and necessary management strategy assessments.

Timeframe: Continuation of current effort.

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

Description: Currently in 2015, 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 water milfoil 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 targeted for herbicide control in 2015. The thresholds 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.

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 most recently conducted on the Eagle River Chain in 2012 to inventory each lake's aquatic plant community. The data collected in 2012 were compared to data collected by Northern Environmental, Inc. in 2006 to determine if the EWM control program was impacting native aquatic plants at the lake-wide level and to determine if the control program was reducing EWM on the lake-wide level. The 2012 data indicated a significant reduction in EWM occurrence chain-wide and that there were few detectable impacts to the native aquatic plant community.

These whole-lake point-intercept surveys will need to be repeated on the each lake within the chain in 2017. These surveys will all need to be conducted within the same summer to remove variability in environmental conditions from year to year.

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 2015/2016.
4. Update management plan to reflect changes in control needs and those of the lake ecosystem.
5. Retain qualified professional to conduct whole-lake point-intercept surveys on the Eagle River Chain in 2017.

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 2016; 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 2017.
2. Research additional sources of funding to continue professional ESAIS Surveys after 2017, 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 there 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 water milfoil, 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

7.0 LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

Great Lakes Indian Fish and Wildlife Service. 2014A. Interactive Mapping Website. Available at http://www.glifwc-maps.org. Last accessed March 2014.

Great Lakes Indian Fish and Wildlife Service. 2014B. GLIFWC website, Wisconsin 1837 & 1842 Ceded Territories Regulation Summaries – Open-water Spearing. Available at http://www.glifwc.org/Enforcement/regulations.html. Last accessed March 2014.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

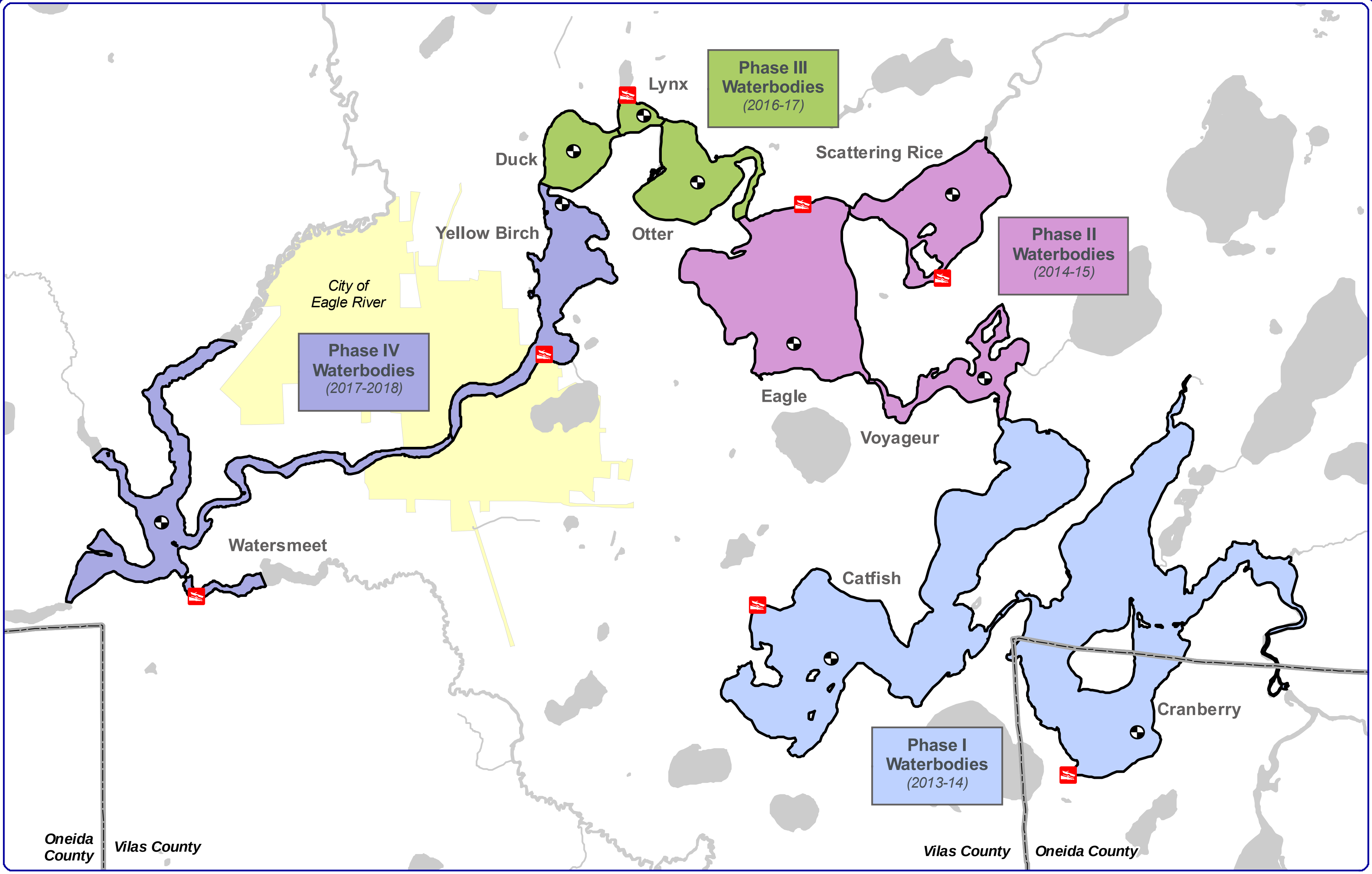
Vander Zanden, M.J. and J.D. Olden. 2008. A management framework for preventing the secondary spread of aquatic invasive species. Canadian Journal of Fisheries and Aquatic Sciences 65 (7): 1512-22.

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

Wisconsin Department of Natural Resources. 2014. Wisconsin 2014 Consolidated Assessment and Listing Methodology (WisCALM).

Wisconsin Department of Natural Resources. 2014. Wisconsin Endangered and Threatened Species Laws and List. WDNR PUBL-ER-001.

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



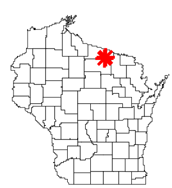
N W E S

4,500

Feet

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

Sources:
Data: Roads and Hydro: WDNR
Map Date: October 16, 2012
Filename: *Map1_ERC_Location.mxd.mxd*



Project Location in Wisconsin

Legend

Public Access

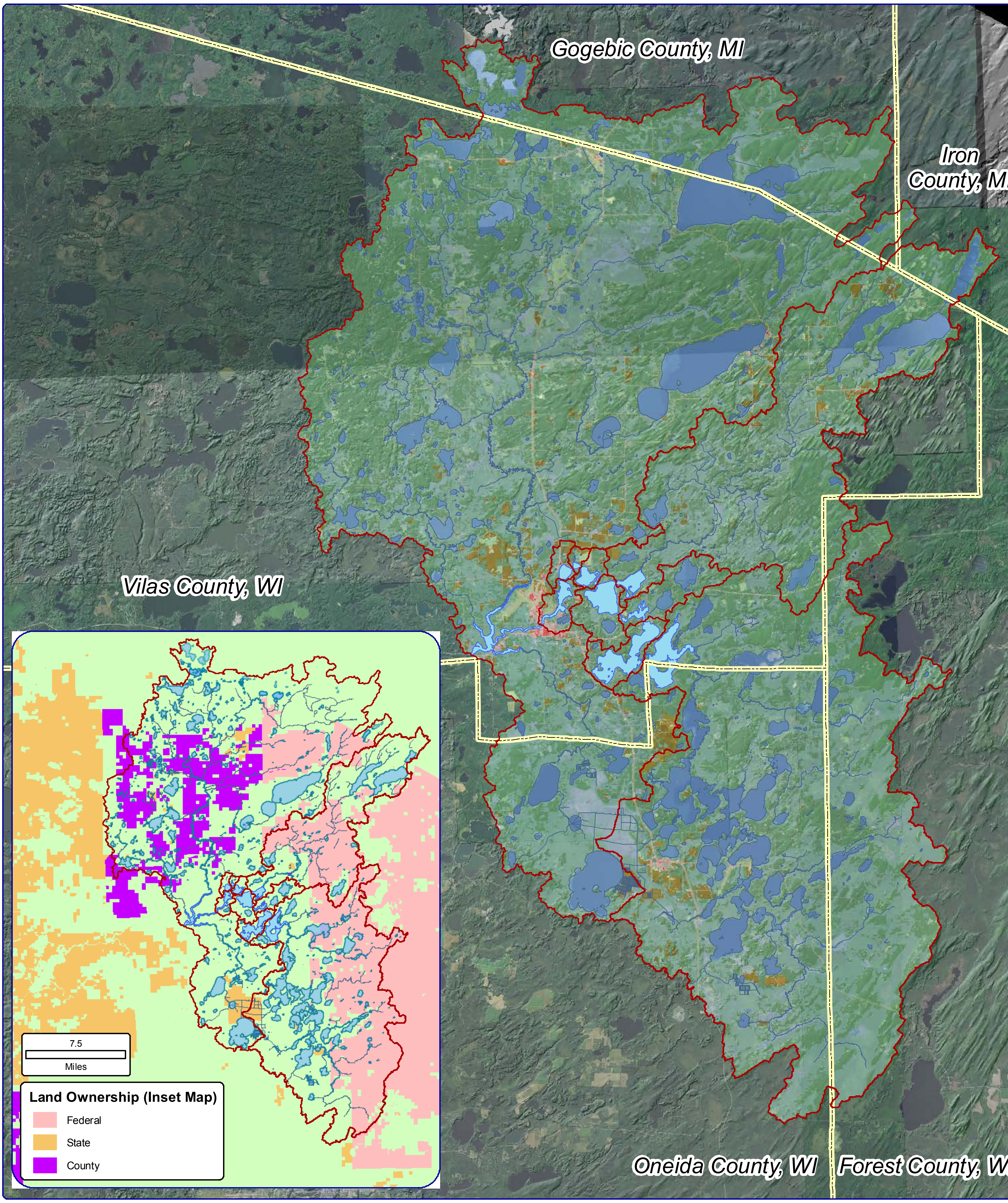
Water Quality Sampling Location

Map 1

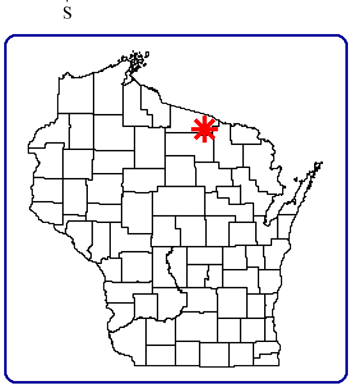
Lower Eagle River Chain of Lakes

Vilas & Oneida Counties, Wisconsin

Project Location &
Lake Boundaries



N
W E
S
4
Miles



Project Location in Wisconsin

Legend

Lower Eagle River Chain of Lakes Watershed Boundary

Land Cover Types

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

Map 2
Lower Eagle River Chain of Lakes
Oneida & Vilas Counties, Wisconsin
Watershed Boundaries & Land Cover Types

Sources:
Land Cover: NLCD 2006
Hydro: WDNR
Orthophotography: NAIP, 2013
Map Date: April 24, 2014
Filename: Map2_ERC_Watershed.mxd

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