Cloverleaf Lakes

Shawano County, Wisconsin

Comprehensive Management Plan

April 2022

Official First Draft

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

Cloverleaf Lakes Planning Committee

Christopher Sampson – Planning Committee Chair	Linda Hosking – Belle Plaine Sportsman's Club	Kris Vomastic – Town of Belle Plaine
Dennis Thornton	Jeff Casperson	Jonathan Vogt
Jessica Meier	Gary Schumacher	Kevin Goodman

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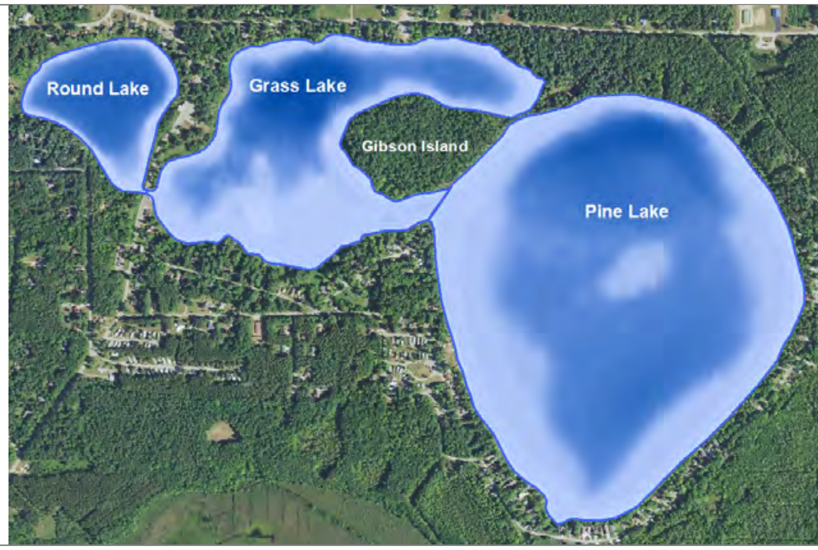
1.0 INTRODUCTION

At the time of this report, the most current orthophoto (aerial photograph) was from the *National Agriculture Imagery Program* (NAIP) collected in 2020. Based on heads-up digitizing of the water level from that photo, Round Lake was determined to be 28 acres, Grass Lake 92 acres, and Pine Lake 219 acres (Map 1). Each of the Cloverleaf Lakes is a deep headwater drainage lake, with Grass Lake being the deepest with a maximum depth of 52 feet, and Pine Lake having the largest surface area of 219 acres. With the three lakes combined, 37 native plant species were found in 2020. Seven non-native plant species were also found in the chain of lakes in 2020, with one of those being considered *naturalized*.

Field Survey Notes

With a public boat launch, swimming beach, fishing pier and tournaments, resorts, and an island with walking trails, the Cloverleaf Lakes are a popular recreational destination in Shawano County. Each of the three lakes also contains Areas of Special Natural Resource Interest (ASNRI) critical habitat areas.



Photograph 1.0-1. Cloverleaf Lakes, Shawano County

Lakes at a Glance – Cloverleaf Chain of Lakes

		Round Lake	**Grass Lake**	**Pine Lake**
Morphology	**Acreage**	28	92	219
	Max. Depth (ft)	39	52	35
	Mean Depth (ft)	26	13	15
Vegetation	**Number of Native Species (all years combined)**	39	45	28
	Non-Native Species	EWM, CLP, PL, PYI, GR, Sf, Wc	EWM, CLP, PL, PYI, GR	EWM, CLP, PYI
Water Quality	**Trophic State**	Mesotrophic		
	Limiting Nutrient	Phosphorus		
	pH	8.6	8.7	8.7
	Sensitivity to Acid Rain	*Not sensitive*		
	Watershed to Lake Area Ratio	25:1	14:1	8:1

EWM = Eurasian watermilfoil; CLP = Curly-leaf pondweed; PL = Purple loosestrife; PYI = Pale-yellow iris; GR = Giant reed; Sf = Sweetflag; Wc = Watercress

Founded in 1936, the Cloverleaf Lakes Protective Association (CLPA) is a volunteer organization dedicated to promoting and preserving the health of the Cloverleaf Chain of Lakes and their continued enjoyment by residents, neighbors and visitors. The CLPA has partnered with the Town of Belle Plaine for numerous years on lake management, planning, and protection projects. Lake management planning projects have been previously conducted on the Cloverleaf Lakes during 1992 (LPL-060), 2003 (ALPT-004-04), and 2010. A Shoreland Restoration Plan (LPL-1246/7-09) was completed in 2011, a healthy lakes project was completed in 2015 (LPT-492-15) and numerous AIS Control projects have taken place (ALPL-009-04, ALPT-004-04, AIRR-012-06, ACEI-025-07, ACEI-124-12, ACEI-204-18). The management planning project presented here (LPL-1730-20) was co-sponsored by the CLPA and the Town, with the Town serving as the grant applicant and being responsible for financial administration of the grant. The CLPA is responsible for the coordination, implementation, and local share financial match.

The Cloverleaf Lakes contains one main boat landing on Grass Lake that has multiple launching stalls and a lined parking lot which accommodates 25 vehicle-trailers. Pine Lake contains one public swimming beach (Sandy Beach Park) and Round Lake contains a public fishing pier (Round Lake Park). Functioning resorts are present on the system. In addition to use by lakeshore property owners (riparians), the lakes are frequented by numerous recreational boaters and anglers.

Round Lake is a Priority Navigable Waterway and being under 50 acres, is considered slow-no-wake by the State of Wisconsin. There are Areas of Special Natural Resource Interest (Sensitive Areas) in all three lakes (Map 1). The Town of Belle Plaine has enacted boating ordinances to "to provide for the safety, welfare, healthful conditions and enjoyment of recreational boating enthusiast and riparian landowners consistent with public rights, interests and capabilities of the waterways listed" (Figure 1.0-1)

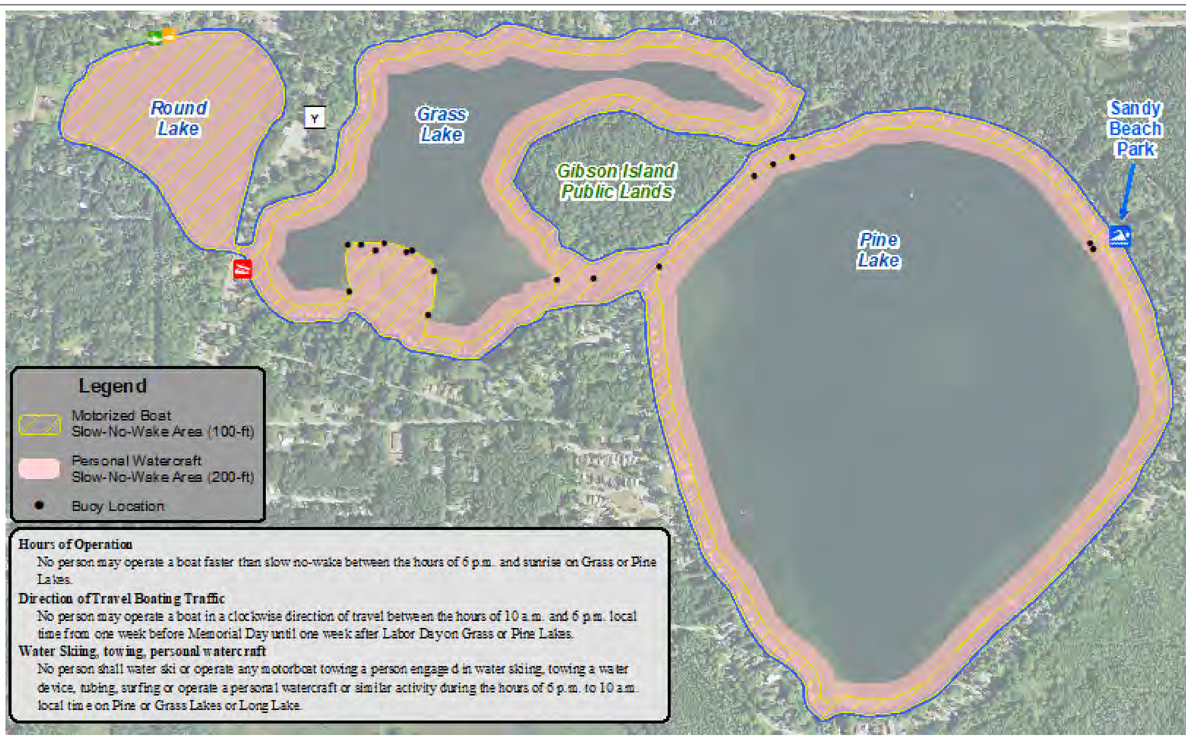


Figure 1.0-1. Cloverleaf Lakes watercraft regulations and ordinances. Belle Plaine Ordinance 1-18; Jan 8, 2018.

The centerpiece of Cloverleaf Lakes is Gibson Island (actually an "island" that has a one-lane walking path isthmus). The 25-acre property was acquired from a private landowner by the Town of Belle Plaine in 2006 through a combination of town funds, local citizens' contributions and a Stewardship grant (Photograph 1.0-2). It is now protected as a natural area forever with no residences or vehicles allowed.

Photograph 1.0-2. Gibson Island. Photo credit: Coldwell Banker Hilgenberg Realtors.

Gibson Island contributes more than 5,000 feet of natural shoreland as well as several "fish sticks" and natural tree falls along the shore. A town Stewardship Committee oversees the property, maintaining trails and controlling invasive plants. Local citizens as well as a youth corps participate in the anti-invasives project and native plants were added on a portion of the property.

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 and the completion of a stakeholder survey.

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

Planning Committee Meeting Introduction

On January 19, 2021, Eddie Heath of Onterra met virtually with the CLPA Planning Committee for nearly 1.5 hours. The main purpose of the meeting was to lightly introduce the project and set expectations for the committee's involvement. Discussion of the 2021 preliminary Eurasian watermilfoil treatment and monitoring strategy was also a focus of the meeting.

Planning Committee Meeting I

On November 30, 2021, Eddie Heath of Onterra met with the CLPA Planning Committee for nearly 4 hours at the Belle Plaine Town Hall. The primary focus of this meeting was the delivery of the study results and conclusions to the committee. Study components including AIS survey results, aquatic plant inventories, water quality analysis, and watershed modeling were presented and discussed.

Planning Committee Meeting II

On December 21, 2021, Eddie Heath of Onterra met with the CLPA Planning Committee for approximately 3 hours at the Belle Plaine Town Hall. The focus of this meeting was to develop management goals and associated management actions to serve as the Implementation Plan Section (5.0).

Management Plan Review and Adoption Process

Based upon the discussion from previous planning meetings, a draft Implementation Plan Section (5.0) was created by Onterra and sent to the planning committee in late-December 2021. Written comments were provided back to Onterra in late-April 2022. These comments were addressed to result in the Official First Draft.

On April 28, 2022, the Official First Draft of the CLPA's Comprehensive Management Plan for the Cloverleaf Lakes was supplied to WDNR (lakes and fisheries programs), and Shawano County, to solicit comments. At that time the Official First Draft was posted to the CLPA's website for public review, with outreach efforts requesting riparians to provide comments

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to lake group members and riparian property owners around the Cloverleaf Lakes. The survey was designed by Onterra staff and the Cloverleaf Lakes planning committee, and reviewed by a WDNR social scientist. During December of 2020, the nine-page, 42-question survey was posted online through Survey Monkey for survey recipients to answer electronically. If requested, a hard copy was sent with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a third-party for analysis. Forty-two percent of the surveys were returned. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately, and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meetings and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Based upon the results of the Stakeholder Survey, much was learned about the people who use and care for the Cloverleaf Lakes. Forty-three percent of respondents indicated that they live on the lake full-time, while 27% use their property for vacation only, 23% are part-time residents, 2% use it as a rental property, and the remaining 5% indicated some other use. Forty-four percent of respondents have owned their property for over 25 years.

The following sections (Water Quality, Watershed, Aquatic Plants and Fisheries Data Integration) discuss the stakeholder survey data with respect these particular topics. Figures 2.0-1-2.0-3 highlight some of the more general questions found within this survey. About 68% of survey respondents indicated that they use a pontoon boat, and 58% said they use a canoe/kayak/paddleboard, or a combination of these vessels on the Cloverleaf Lakes (Question 14). On relatively small lakes such as these, the importance of responsible boating is increased. The need for responsible boating increases even more so during weekends, holidays, and times of nice weather or good fishing conditions, due to increased traffic. As seen in Question 17, some of the top recreational activities on the lake involve boat use. Excessive watercraft traffic and unsafe watercraft practices were selected as some of the top concerns of stakeholders in the Cloverleaf Lakes, while aquatic invasive species introduction ranked as the number one concern (Question 19).

Question 14: What types of watercraft do you currently use on the Cloverleaf Lakes?

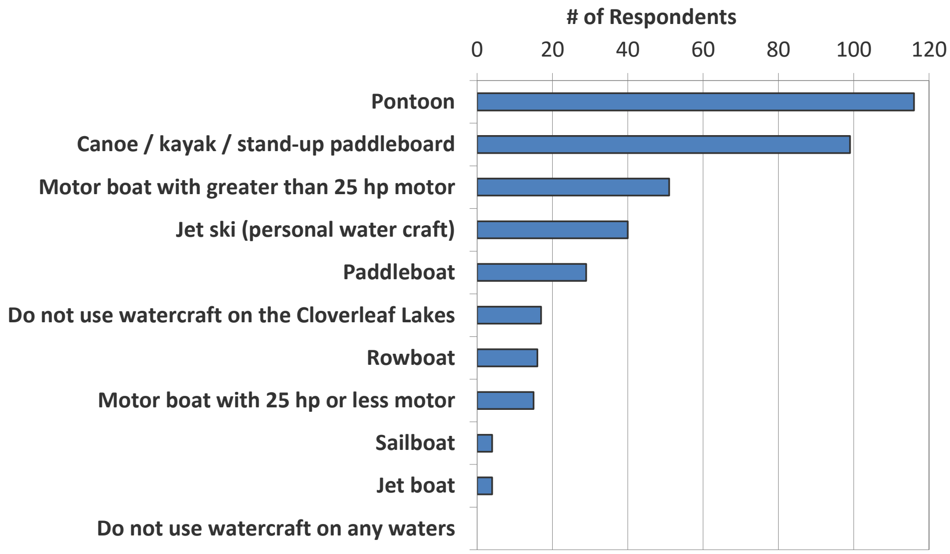


Figure 2.0-1. Select survey responses from the Cloverleaf Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 17: Please rank up to three activities that are important reasons for owning your property on or near the Cloverleaf Lakes.

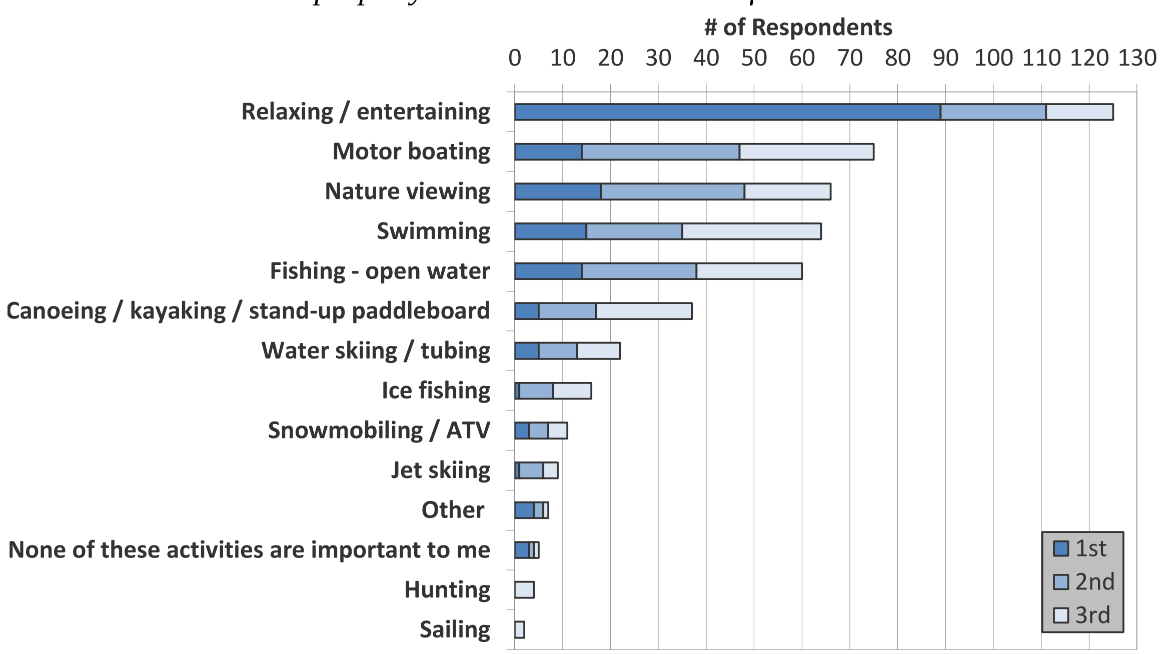


Figure 2.0-2. Select survey responses from the Cloverleaf Lakes Stakeholder Survey. Additional questions and response charts may be found in Appendix B.

Question 19: Please rank your top three concerns regarding the Cloverleaf Lakes.

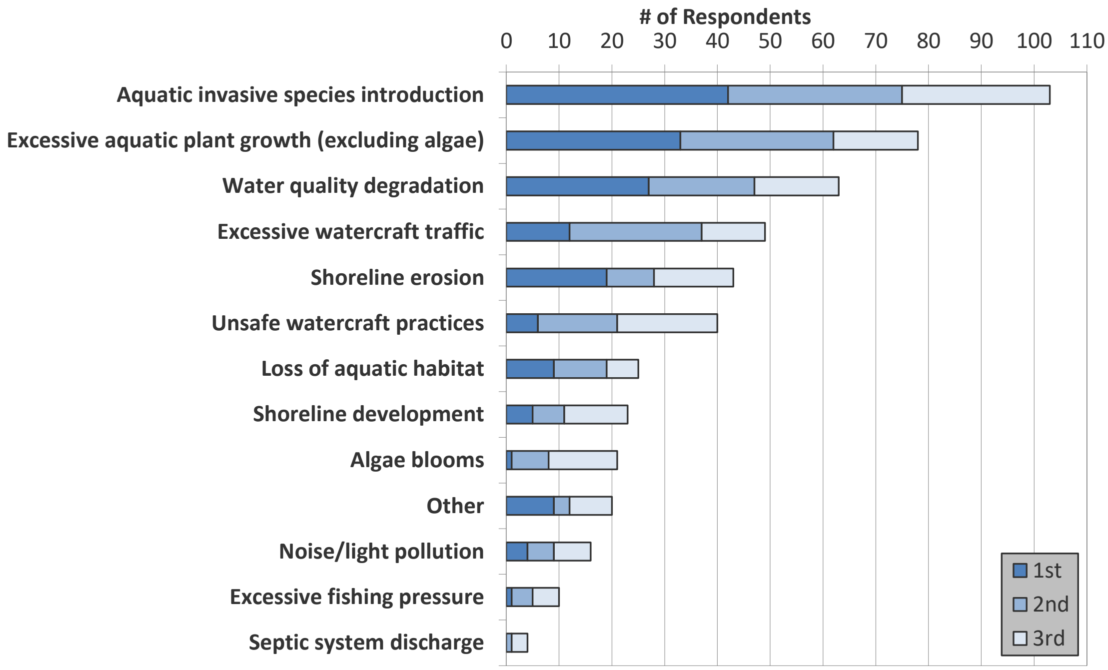


Figure 2.0-3. Select survey responses from the Cloverleaf Lakes Stakeholder Survey, continued. Additional questions and response charts may be found in Appendix B.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Primer on Water Quality Data Analysis and Interpretation

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

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

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

Phosphorus is the nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both algae and macrophytes. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

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

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrants (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, Nelson, & Everett, 1994), (Dinius, 2007), and (Smith, Cragg, & Croker, 1991).

Trophic State

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

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

However, through the use of a trophic state index (TSI), an index number can be calculated using phosphorus, chlorophyll-*a*, and clarity values that represent the lake's position within the eutrophication process. This allows for a clearer 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 processes that occur within a lake. Internal nutrient loading is an excellent example that is described below.

Internal Nutrient Loading*

In lakes that support stratification, whether throughout the summer or periodically between mixing events, the hypolimnion can become devoid of oxygen both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae and some macrophytes. In lakes that mix periodically during the summer (polymictic lakes), this cycle can *pump* phosphorus from the sediments into the water column throughout the growing season. In lakes that only mix during the spring and fall (dimictic lakes), this burst of phosphorus can support late-season algae blooms and even last through the winter to support early algal blooms the following spring. Further, anoxic conditions under the winter ice in both polymictic and dimictic lakes can add smaller loads of phosphorus to the water column during spring turnover that may support algae blooms long into the summer. This cycle continues year after year and is termed "internal phosphorus loading"; a phenomenon that can support nuisance algal blooms decades after external sources are controlled.

The first step in the analysis is determining if the lake is a candidate for significant internal phosphorus loading. Water quality data and watershed modeling are used to determine actual and predicted levels of phosphorus for the lake. When the predicted phosphorus level is well below the actual level, it may be an indication that the modeling is not accounting for all of the phosphorus sources entering the lake. Internal nutrient loading may be one of the additional contributors that may need to be assessed with further water quality analysis and possibly additional, more intense studies.

Non-Candidate Lakes

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

Candidate Lakes

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

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

Comparisons with Other Datasets

The WDNR document *Wisconsin 2018 Consolidated Assessment and Listing Methodology* (WDNR, 2018) is an excellent source of data for comparing water quality from a given lake to lakes with similar features and lakes within specific regions of Wisconsin. Water quality among lakes, even among lakes that are located in close proximity to one another, can vary due to natural factors such as depth, surface area, the size of its watershed and the composition of the watershed's land cover. For this reason, the water quality of the Cloverleaf Lakes will be compared to lakes in the state with similar physical characteristics. The WDNR groups Wisconsin's lakes into 6 classifications (Figure 3.1-1).

First, the lakes are classified into two main groups: **shallow (mixed)** or **deep (stratified)**. Shallow lakes tend to mix throughout or periodically during the growing season and as a result, remain well-oxygenated. Further, shallow lakes often support aquatic plant growth across most or all of the lake bottom. Deep lakes tend to stratify during the growing season and have the potential to have low oxygen levels in the bottom layer of water (hypolimnion). Aquatic plants are usually restricted to the shallower areas around the perimeter of the lake (littoral zone). An equation developed by (Lathrop & 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.

Because of their depth, relatively small watershed, and hydrology, all three Cloverleaf Lakes are classified as a deep headwater drainage lakes for comparative purposes (category 3, Figure 3.1-1).

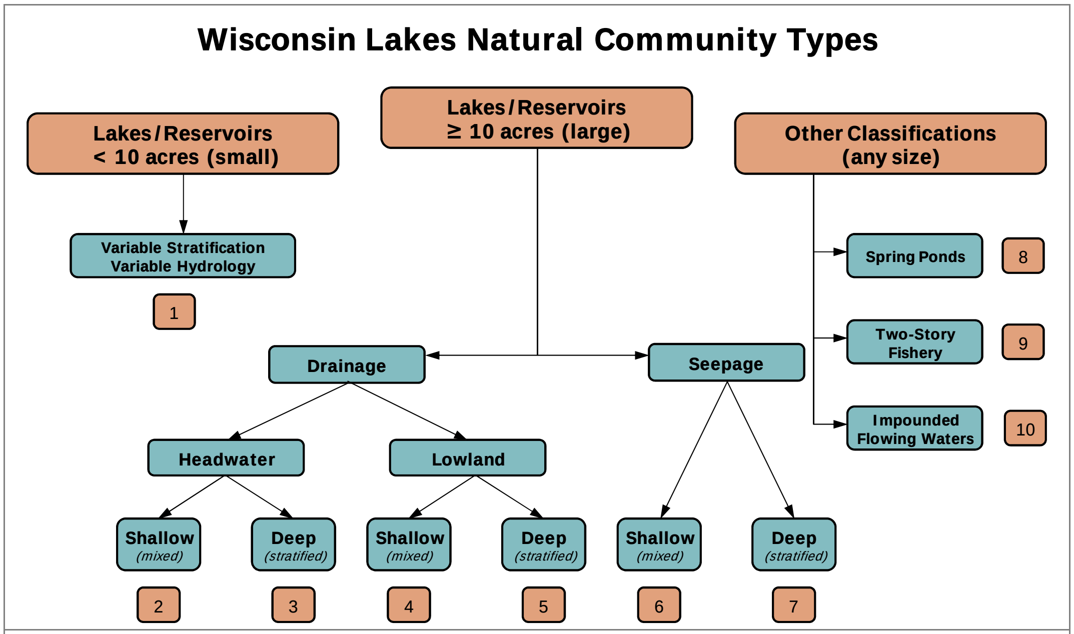


Figure 3.1-1. Wisconsin Lake Classifications. Adapted from WDNR 2017.

Lathrop and Lillie developed statewide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for each of the six 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 Cloverleaf Lakes are within the North Central Hardwood Forests ecoregion.

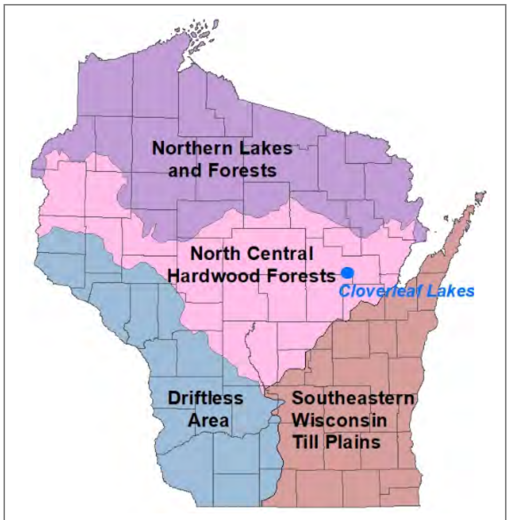


Figure 3.1-2. Location of Cloverleaf Lakes within the ecoregions of Wisconsin. After (Nichols, 1999).

The Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM), created by the WDNR, is a process by which the general condition of Wisconsin surface waters are assessed to determine if they meet federal requirements in terms of water quality under the Clean Water Act. It is another useful tool in helping lake stakeholders understand the health of their lake compared to others within the state. This method incorporates both biological and physical-chemical indicators to assess a given waterbody's condition. In the report, they divided the phosphorus, chlorophyll-*a*, and Secchi disk transparency data of each lake class into ranked categories and assigned each a "quality" label from "Excellent" to "Poor". The categories were based on pre-settlement conditions of the lakes inferred from sediment cores and their experience.

These data along with data corresponding to statewide natural lake means, historic, current, and average data from the Cloverleaf Lakes is displayed in Figures 3.1-3 - 3.1-8. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or summer months (June-August). Furthermore, the phosphorus and chlorophyll-*a* data represent only surface samples. Surface samples (top 3 feet) 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.

Cloverleaf Lakes Water Quality Analysis

Cloverleaf Lakes Long-term Trends

This Cloverleaf Lakes Management Plan contains water quality data from all three lakes: Round, Grass, and Pine. Data has been collected largely by citizen volunteers, although Onterra staff sampled the lakes in 2020 and February 2021. The individual lake sections provide in-depth discussions of each respective lake's water quality. The data presented in this section will serve to compare the lakes with each other and lakes in Wisconsin that are similar hydrologically and morphologically as well all lakes in the same ecoregion.

Total Phosphorus

As discussed previously, phosphorus is the primary nutrient controlling the growth of phytoplankton in the majority of Wisconsin's lakes. To determine whether phosphorus is the limiting nutrient within a lake, the concentration of phosphorus is compared to the concentration of nitrogen. Mid-summer total phosphorus and total nitrogen concentrations from the Cloverleaf Lakes indicate that all lakes are clearly phosphorus-limited (Figure 3.1-3). These ratios indicate that all lakes are phosphorus-limited, and that increases in phosphorus inputs would likely result in increased phytoplankton (algal) production. The ratio in Round Lake is unusually high because of the high nitrogen concentration. This will be discussed later in this section.

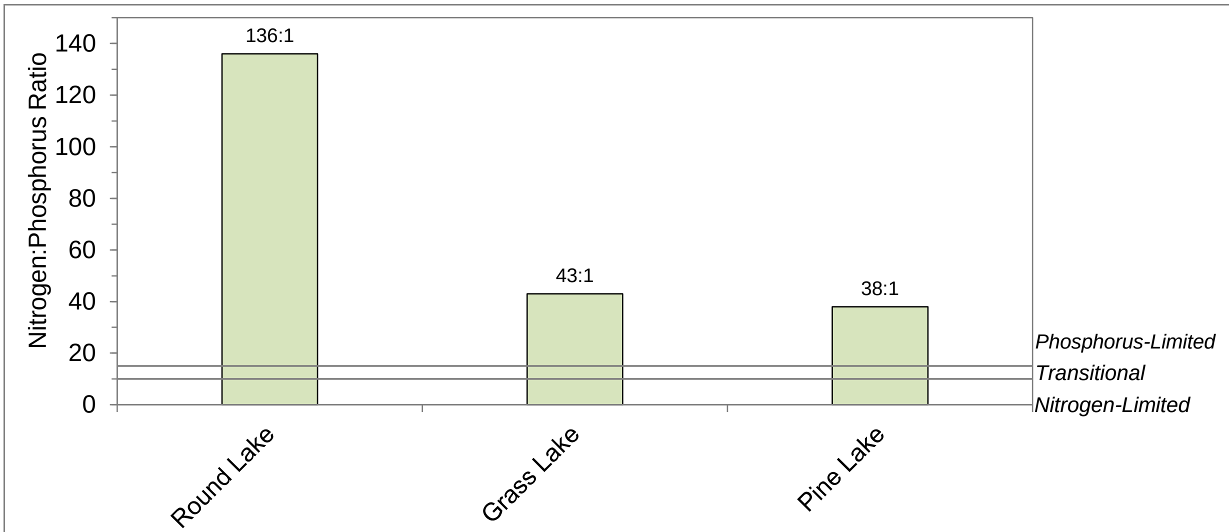


Figure 3.1-3. Cloverleaf Lakes mid-summer total nitrogen to total phosphorus. Data represent surface samples collected July 2020.

The average summer near-surface total phosphorus concentration was calculated for each lake using data collected as part of this project along with any available historical data. The longest data set is for Pine Lake (1991-2020) although there is data for at least 15 years for all of the lakes. Near-surface summer total phosphorus concentrations ranged from 12.8 µg/L in Round Lake to 15.9 in Grass Lake (Figure 3.1-4). In general, more voluminous (deep) lakes with smaller watersheds (headwater) tend to have naturally lower phosphorus concentrations as they receive lesser amounts of phosphorus from their watersheds and they are better able to dilute incoming phosphorus. In contrast, lakes that are less voluminous (shallow) with larger watersheds (lowland) tend to have naturally higher phosphorus concentrations as they receive higher amounts of phosphorus from the watershed and are less able to dilute incoming phosphorus. All three lakes are classified as deep headwater drainage lakes and thus can be compared with each other. The mean summer phosphorus concentration places all of the lakes in the excellent category (Figure 3.1-4). The Cloverleaf Lakes summer phosphorus concentrations are less than the median value for all deep headwater drainage lakes in Wisconsin (17 µg/L) and much less than the median value for all lake types in the Northcentral Hardwood Forest ecoregion (NCHF) (52 µg/L).

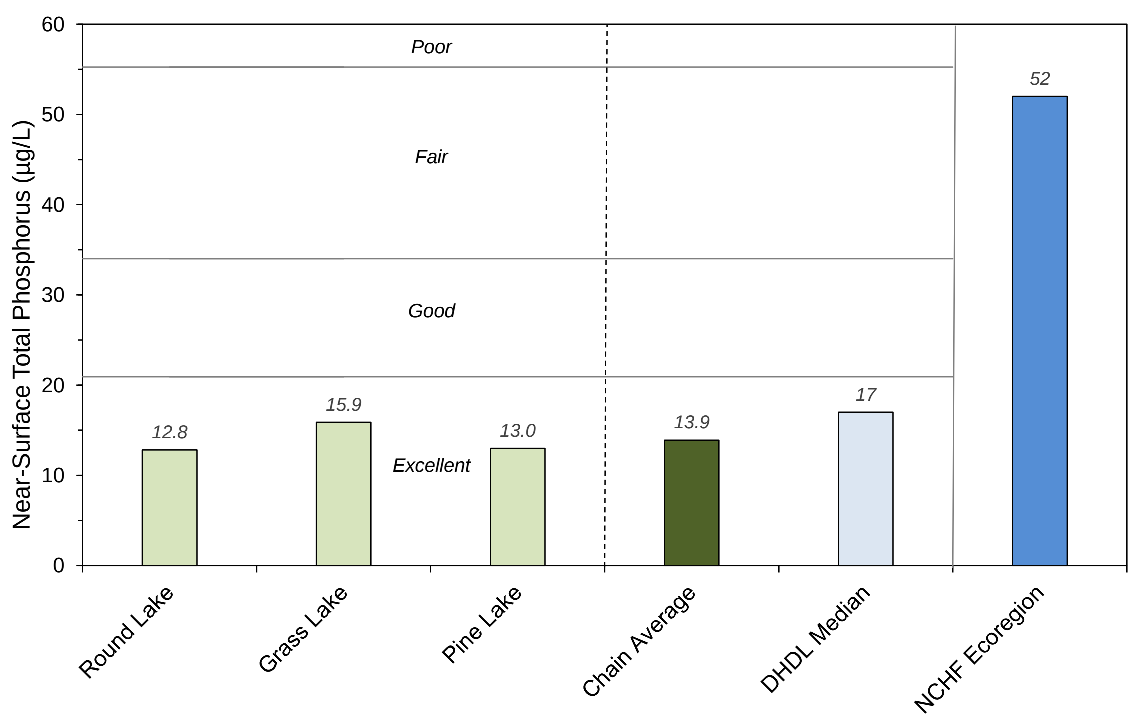


Figure 3.1-4. Cloverleaf Lakes near-surface total phosphorus concentrations and median summer near-surface total phosphorus concentrations from comparable lakes.

Total Nitrogen

There is much less historical data for nitrogen than many of the other parameters. Nitrogen concentrations were highest in Round Lake at 1,290 µg/L and lowest in Pine Lake at 610 µg/L (Figure 3.1-5). Nitrogen data is not often collected in routine sampling so there is not sufficient data from other lakes to compare the concentrations in Cloverleaf Lakes with lakes statewide. The concentration in Round Lake is higher than expected given the phosphorus value. As will be discussed in the individual lake sections, the limited data available suggest that nitrogen concentrations in Round Lake have increased in the last decade but not in the other lakes.

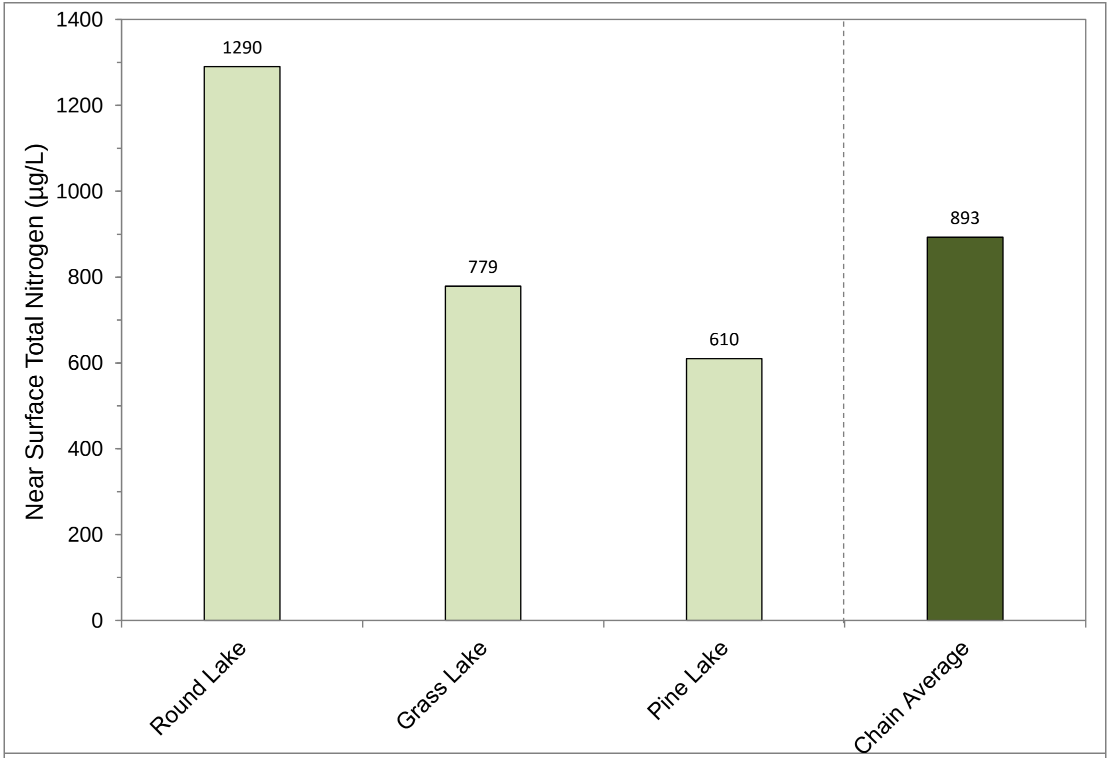


Figure 3.1-5. Cloverleaf Lakes near-surface total nitrogen concentrations.

Chlorophyll-α

Average summer chlorophyll-*a* concentrations measured within three lakes ranged from 3.4 µg/L in Pine Lake to 5.9 µg/L in Grass Lake (Figure 3.1-6). Chlorophyll-*a* concentrations are considered to be *excellent* their respective lake type, and no lakes were found to have concentrations approaching 20 µg/L, the concentration which is considered to create nuisance algal blooms. The average chlorophyll-*a* concentration for the Cloverleaf Lakes of 4.4 µg/L is less than the median value for deep headwater lakes in the state (5.0 µg/L) and much less than the median value for all lake types in the NCHF ecoregion (15.2 µg/L).

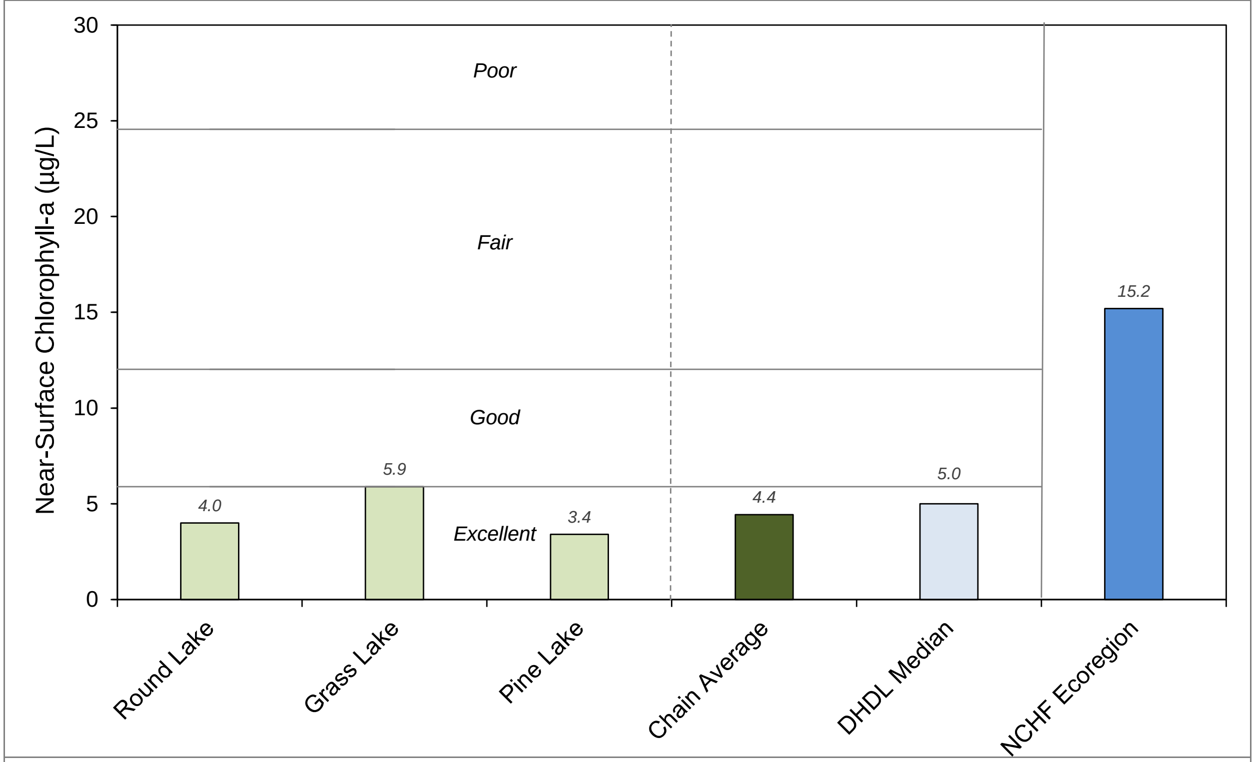


Figure 3.1-6. Cloverleaf Lakes summer average chlorophyll-α concentrations and median summer chlorophyll-α concentrations from comparable lakes.

As discussed previously, all ten lakes were found to be phosphorus-limited, meaning that algal production is going to be regulated largely by phosphorus availability. Figure 3.1-7 illustrates that average chlorophyll-*a* concentrations were positively correlated with average summer phosphorus concentrations, with the exception of Tamarack Lake. Tamarack Lake had an average summer phosphorus concentration of 32 µg/L, and based on the relationship between phosphorus and chlorophyll-*a* in the other nine lakes, Tamarack Lake was predicted to have a chlorophyll-*a* concentration of 16 µg/L. However, the measured average summer chlorophyll-*a* concentration in Tamarack Lake was considerably lower at 5.6 µg/L. It is not clear why algal production in Tamarack Lake is lower than expected, but it could be related to the lake's high aquatic plant abundance and/or food web dynamics.

Water Clarity

Average summer Secchi disk depth measured within the ten study lakes ranged from 9.1 feet in Grass Lake to 10.8 in Pine Lake (Figure 3.1-7). These Secchi disk values fall within the *excellent* category for deep headwater drainage lakes. The mean Secchi disk depth for the lakes is 9.9 feet which is slightly less than the median value for all deep headwater drainage lakes in Wisconsin (10.38 feet) but it is much better than the median value for all lake types in the NCHF ecoregion (5.3 feet).

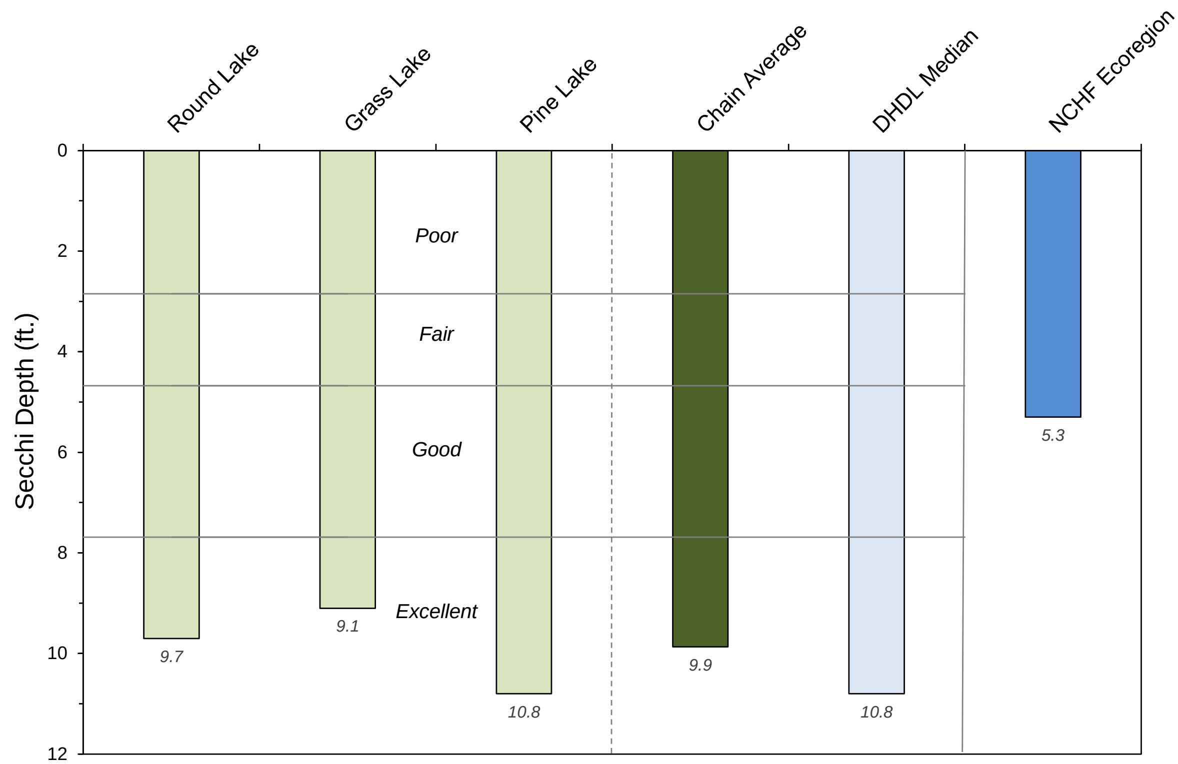


Figure 3.1-7. Cloverleaf Lakes summer average Secchi disk depth and median summer Secchi disk depths from comparable lakes.

Cloverleaf Lakes Trophic State

Figure 3.1-8 contains the weighted average Trophic State Index (TSI) values for each of the Cloverleaf Lakes. These TSI values are calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with available historical data. In general, the best values to use in assessing a lake's trophic state are chlorophyll-*a* and total phosphorus, as water clarity can be influenced by factors other than phytoplankton such as dissolved compounds within the water. The closer the calculated TSI values for these three parameters are to one another indicates a higher degree of correlation.

The weighted TSI values for total phosphorus and chlorophyll-*a* in the lakes indicate these lakes *mesotrophic* (Figure 3.1-8). The trophic status of the lakes is similar to the median TSI for all deep headwater drainage lakes in Wisconsin and have lower productivity than most all lake types in the NCHF ecoregion.

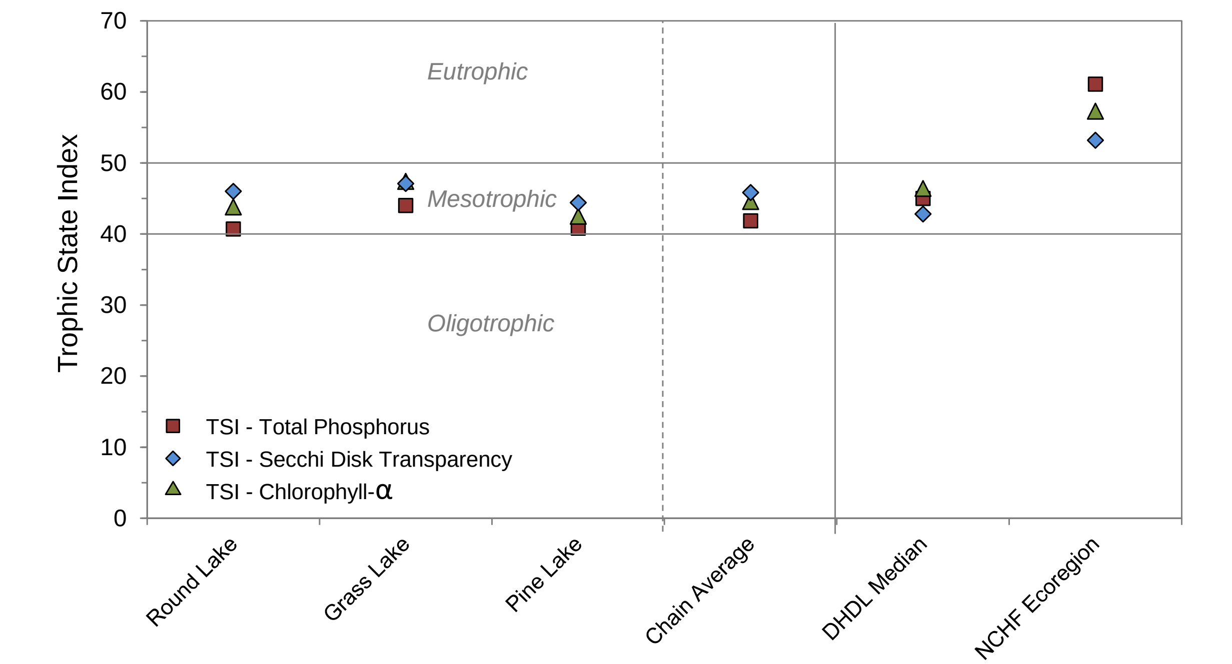


Figure 3.1-8. Cloverleaf Lakes Trophic State Index. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Additional Water Quality Data Collected on the Cloverleaf Lakes

The previous sections were largely focused on lake eutrophication. However, parameters other than nutrients, chlorophyll-*a*, and water clarity were collected as part of the project. These other parameters were collected to increase the Cloverleaf 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 and highly productive lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw and Nimphius 1985). The pH values were similar in all three lakes at 8.6-8.7 (Figure 3.1-9). This is slightly higher than the normal range for Wisconsin lakes but this is because these lakes are marl lakes.

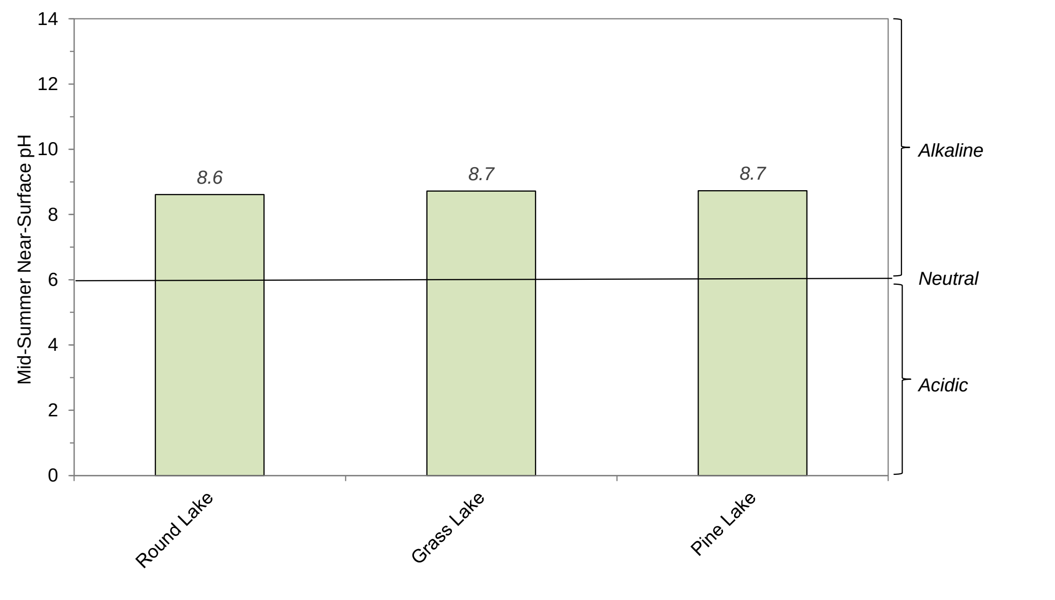


Figure 3.1-9. Cloverleaf Lakes mid-summer near-surface pH values. Data was collected in July 2020.

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. The alkalinity values ranged from 144 mg/L in Pine Lake to 167 mg/L in Round Lake (Figure 3.1-10). These values confirm that these are marl lakes and not at all sensitive to acid rain.

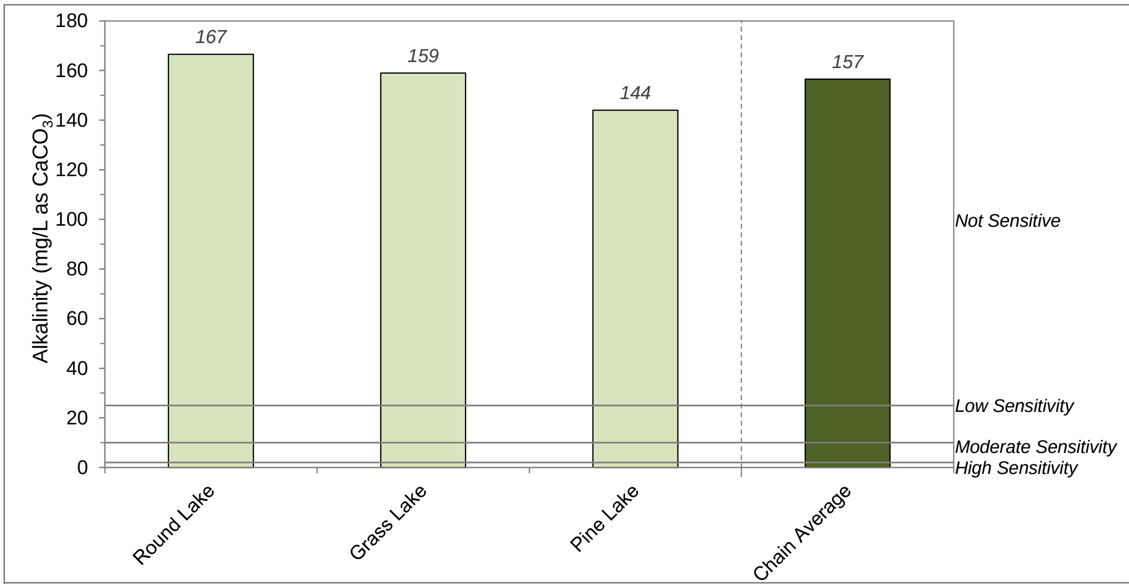


Figure 3.1-10. Cloverleaf Lakes average growing season total alkalinity and sensitivity to acid rain. Samples collected from the near-surface in 2020.

Calcium

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, and the pH of the ten project lakes fall within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have *very low susceptibility* to zebra mussel establishment. Measured calcium concentrations within the lakes ranged from 34.7 mg/L in Pine Lake to 45.0 mg/L in Round Lake (Figure 3.1-11). As these lakes already have zebra mussels it is not surprising that they are high susceptible to these organisms.

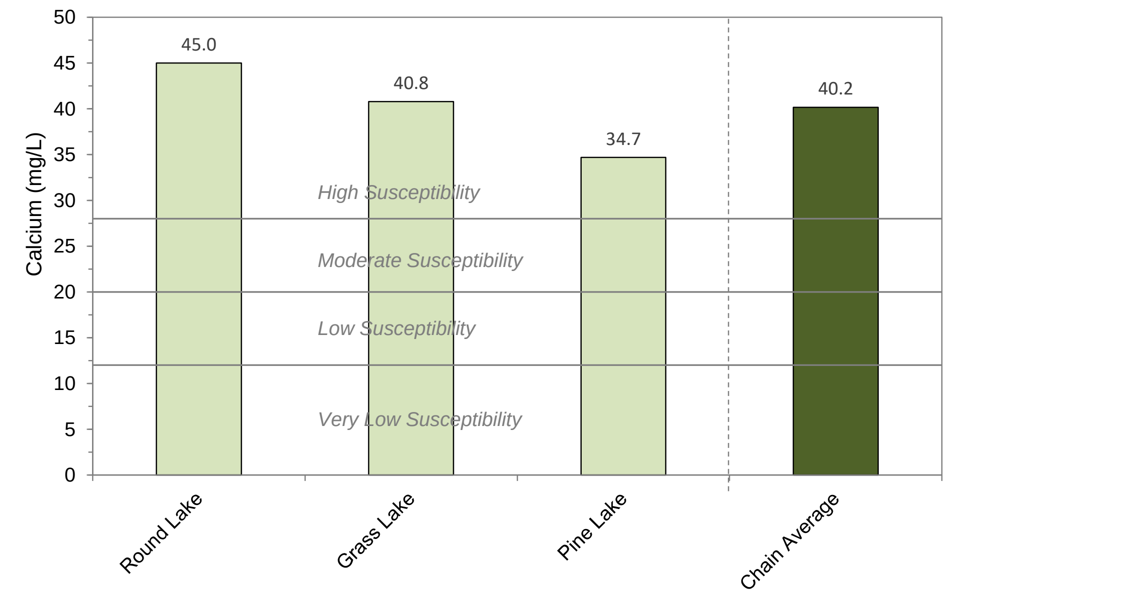


Figure 3.1-11. Cloverleaf Lakes average growing season calcium concentrations and susceptibility to zebra mussel establishment. Samples collected from the near-surface in 2020.

Color

A measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured in 2020 at 10 SU (standard units) in Round and Grass lakes and 7.5 SU in Pine Lake (Figure 3.1-14), indicating the lake's water was on the border between *slightly tea-colored* and *clear*. For comparison, nearby Shawano Lakes' true color is 15 SU and Loon Lake's true color is 60 SU. Loon lake's water clarity would be considered primarily influenced by dissolved components in the water as opposed to free-floating algae (i.e. c chlorophyll-*a*).

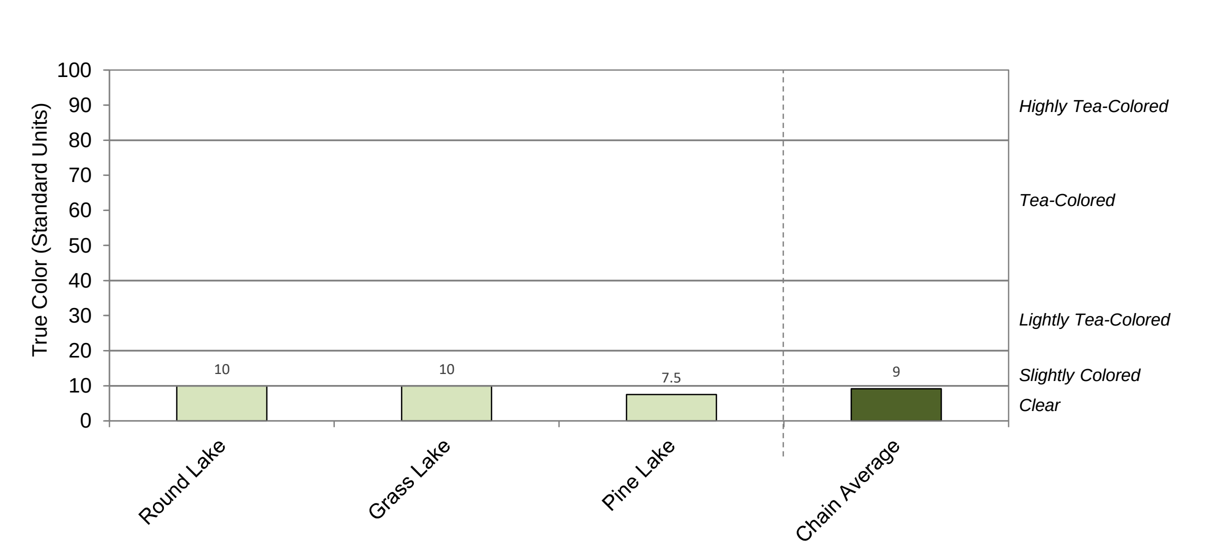


Figure 3.1-12. Cloverleaf Lakes average true color values. Samples collected from the near-surface in 2020.

Stakeholder Survey Responses to Cloverleaf Lakes' Water Quality

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lakes and how they may have changed over the years. Figures 3.1-13 and 3.1-14 display the responses of members of Cloverleaf Lakes stakeholders to questions regarding water quality and how they feel it has changed over their years visiting the lakes. Most survey respondents indicated that they think the overall water quality of the Cloverleaf Lakes is "good."

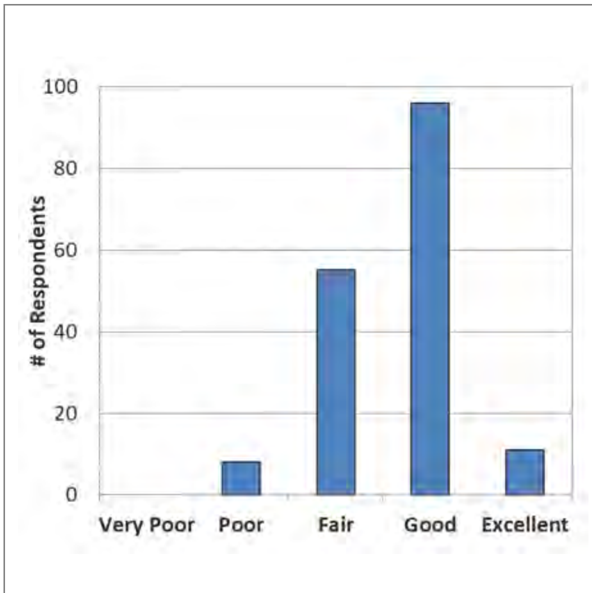


Figure 3.1-13. Stakeholder survey response Question #20. How would you describe the overall current water quality of the Cloverleaf Lakes?

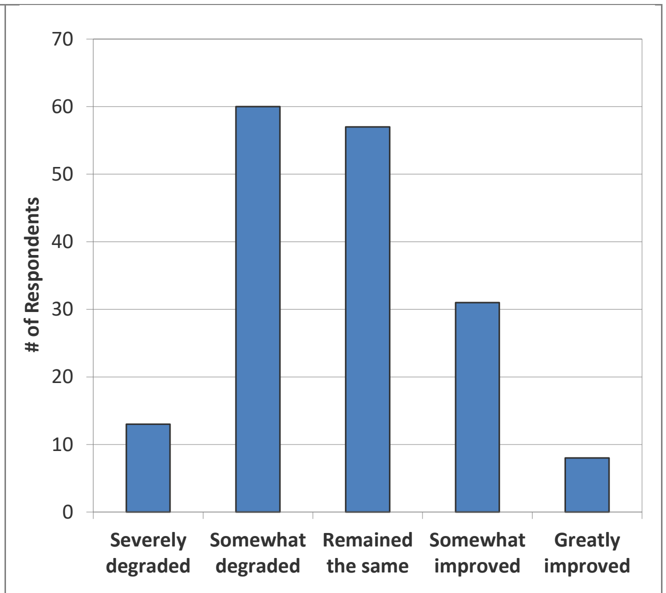
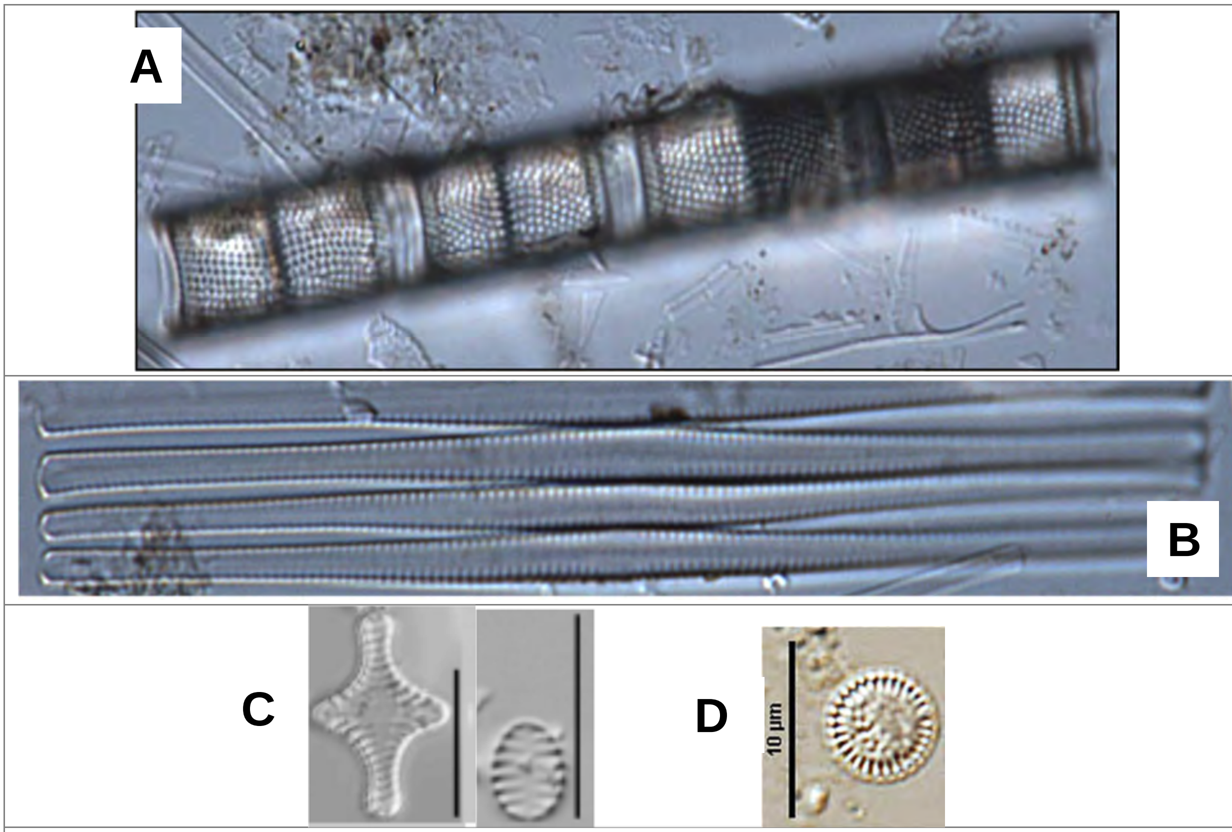


Figure 3.1-14. Stakeholder survey response Question #21. How has the overall water quality changed in the Cloverleaf Lakes since you first visited?

Paleoecology

Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution. These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The diatom community are especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Photograph 3.1-1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to objects such as aquatic plants or the lake bottom.



Photograph 3.1-1. Photomicrographs of the diatoms commonly found in the sediment cores. The diatoms (A) *Aulacoseira ambigua* and *Fragilaria crotonensis* (B) are typically found floating in the open water. *F crotonensis* is more common with moderate phosphorus levels but indicates higher nitrogen concentrations. *Staurosira construens* and *S. construens var. venter* (C) are part of the benthic *Fragilaria* and are typically found growing on macrophytes and other substrates. *Cyclotella comensis* (D) is thought to be an invasive from Europe and is found in lakes with moderate phosphorus concentrations.

The chemical composition of the sediments may indicate the composition of particles entering the lake as well as the past chemical environment of the lake itself. By collecting an intact sediment core, sectioning it off into layers, and utilizing all of the information described above, paleoecologists can reconstruct changes in the lake ecosystem over any period of time since the establishment of the lake.

One often used paleoecological technique is collecting and analyzing top/bottom cores. The top/bottom core only analyzes the top (usually 1 cm) and bottom sections. The top section represents present day conditions and the bottom section is hoped to represent pre-settlement conditions by having been deposited at least 100 years ago. While it is not possible to determine the actual date of deposition of bottom samples, a determination of the radionuclide lead-210 estimates if the sample was deposited at least 100 years ago. The primary analysis conducted on this type of core is the diatom community leading to an understanding of past nutrients, pH, and general macrophyte coverage.

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Shadow Lake, an exploratory detrended correspondence analysis (DCA) was performed with CANOCO 5 software (Ter Braak & Smilauer, 2012). The DCA analysis has been done on many WI lakes to examine the similarities of the diatom communities between the top and bottom samples of the same lake. The results revealed two clear axes of variation in the diatom data, with 44% and 31% of the variance explained by axis 1 and axis 2, respectively (Figure 3.1-15). Sites with similar sample scores occur in close proximity reflecting similar diatom composition. The arrows symbolize the trend from the bottom to the top samples.

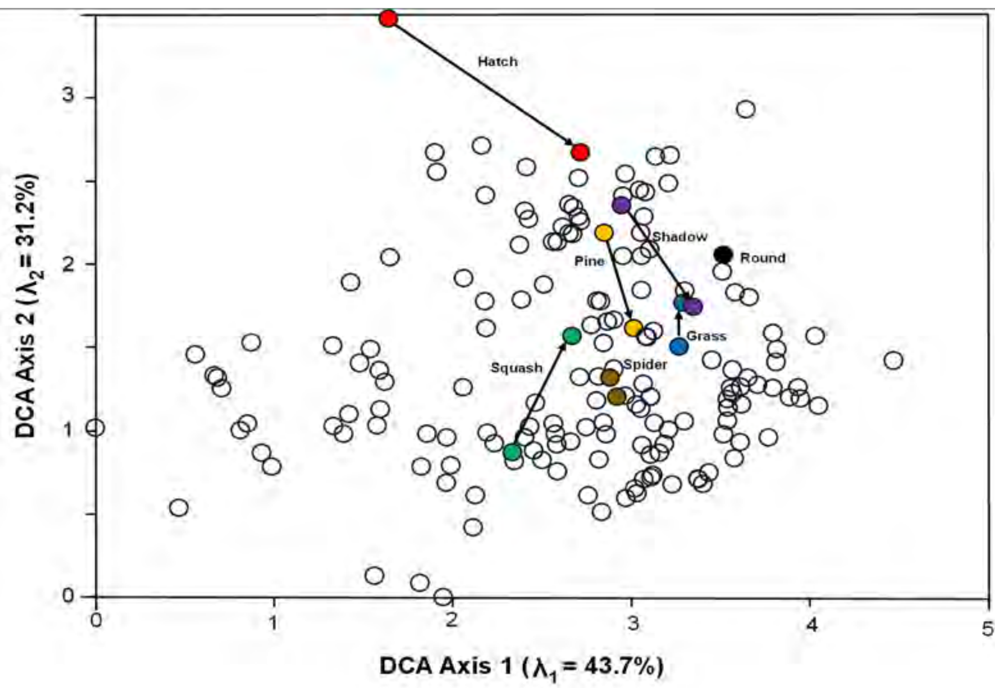


Figure 3.1-15. DCA plot of top/bottom samples from Cloverleaf Lakes and highlighting lakes where Onterra staff collected sediment cores in 2020. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed.

The diatom community suggests there has been a greater change in Pine Lake compared with Grass Lake (Figure 3.1-15). Even though the greatest change occurred in Pine Lake is it much less than in three of the other lakes where sediment cores were analyzed by Onterra staff in 2020. As will be discussed below, diatoms fossils did not preserve in the bottom of Round Lake so only the top sample is shown on this figure.

Diatom Community Changes

While diatoms were plentiful in the both top and bottom sections from the Grass and Pine lake cores, and also plentiful in the top section of the core from Round Lake; they were absent from the bottom section if Round Lake. This is unusual but it does occasionally happen. This is more common in very hardwater lakes where the higher pH values facilitate dissolution of the siliceous shells of the diatoms. It is unclear why there was dissolution of the diatom shells in Round Lake but it may be related to the high iron levels in the deeper sediments of the lake. Another lake which had high sediment iron levels also experienced complete dissolution of the diatom shells.

By determining changes in the diatom community, it is possible to determine water quality changes that have occurred in the lake. The diatom community provides information about changes in nutrient, water color, and pH conditions as well as alterations in the aquatic plant (macrophyte) community.

Pine Lake

The dominant diatoms at the top of the core were planktonic diatoms which grow in the open water of the lake. These types of diatoms made up over 60 per cent of the diatom community (Figure 3.1-16). The dominant taxa were *Aulacoseira ambigua* and *Fragilaria crotonensis* which are pictured in Photograph 3.1-1 A and B. At the bottom of the core planktonic diatoms only made up about 20 per cent of the diatom community. The dominant diatoms were those that grow attached to aquatic plants or other bottom substrates. An example of this type of diatom is shown in Photograph 3.1-1C. Studies have found that as nutrients increase, even by a small amount, planktonic diatoms become much more common. The large change in the diatom community from the bottom to the top of the core in Pine Lake indicates there has been an increase in nutrients during the last 100 years. It is likely the increase in nutrients has not been more than 5 µg/L since the dominant diatom taxa are usually found in lakes with moderate nutrient levels. Benthic *Fragilaria* grow on substrates such as aquatic plants. Their decline from the bottom to the top of the core does not necessarily mean there are less plants at the present time compared with historical times. It is hypothesized that the plant community at the present time is similar in distribution, although composition of the community may have changed.

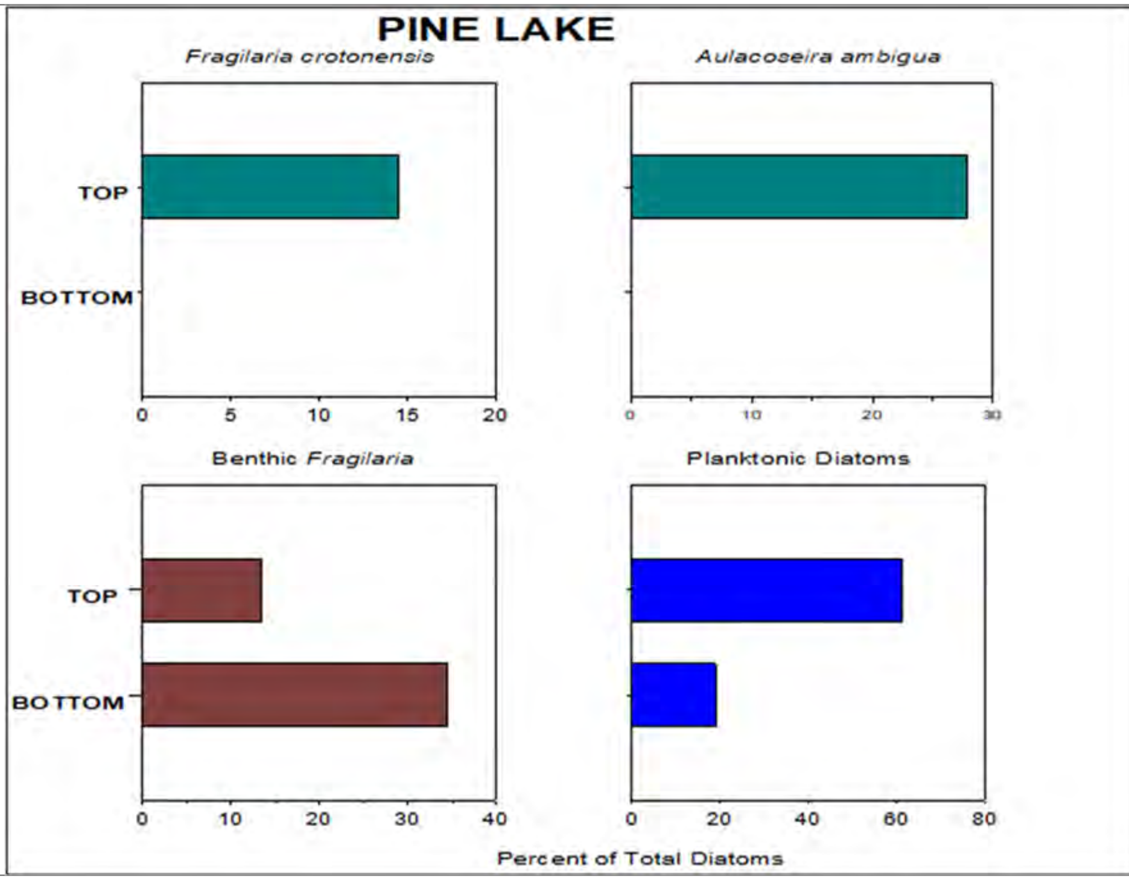


Figure 3.1-16. Changes in abundance of important diatoms found at the top and bottom of the sediment core from Pine Lake. The diatoms in the top panels are found in the open water of the lake while Benthic *Fragilaria* grow on substrates such as plants. The large increase in planktonic diatoms from the bottom to the top of the core indicates a small, but significant increase in nutrients.

Grass Lake

Unlike Pine Lake, the diatom community does not indicate a significant change in nutrients from the bottom to the top of the core. Planktonic diatoms were the dominant type of diatoms in both the top and bottom of the core from Grass Lake (Figure 3.1-17). This is surprising since the lakes are adjacent to each other and connected. It would be expected the diatom community at the bottom of the cores from the lakes would be similar even if the community at the top of the cores were different. It is likely that the bottom section of the core from Grass Lake was not deposited prior to European settlement. The sediment in the location where the core was taken may have been previously disturbed, for example, by a boat anchor. It is also possible that the length of the core was not great enough. The core from Pine Lake was 20 cm longer than the one from Grass Lake. In most other lakes, the length of the core from Grass Lake (47 cm) would have been long enough to cover over 100 years, but the sedimentation rate in Grass Lake may be usually high.

Because the authors do not have confidence that the bottom section represents a pre-settlement time period it is not possible to directly compare changes in the core from top to bottom. If it is assumed that the pre-settlement diatom community in Grass Lake was similar to Pine Lake then Grass Lake has undergone similar changes in nutrient levels as Pine Lake. As with Pine Lake there has also not been a significant change in the aquatic plant community either.

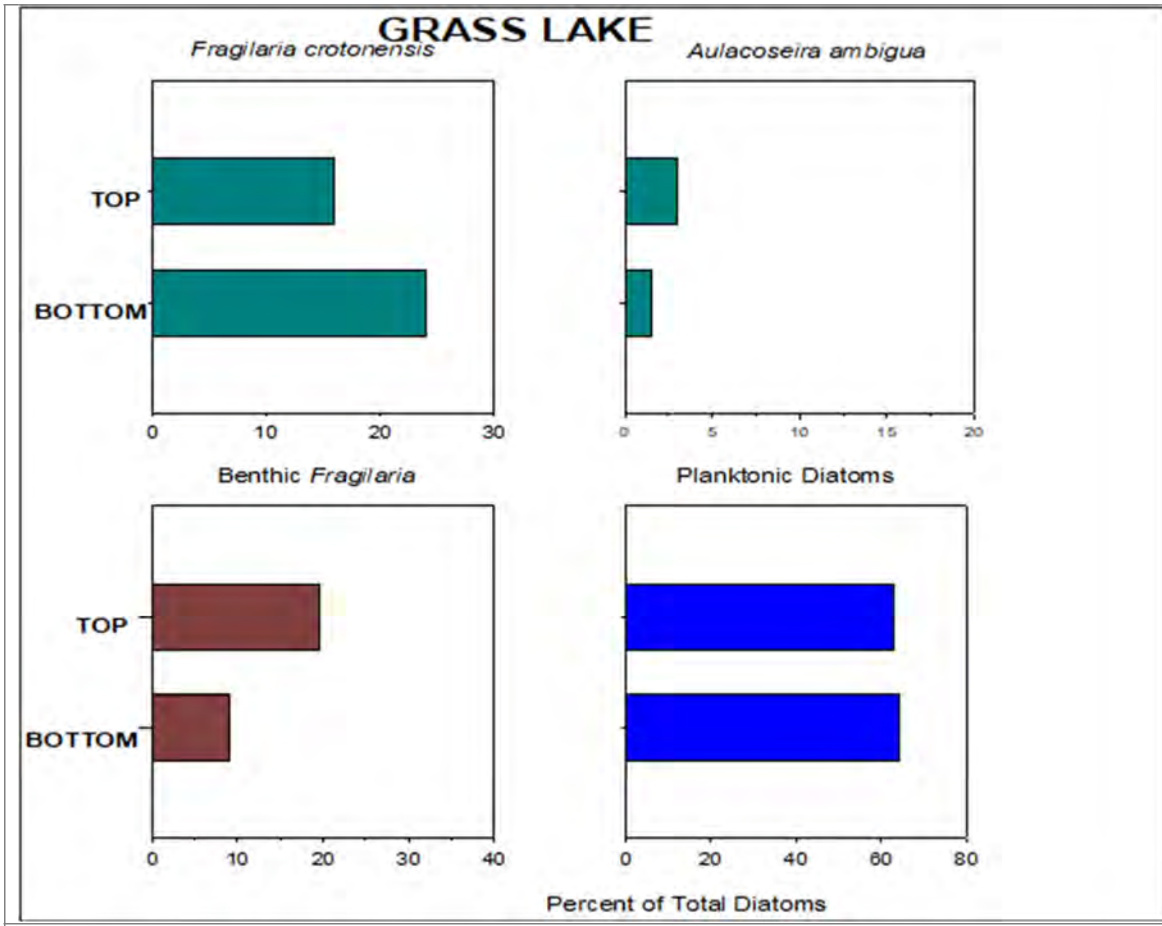


Figure 3.1-17. Changes in abundance of important diatoms found at the top and bottom of the sediment core from Grass Lake. Unlike Pine Lake there was not a significant change in the diatom community from the bottom to the top of the core. This likely indicates the core was either not long enough or the coring site had been previously disturbed.

Round Lake

As mentioned previously, no diatoms were preserved in the bottom section of this core. It is likely that the diatom community found at the bottom of the core from Pine Lake was the historical community in Round Lake. If this is true then there have been greater increases in nutrients in this lake than the other two lakes. While planktonic diatoms comprised about 60 percent of the diatom community in the surface sediments of Pine and Grass lakes, they were almost 90 per cent of the community in Round

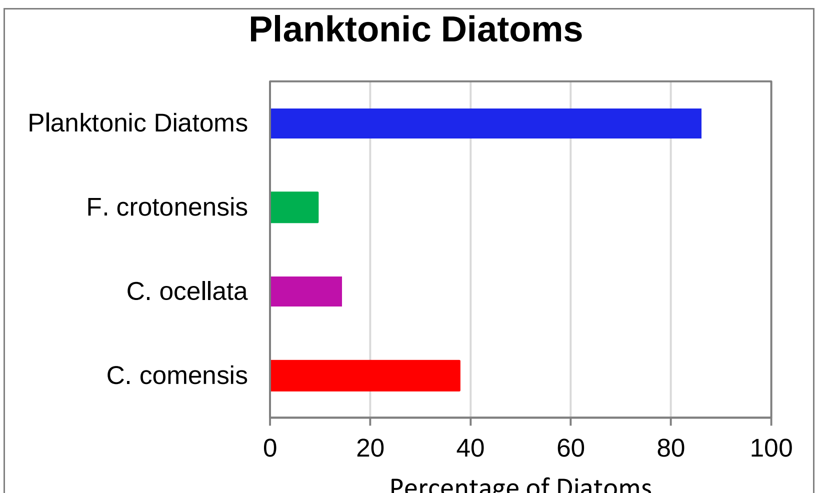


Figure 3.1-18. Abundance of common diatoms in the surface of Round Lake. *Cyclotella comensis* is thought to be an invasive diatom from northern Europe.

Lake (Figure 3.1-18). The dominant diatom was the planktonic diatom *Cyclotella comensis*. This diatom is thought to be an invasive from northern Europe. It is thought to have arrived during the 1950s via Great Lakes shipping. It seems to indicate elevated nutrient levels. Only a couple of these diatoms were found in Grass or Pine lakes. One of the most common diatoms in the surface of the other two lakes was *F. crotonensis*.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson et al. 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 75th percentiles for reference lakes in the Upper Midwest. The LDCI was used in the 2007 National Lakes Assessment to determine the biological integrity of the nation's lakes.

The LDCI analysis indicates the only Pine Lake historically had a biotic condition in the good range (Figure 3.1-19). As mentioned above it is likely that the bottom sample from Grass Lake does not represent historical conditions. There were no diatoms preserved in the bottom sample from Round Lake. It is likely that the biotic condition of Round and Grass lakes was in the good range since all of these lakes historically would have had similar land use in their watersheds. The present condition of Round Lake is in the poor range because of the invasive diatom *C. comensis*.

Inference models

Diatom assemblages have been used as indicators of trophic changes in a qualitative way (Bradbury, 1975), (Carney, 1982), (Anderson, Rippey, & Stevenson, 1990) but quantitative analytical methods exist. Ecologically relevant statistical methods have been developed to infer environmental conditions from diatom assemblages. These methods are based on multivariate ordination and weighted averaging regression and calibration (Birks, Line, Juggins, Stevenson, & Ter Braak, 1990). Ecological preferences of diatom species are determined by relating modern limnological variables to surface sediment diatom assemblages. The species-environment relationships are then used to infer environmental conditions from fossil diatom assemblages found in the sediment core.

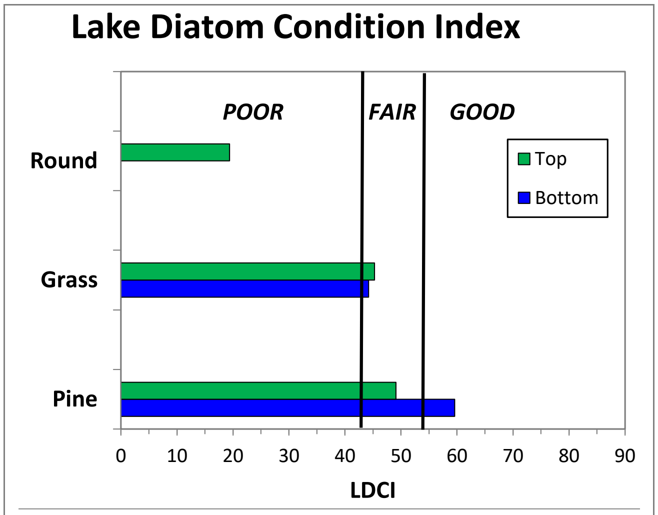


Figure 3.1-19. The Lake Diatom Condition Index (LDCI) for the Cloverleaf Lakes. The index is poor for Round Lake because of the relatively large presence of the invasive diatom *C. comensis*.

Weighted averaging calibration and reconstruction (Birks, Line, Juggins, Stevenson, & Ter Braak, 1990) were used to infer historical water column summer average phosphorus concentration in the sediment cores. A training set that consisted of 60 stratified lakes was used. Training set species and environmental data were analyzed using weighted average regression software (C2; (Juggins, 2014).

Table 3.1-1 shows the diatom inferred mean summer phosphorus concentrations for the three lakes. The estimated historical phosphorus concentration in Pine Lake is 13 μg/L. It is likely this was the historical value in Grass and Round lakes as well. The estimated surface phosphorus concentration in Pine and Grass lakes are higher than what has been measured in recent years. This suggests the model is over estimating phosphorus levels but it is likely that phosphorus concentrations in the lakes have increased only a small amount. Probably in the range of 2 to 3 μg/L.

Table 3.1-1. Diatom inferred phosphorus concentrations in core samples (μg/L).

Lakes	Phosphorus
Pine Top	20
Pine Bottom	13
Grass Top	19
Grass Bottom	20
Round Top	12

In summary, the core from Round Lake only had diatoms in the surface section. The bottom section of the core from Grass Lake did not represent pre-settlement conditions but the Pine Lake core was a good core. If it is assumed that the diatom community present in the bottom section of the Pine Lake core is representative of historical conditions in all three lakes, then nutrient levels at the present time are higher than they were historically. Nutrient levels appear to have increased the least in Pine Lake and the most in Round Lake.

3.2 Watershed Assessment

Watershed Modeling

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

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

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

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

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

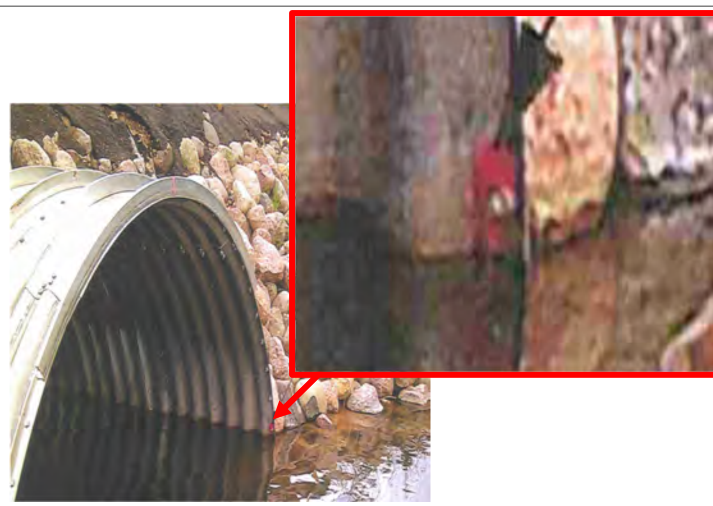
Regardless of the size of the watershed or the makeup of its land cover, it must be remembered that every lake is different and other factors, such as flushing rate, lake volume, sediment type, and many others, also influence how the lake will react to what is flowing into it. For instance, a deeper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

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

Cloverleaf Lakes Water Levels

The water levels of the Cloverleaf Lakes were intended to be controlled by a small dam at the south end of Pine Lake (Photograph 3.2-1). Matteson Creek, the outlet, flows through the Matteson Creek Wildlife Area before draining into the Embarrass River and eventually into the Wolf River. Some area residents believe that downstream beaver dams and the Auld & Rohrer Dam (at The Pines, formerly Pine Manor) may also have an influence on the Cloverleaf Lakes water levels, perhaps even more of an influence than the Pine Lake dam.

Photograph 3.2-1. Pine Lake Dam. Photo Credit: Onterra. September 2021



Photograph 3.2-2. Culvert between Round & Grass lakes. Shows nut used as benchmark for dam operation. Photo Credit: WDNR.

The Public Service Commission set the operating order of the Pine Lake dam on Rustic Drive in 1955, in which the normal water level is 799.58 ft above sea level, low water at 799.28 ft, and high water at 799.88 ft. Therefore, the Cloverleaf Lakes have an operating range of 7.2 inches. Prior to 2017, the benchmark for dictating the dam operations was the culvert between Round and Grass lakes. When measuring down from the top of the culvert< on the Round Lake end, to the waterline, 72 inches would correspond to the high-water benchmark. If the water level was higher than that (i.e., if that measurement was less than 72 inches) the WDNR ordered the outlet dam at the south end of Pine Lake to be opened.

In 2016-2017, that corrugated metal pipe-style culvert was replaced with a bottomless arch culvert so that previous 72-inch measurement is no longer functional at the site. The WDNR reestablished a benchmark in May 2017 using an identifying feature on the new culvert, the top of the lower-most nut (Photograph 3.2-2). The top of the nut is set at 800.44 ft above sea level, which is approximately 6 ¾ inches above the designated high-water level. If the measurement is less than 6 ¾ inches, then the dam would need to be opened.

The dam is currently owned by the Town of Belle Plaine, after an ownership transfer from the CLPA. The CLPA continues to operate the Pine Lake dam and has requested the WDNR fashion an accessible and readable benchmark or gage to the culvert assembly.

Since 1976, volunteers have been recording the water level elevations of the Cloverleaf Lakes (Figure 3.2-1). The latest data record is courtesy of Dennis (Denny) Nodolf, being recorded almost daily during the summer months. The water levels are based upon a benchmark nearby Denny's residence that is calibrated to the WDNR benchmark approximately twice per year.

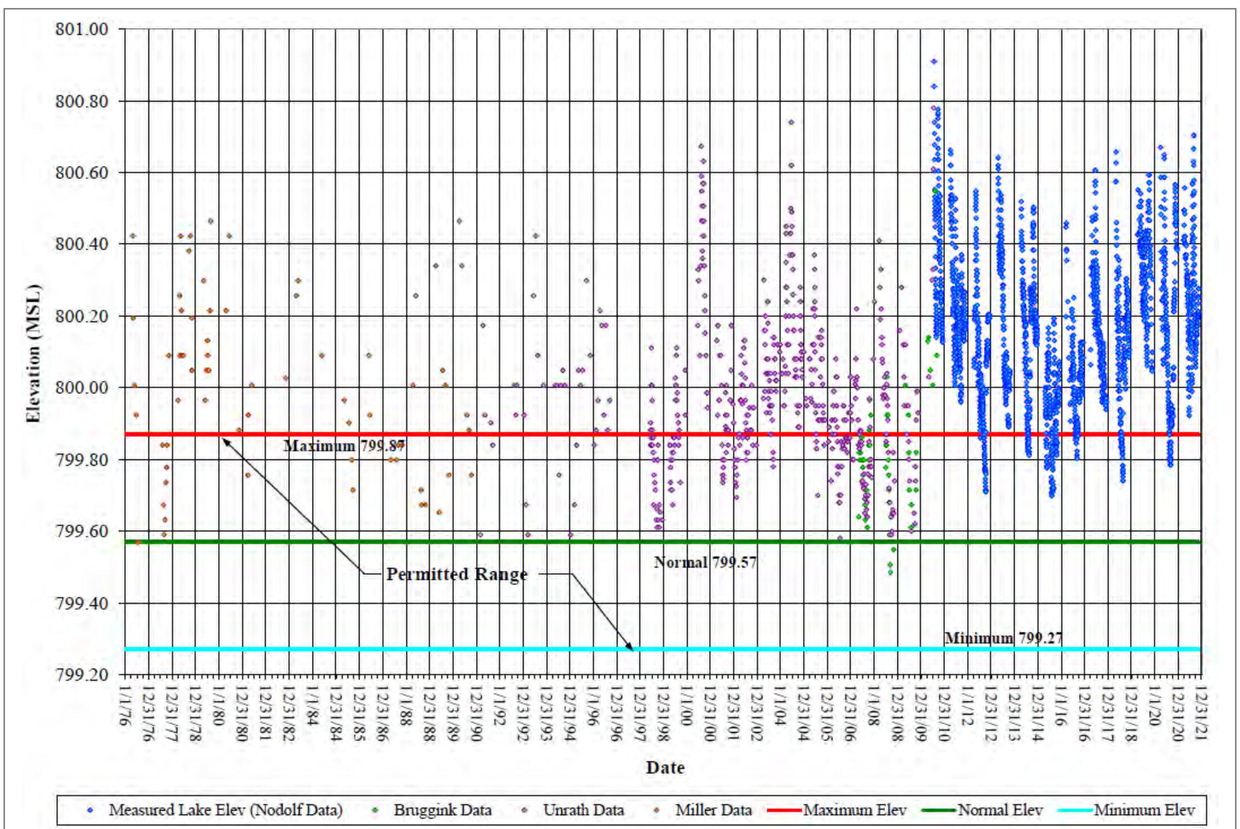


Figure 3.2-1. Cloverleaf Lakes historic lake elevations. Data credit: Denny Nodolf and other CLPA volunteers.

Cloverleaf Lakes Watershed Assessment – TMDL Model

Section 303(d) of the Clean Water Act (CWA) requires states to determine which waterbodies are impaired and orchestrate a plan to reach the goal of restoring all identified impaired waters to meet applicable water quality standards (WDNR 2020). One of the tools WDNR biologists use to achieve this goal is to develop a total maximum daily load (TMDL) for an impaired waterbody. The primary objective of an approved TMDL is to establish pollutant load allocations to point and nonpoint sources in order to achieve pollutant load reductions needed to meet water quality goals (WDNR 2020). Meeting these water quality goals in turn should theoretically improve water quality and eventually lead to the delisting of the impaired waterbody from the impaired waters and restoration waters list.

The Wolf River TMDL watershed is approximately 2,387,200 acres (3,730 square miles), includes portions of eleven counties, and covers approximately 10% of the state of Wisconsin. The watershed originates in Pine Lake and discharges into Lake Poygan of the Lake Winnebago System. The Wolf River watershed is subdivided into twenty sub-watersheds (Figure 3.2-2). The U.S. EPA approved the Wisconsin River TMDL on February 27, 2020. This report can be accessed here: https://dnr.wisconsin.gov/topic/TMDLs/FoxWolf/index.html

Code	Name	Acres
WR20	Upper Wolf River and Post Lake	131,503
WR19	Lily River	132,673
WR18	Wolf River - Langlade and Evergreen River	115,035
WR17	West Branch Wolf River	161,114
WR16	Red River	132,556
WR15	Shawano Lake	45,544
WR14	Middle Wolf River	85,619
WR13	Shioc River	121,447
WR12	Wolf River - New London and Bear Creek	91,191
WR11	Middle and South Branches Embarrass River	160,004
WR10	Pigeon River	74,444
WR09	North Branch and Mainstem Embarrass River	200,074
WR08	South Branch Little Wolf River	102,586
WR07	Upper Little Wolf River	116,512
WR06	Lower Little Wolf River	98,307
WR05	Waupaca River	186,096
WR04	Lower Wolf River	76,768
WR03	Walla Walla and Alder Creeks	71,739
WR02	Pine and Willow Rivers	193,329
WR01	Arrowhead River and Daggets Creek	91,463

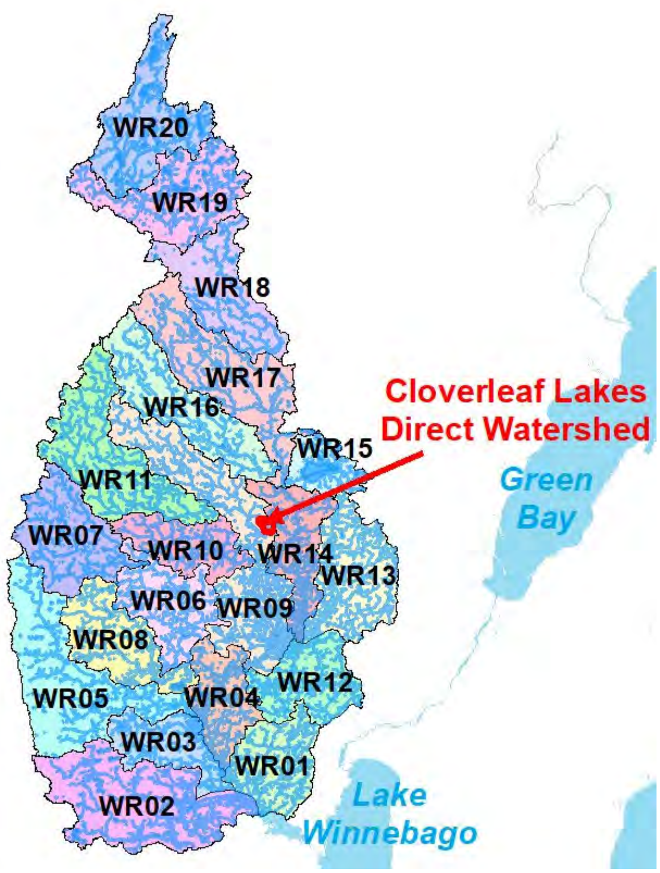


Figure 3.2-2. Wolf River Watershed.

Within the Wolf River watershed is the subbasin North Branch and Mainstem Embarrass River Watershed (WR09 in Figure 3.2-2). This watershed lies in Outagamie, Waupaca, and Shawano Counties and covers 200 acres. This watershed includes 99 miles of the North Branch and Mainstem of the Embarrass River which harbor between good and excellent quality of fish and aquatic life.

Cloverleaf Lakes Watershed Assessment – WiLMS Model

Cloverleaf Lake's entire watershed encompasses an area of approximately 1,799 acres. The direct watershed for each of the Cloverleaf Lakes was determined by examining topographical maps to estimate where water eventually drains to each lake (Figure 3.3-3). These analyses are discussed in the subsequent sections.

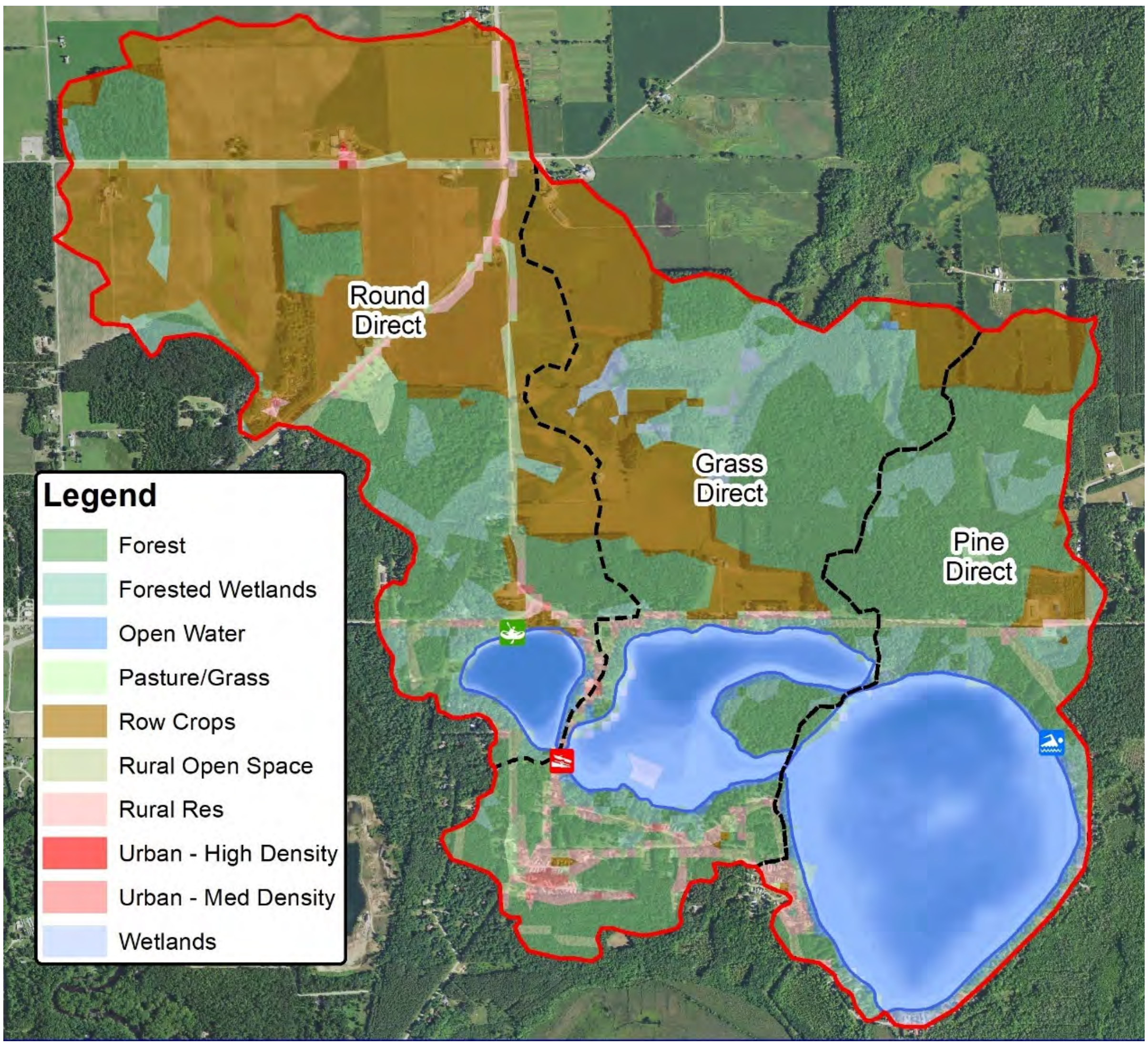


Figure 3.2-3. Cloverleaf Lakes entire and direct watersheds.

When modeling the watershed impact of lakes in a series, such as the Cloverleaf Lakes, upstream lakes are considered as a point-source to the downstream lakes; therefore, Round is considered a point-source to Grass, and Grass is considered a point-source to Pine. Typically, upstream lakes act as a sedimentation basin for downstream lakes, this methodology accounts for that in the modeling. So, downstream lakes have essentially two sources of input, the water flowing from the upstream lake (point-source) and the water running off from the lake's direct watershed (nonpoint-source).

Round Lake Watershed Assessment

Round Lake's direct watershed is 713 acres in area (Figure 3.2-3 and 3.2-4). Compared to Round Lake's surface area of 28 acres, this makes for a large watershed to lake area ratio of 24:1. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Round Lake's residence time, based upon surface inflow, is a bit less than a year. Of the 713-acre watershed, 61% is row crops, 19% is forest, 8% is wetlands, 5% is pasture/grass, 4% is the lake surface itself, 3% are shoreland homes, and row crops make up less than 1% of the total watershed (Figure 3.2-4).

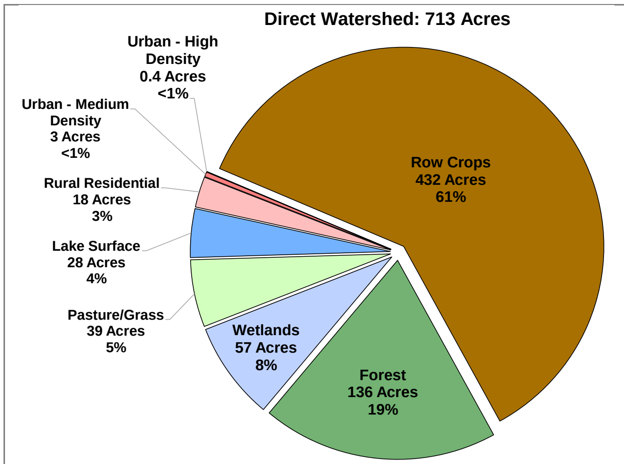


Figure 3.2-4. Round Lake direct watershed proportion of land cover types. Based upon National Land Cover Database (USGS, 2019). As detailed in the text, the effective watershed is likely much less than shown in the chart.

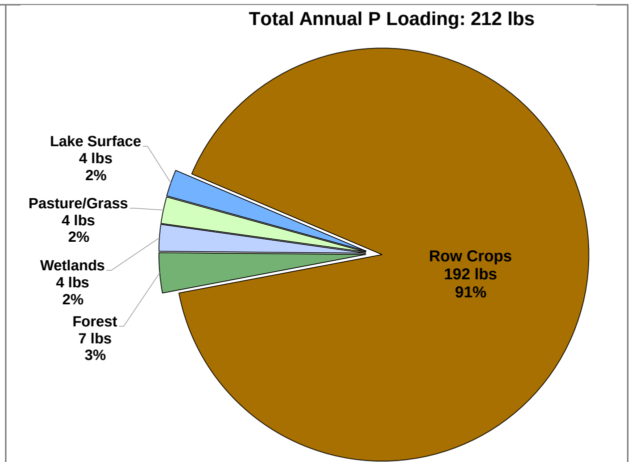


Figure 3.2-5. Round Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates. As detailed in the text it is likely the actual phosphorus load is less than depicted in the chart.

Using the land cover types and their acreages within Round Lake's watershed, WiLMS was utilized to estimate the annual potential phosphorus load delivered to Round Lake from its watershed. Of the estimated 212 pounds of phosphorus delivered to the lake annually, 192 pounds (91%) is derived from row crops, 7 pounds (3%) is from forest lands, 4 pounds (2%) is from the lake itself, 4 pounds (2%) from wetlands, 4 pounds (5%) from grasslands, and 4 pounds (2%) from residential areas (Figure 3.2-5).

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 49 µg/L, which is considerably higher than the measured growing season average total phosphorus concentration of 14 µg/L. The predicted value is likely much higher for three reasons: 1) the effective watershed is much smaller than shown in Figure 3.2-3. Meaning that although the water could make its way to the lake from the entire area, some of the runoff likely does not and instead is percolated into the groundwater before it reaches the lake. For example, it is likely that the croplands shown in the northern part of the watershed do not contribute a significant amount of phosphorus to Round Lake. 2) It is also likely that the wetland north of the lake is intercepts and retains a significant amount of phosphorus. 3) The Cloverleaf Lakes are considered to be *marl* lakes, which means that the lakes have a large amount of calcium carbonate in the water because of the regional geology. The calcium-carbonate enters the lake with groundwater and once oxygenated, begins to precipitate as marl. The marl binds with dissolved phosphorus and settles it out of the water column.

Grass Lake Watershed Assessment

Grass Lake's estimated direct watershed is 611 acres in area (Figure 3.2-2). The total surface area draining to Grass Lake, including the indirect watershed entering through Round Lake, is approximately 1,324 acres yielding a watershed to lake area ratio of 13:1. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Grass Lake's residence time, based upon surface inflow, is about a year and a half. Of the 611-acre direct watershed, 35% is forest land, 24% is row crops, 18% is wetlands, 15% is the lake surface itself, 4% is grassland, and 4% are rural homes (Figure 3.2-6).

Using the land cover types and their acreages within Grass Lake's watershed, plus the input from Round Lake, modeling estimates the annual potential phosphorus load delivered to Grass Lake is approximately 202 pounds. Of that, 128 pounds (63%) is derived from row crops, 18 pounds (9%) is from forest lands, 15 pounds (7%) is added to the lake directly as atmospheric fallout, 9 pounds (5%) from wetlands, 7 pounds (3%) from grasslands, 4 pounds (2%) from rural homes, and the remain 11%, or about 22 pounds enters from Round Lake. (Figure 3.2-7).

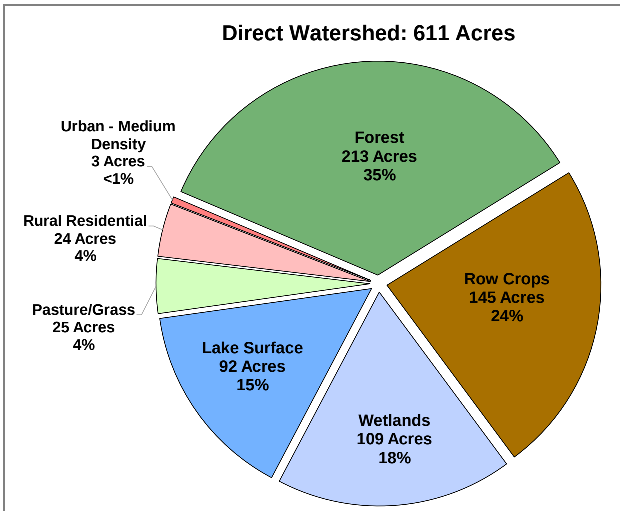


Figure 3.2-6. Grass Lake direct watershed proportion of land cover types. Based upon National Land Cover Database (USGS, 2019).

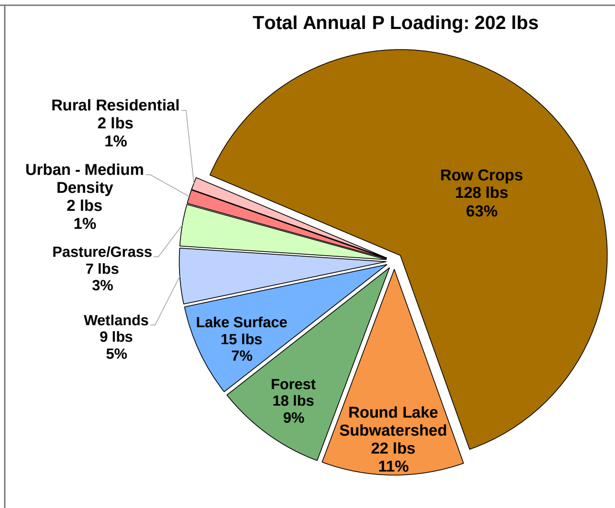


Figure 3.2-7. Grass Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 25 μg/L, which is only slightly higher than the measured growing season average total phosphorus concentration of 17 μg/L. The difference is likely brought on to a great degree by marl precipitation as described for Round Lake.

Pine Lake Watershed Assessment

Pine Lake's direct watershed is 475 acres and its total watershed, including the land first flowing through Round and Grass lakes, is approximately 1,800 acres (Figure 3.2-3). Compared to Pine Lake's surface area of 219 acres, this makes for a relatively small watershed to lake area ratio of 7:1. Wisconsin Lakes Modeling Suite (WiLMS) modeling indicates that Pine Lake's residence time, based upon surface inflow, is about a year. Of the 475-acre direct watershed, 46% is the lake surface itself, 28% is forest land, 12% is wetlands, 8% is row crops, 4% is grassland, and 2% are rural homes (Figure 3.2-8).

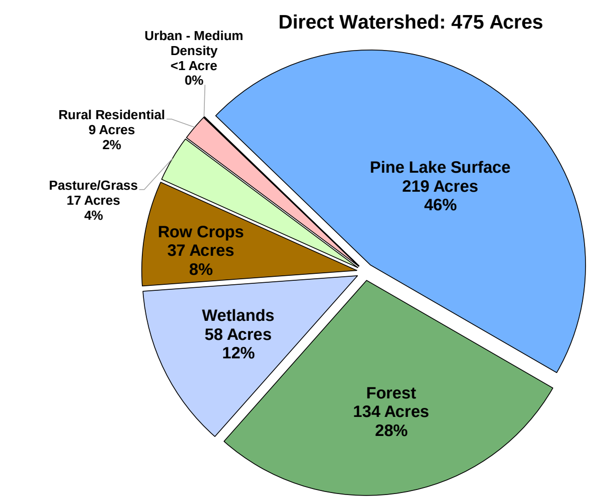


Figure 3.2-8. Pine Lake direct watershed proportion of land cover types. Based upon National Land Cover Database (USGS, 2019).

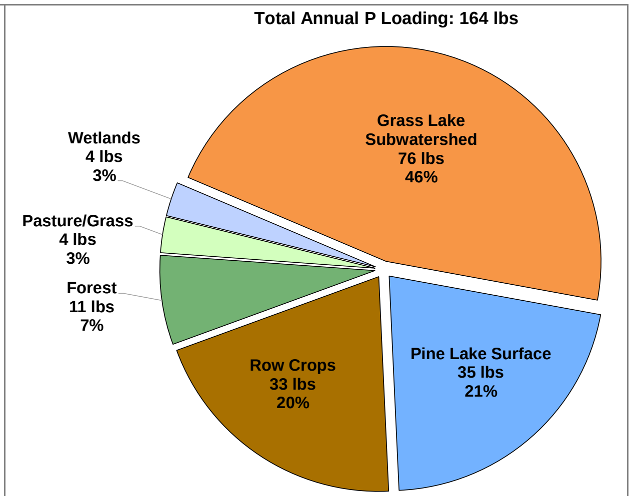


Figure 3.2-9. Pine Lake watershed phosphorus loading in pounds. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

Using the land cover types and their acreages within Pine Lake's watershed and the contributions from Grass Lake, it is estimated that the annual potential phosphorus load of Pine Lake is 164 pounds. Of that total, 76 pounds (46%) enters through Grass Lake, 35 pounds (21%) enters the lake directly through its surface, 33 pounds (20%) is derived from row crops, 11 pounds (7%) is from forest lands, 4 pounds (3%) from grasslands, and 4 pounds (2%) wetlands (Figure 3.2-9).

Using the estimated annual potential phosphorus load, WiLMS predicted an in-lake growing season average total phosphorus concentration of 13 µg/L, which is only slightly lower than the measured growing season average total phosphorus concentration of 13.6 µg/L, indicating that the model is correctly estimating phosphorus levels in the lake and there are no unknown sources of phosphorus.

3.3 Shoreland Condition

The Importance of a Lake's Shoreland Zone

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

Wisconsin's shoreland zoning rule, NR 115, sets the minimum standards for shoreland development. First adopted in 1966, the code set a deadline for county adoption of January 1, 1968. By 1971, all counties in Wisconsin had adopted the code and were administering the shoreland ordinances it specified. Interestingly, in 2007 it was noted that many (27) counties had recognized inadequacies within the 1968 ordinance and had actually adopted stricter shoreland ordinances. Revised in February of 2010, and again in October of 2014, the finalized NR 115 allowed many standards to remain the same, such as lot sizes, shoreland setbacks and buffer sizes. However, several standards changed as a result of efforts to balance public rights to lake use with private property rights. The regulation sets minimum standards for the shoreland zone, and requires all counties in the state to adopt shoreland zoning ordinances. Counties were previously able to set their own, stricter, regulations to NR 115 but as of 2015, all counties have to abide by state regulations. Minimum requirements for each of these categories are described below.

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

- Impervious surface standards: In general, the amount of impervious surface is restricted to 15% of the total lot size, on lots that are within 300 feet of the ordinary high-water mark of the waterbody. If a property owner treats their run off with some type of treatment system, they may be able to apply for an increase in their impervious surface limit, up to 30% for residential land use. Exceptions to this limit do exist if a county has designated highly-developed areas, so it is recommended to consult county-specific zoning regulations for this standard.

- Nonconforming structures: Nonconforming structures are structures that were lawfully placed when constructed but do not comply with distance of water setback. Originally, structures within 75 ft of the shoreline had limitations on structural repair and expansion. Language in NR-115 allows construction projects on structures within 75 feet. Other specifications must be met as well, and local zoning regulations should be referenced.

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

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

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

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

National Lakes Assessment

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

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

Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat*".

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

Native Species Enhancement

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

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

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

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

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.3-1).

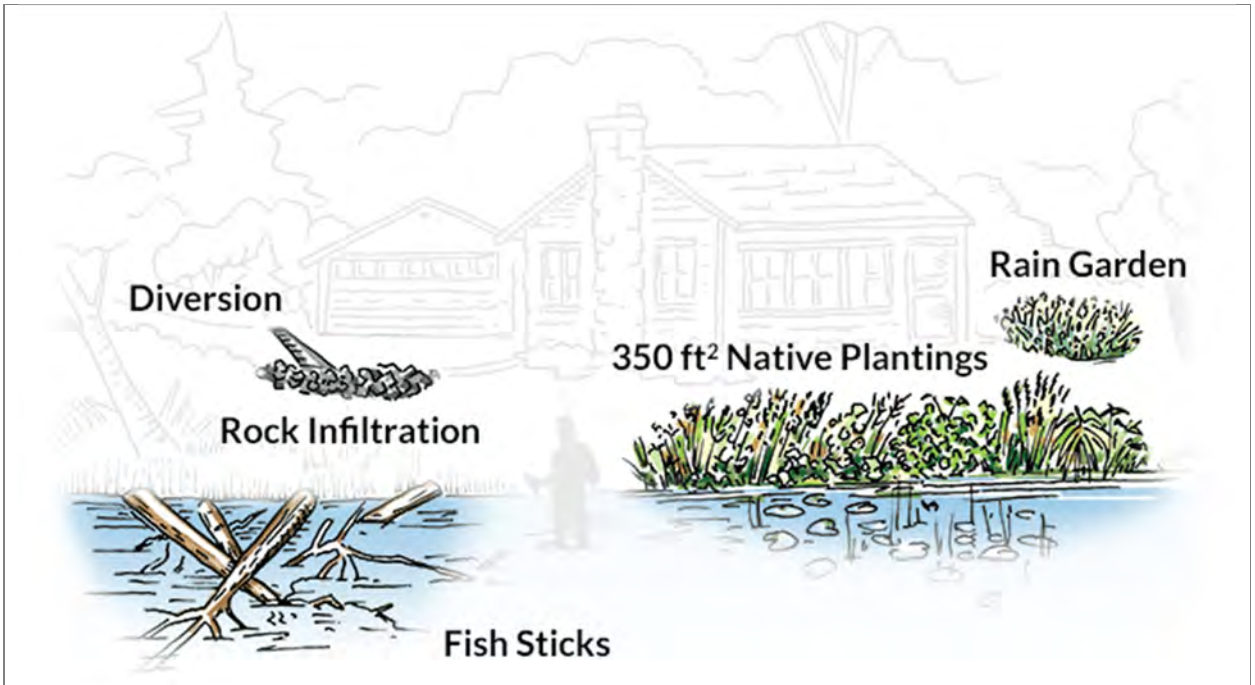


Figure 3.3-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

- Rain Gardens: This upland best practice consists of a landscaped and vegetated shallow depression aimed at capturing water runoff and allowing it to infiltrate into the soil.
- Rock Infiltration: This upland best practice is an excavated pit or trench, filled with rock, that encourages water to infiltrate into the soil. These practices are strategically placed at along a roof line or the downward sloping area of a driveway.
- Diversion: This best practice can occur in the transition or upland zone. These practices use berms, trenches, and/or treated lumber to redirect water that would otherwise move downhill into a lake. Water diversions may direct water into a Rock Infiltration or Rain Garden to provide the greatest reductions in runoff volumes.
- Native Plantings: This best practice aims to installing native plants within at least 350 square-foot shoreland transition area. This will slow runoff water and provide valuable habitat. One native planting per property per year is eligible.
- Fish Sticks: These in-lake best practices (not eligible for rivers) are woody habitat structures that provide feeding, breeding, and nesting areas for wildlife. Fish sticks consist of multiple whole trees grouped together and anchored to the shore. Trees are not felled from the shoreline, as existing trees are valuable in place, but brought from a short distance or dragged across the ice. In order for this practice to be eligible, an existing vegetated buffer or pledge to install one is required.

The Healthy Lakes and Rivers Grant Program allows partial cost coverage for implementing best practices. Competitive grants are available to eligible applicants such as lake associations and lake districts. The program allows a 75% state cost share up to $1,000 per practice. Multiple practices can be included per grant application, with a $25,000 maximum award per year. Eligible projects need to be on shoreland properties within 1,000 feet of a lake or 300 feet from a river. The landowner must sign a Conservation Commitment pledge to leave the practice in place and provide continued maintenance for 10 years. More information on this program can be found here:

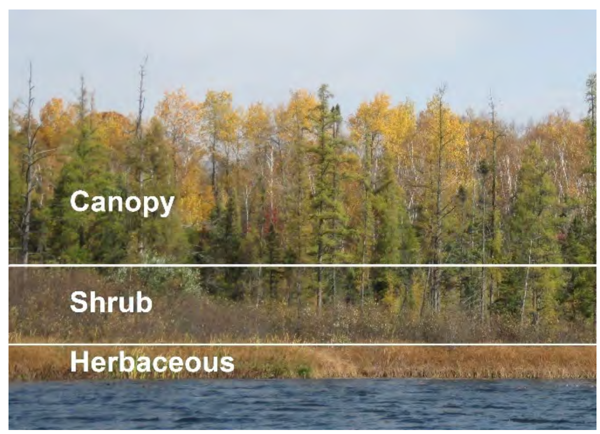
https://healthylakeswi.com/

It is important to note that this grant program is intentionally designed for relatively simple, low-cost, and shovel-ready projects, limiting 10% of the grant award for technical assistance. Larger and more complex projects, especially those that require engineering design components may seek alternative funding sources potentially through the County. Small-Scale Lake Planning Grants can provide up to $3,000 to help build a Healthy Lakes and Rivers project. Eligible expenses in this grant program are surveys, planning, and design.

Cloverleaf Lakes Shoreland Zone Condition

Shoreland Development

The entire shoreline of Round, Grass, and Pine Lakes was surveyed in June of 2020 by the Fox-Wolf Watershed Alliance. A draft WDNR Lake Shoreland & Shallows Habitat Monitoring Field Protocol (WDNR, Lake Shoreland & Shallows Habitat Monitoring Field Protocol 2020) was utilized to evaluate the shoreland zone on a parcel-by-parcel basis beginning at the estimated high-water level mark and extending inland 35 feet. The full report of the assessment, including maps and complete survey methodology, can be found in Appendix D. The main takeaway from the study is that the Cloverleaf Lakes, like many other lakes, is in need of shoreline restoration. Increased plantings within the buffer zone will help increase infiltration and decrease runoff into the lakes. More information about possible funding assistance to complete restoration projects can be found on page 21 of the report.



Photograph 3.3-3. Example of canopy, shrub and herbaceous layers.

While producing a completely natural shoreland 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. Thirty-seven percent of lawns on the Cloverleaf Lakes were categorized as "poor", meaning they are too manicured and unnatural. Manicured Lawns also attract geese which can be a nuisance. 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. And, allowing tree falls and other natural habitat features to remain along a shoreline may result not only in reducing shoreline erosion, but creating wildlife habitat also.

Coarse Woody Habitat

As part of the shoreland condition assessment, the Cloverleaf Lakes were also surveyed to determine the extent of their coarse woody habitat. Coarse woody habitat greater than 4 inches in diameter was identified and classified by three categories: branches (no branches, few branches, trees with full crown), if it touches shore, and if it is in the water. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey et al. 2005). During this survey, 165 total pieces of coarse woody habitat were observed. Most of the woody habitat was observed along the shores of Gibson Island. Information regarding funding assistance for increasing coarse woody habitat, as well as a map of current woody habitat locations, can be found on page 20 of the report in Appendix D.

Cloverleaf Lakes Sanitary District

The Cloverleaf Lakes Sanitary District #1 was created in 1982 to provide public sewer services to people living around the Cloverleaf Lakes and Long Lake in the Town of Belle Plaine (Figure 3.3-2). All Cloverleaf Lakes riparian properties are connected to the municipal sewer system, which ensures that all onsite wastewater is properly treated before discharged into the environment.

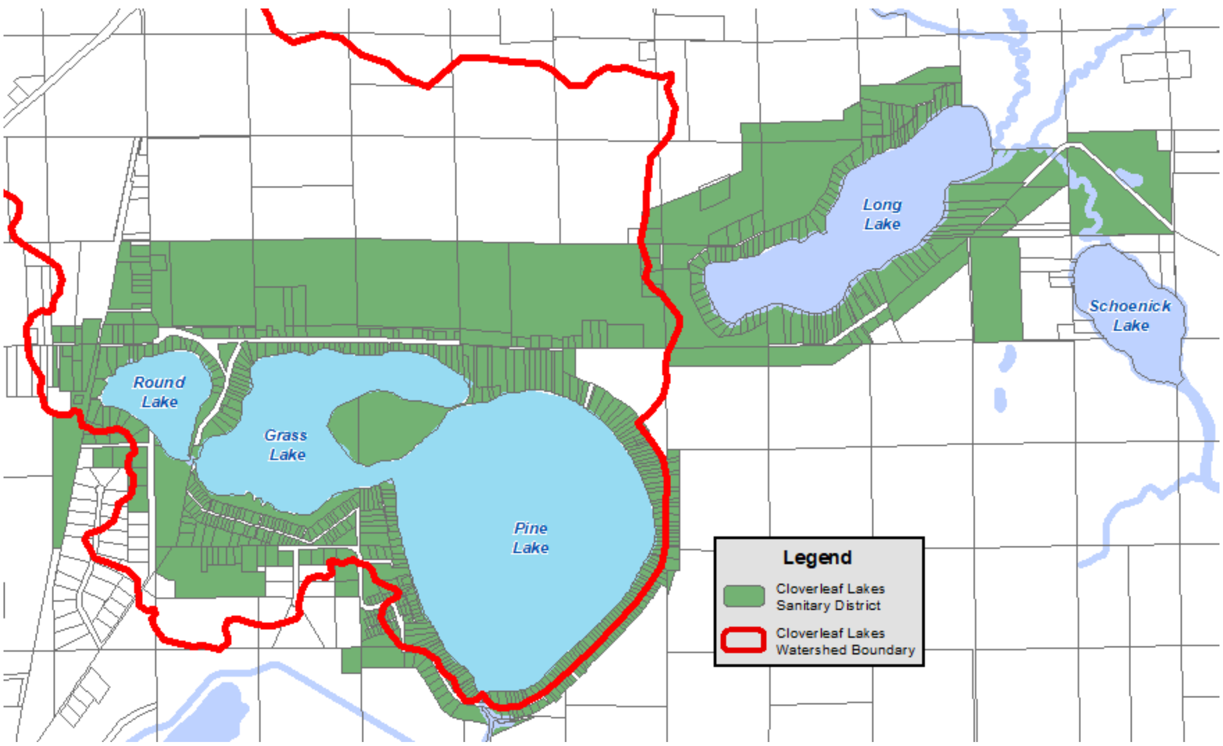


Figure 3.3-2. Cloverleaf Lakes Sanitary District #1.

3.4 Aquatic Plants

Introduction

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

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

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

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

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

Aquatic Plant Management and Protection

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

Important Note:
Even though some of these techniques are not applicable to the Cloverleaf Lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques that are applicable to the Cloverleaf Lakes are discussed in the 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 (Hand-Harvesting & DASH)

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.

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

Manual removal or hand-harvesting of aquatic invasive species has gained favor in recent years as an alternative to herbicide control programs. Professional hand-harvesting firms can be contracted for these efforts and can either use basic snorkeling or scuba divers, whereas others might employ the use of a Diver Assisted Suction Harvest (DASH) which involves divers removing plants and feeding them into a suctioned hose for delivery to the deck of the harvesting vessel. The DASH methodology is considered a form of mechanical harvesting and thus requires a WDNR approved permit. DASH is thought to be more efficient in removing target plants than divers alone and is believed to limit fragmentation during the harvesting process.

Cost

Contracting aquatic invasive species removal by third-party firm can cost approximately $1,500 per day for traditional hand-harvesting methods whereas the costs can be closer to $2,500 when DASH technology is used. Additional disposal, travel, and permitting fees may also apply.

Advantages	***Disadvantages***
• Very cost effective for clearing areas around docks, piers, and swimming areas. • Relatively environmentally safe if large-scale efforts are conducted after June 15th.to correspond with fish spawning • 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.

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.

Mechanical Harvesting


Photograph 3.4-3. Mechanical harvester.

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

Cost

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

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

Herbicide Treatment

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

Photograph 3.4-4. Liquid herbicide application. Photo credit: Amy Kay, Clarke.

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. Table 3.4-1 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.

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.

Table 3.4.1. Common herbicides used for aquatic plant management.

	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; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen -benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with 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

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

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

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

Cost

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

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

Biological Controls

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

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

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1,000 or more.

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

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

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

Cost

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

Advantages	***Disadvantages***
• Extremely inexpensive control method. • Once released, considerably less effort than other control methods is required. • Augmenting populations may 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 emergent 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 the Cloverleaf 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 in the lakes. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed on the 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 aquatic plant 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 survey completed on the Cloverleaf 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. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

The floristic quality of a lake's aquatic plant community is calculated using its native *species richness* and their *average conservatism*. Species richness is the number of native aquatic plant species that were physically encountered on the rake during the point-intercept survey. Average conservatism is calculated by taking the sum of the coefficients of conservatism (C-values) of the native species located and dividing it by species richness. Every plant in Wisconsin has been assigned a coefficient of conservatism, ranging from 1-10, which describes the likelihood of that species being found in an undisturbed environment. Species which are more specialized and require undisturbed habitat are given higher coefficients, while species which are more tolerant of environmental disturbance have lower coefficients.

For example, algal-leaf pondweed (*Potamogeton confervoides*) is only found in nutrient-poor, acid lakes in northern Wisconsin and is prone to decline if degradation of these lakes occurs. Because of algal-leaf pondweed's special requirements and sensitivity to disturbance, it has a C-value of 10. In contrast, sago pondweed (*Stuckenia pectinata*) with a C-value of 3, is tolerant of disturbance and is often found in greater abundance in degraded lakes that have higher nutrient concentrations and low water clarity. Higher average conservatism values generally indicate a healthier lake as it is able to support a greater number of environmentally-sensitive aquatic plant species. Low average conservatism values indicate a degraded environment, one that is only able to support disturbance-tolerant species.

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 (equation shown below). This assessment allows the aquatic plant community in each of the lakes to be compared to other lakes within the region and state.

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

Species Diversity

Species diversity is often confused with species richness. As defined previously, species richness is simply the number of species found within a given community. While species diversity utilizes species richness, it also takes into account evenness or the variation in abundance of the individual species within the community. For example, a lake with 10 aquatic plant species that had relatively similar abundances within the community would be more diverse than another lake with 10 aquatic plant species were 50% of the community was comprised of just one or two species.

An aquatic system with high species diversity is 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. A lake with a diverse plant community may also better suited to compete against exotic infestations than a lake with a lower diversity. However, in a recent study of 1,100 Minnesota lakes, researchers concluded that more diverse communities were not more resistant or resilient to invaders (Muthukrishnan, Davis, Jordan, & Forester, 2018). The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from the Cloverleaf Lakes is compared to data collected by Onterra and the WDNR Science Services on 85 lakes within the North Central Hardwood Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

While the point-intercept survey is a valuable tool to understand the overall aquatic plant community of a lake, it often underrepresents the floating-leaf and emergent plant communities largely found around the margins of a lake. The emergent and floating-leaf aquatic plant community assessment is a delineation of these plant communities within each lake. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in the Cloverleaf Lakes were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Cloverleaf Lakes Aquatic Plant Survey Results

Point-intercept (PI) surveys have been completed on the Cloverleaf Lakes as a part of past projects and management. In 2010, Lake and Pond Solutions completed PI surveys on the three Cloverleaf Lakes. In 2012, 2013, 2015, and 2017-2021, Onterra completed PI surveys on the Cloverleaf Lakes, with the exception of the 2015 survey on Round Lake being conducted by the WDNR, and no survey being completed on Round Lake in 2018. All available years of data are included within some of the following chain-wide analyses, as well as within the individual lake sections at the end of this report. The point-intercept survey method as described by the 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 Cloverleaf Lakes. The sampling location spacing (resolution) and resulting total number of locations varied by lake and were created based upon guidance from the WDNR (Table 3.4-2). During the 2020 PI survey in mid-July, Onterra also completed the first emergent and floating-leaf community map for the Cloverleaf Lakes. More detailed information about this survey is given at the end of this section, while the species that were found during this survey are displayed on the 2020 species list along with the species located during the PI (Table 3.4-3). Species lists for each lake which includes all years of data can be found within the respective individual lake sections.

Table 3.4-2. Cloverleaf Lakes point-intercept resolutions.

Lake	Distance Between Sampling Points (meters)	Number of Sampling Locations
Round	25	174
Grass	40	233
Pine	47	398

During 2020, point-intercept and aquatic plant community mapping surveys were completed. Although more recent point-intercept data was collected in 2021 as part of this planning project,

Table 3.4-3 shows information from the more comprehensive survey year of 2020. During these surveys, a total of 44 species of plants were located in the Cloverleaf Lakes. Six are considered non-native, invasive species: Eurasian watermilfoil, curly-leaf pondweed, pale-yellow iris, purple loosestrife, watercress, and giant reed (also known as common reed). In 2021, an additional non-native aquatic macro-algae, starry stonewort (*Nitellopsis obtusa*) was located. These non-native species will be discussed in a subsequent section, Non-native Aquatic Plants in the Cloverleaf Lakes. Another species that was located in Round Lake, sweetflag (*Acorus calamus*), is considered non-native, but has a *naturalized* status, which means it has over time naturalized itself within native plant communities and has not shown invasive growth habits. Because of this, it will not be discussed within the subsequent non-native section.

Table 3.4-3. Aquatic plant species located in the Cloverleaf Lakes during July 2020 surveys.

Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	Growth Form	Round 2020	Grass 2020	Pine 2020
Acorus calamus	Sweetflag	Non-Native - Naturalized	N/A	E	I		
Brasenia schreberi	Watershield	Native	7	FL	I	X	I
Carex aquatilis	Long-bracted tussock sedge	Native	7	E	I	I	
Ceratophyllum demersum	Coontail	Native	3	S	X	X	X
Chara spp.	Muskgrasses	Native	7	S	X	X	X
Decodon verticillatus	Water-willow	Native	7	E		I	
Eleocharis palustris	Creeping spikerush	Native	6	E	I		
Elodea canadensis	Common waterweed	Native	3	S	X	X	X
Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A	E	I	I	I
Lemna minor	Lesser duckweed	Native	5	FF	X		
Lemna trisulca	Forked duckweed	Native	6	FF		X	
Lemna turionifera	Turion duckweed	Native	2	FF	X		
Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	E	I	I	
Myriophyllum sibiricum	Northern watermilfoil	Native	7	S			X
Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	S	X	X	X
Najas flexilis	Slender naiad	Native	6	S	X	X	X
Najas guadalupensis	Southern naiad	Native	7	S		X	X
Nasturtium officinale	Watercress	Non-Native - Invasive	N/A	S/E	X		
Nitella spp.	Stoneworts	Native	7	S	X		X
Nuphar variegata	Spatterdock	Native	6	FL	X	X	I
Nymphaea odorata	White water lily	Native	6	FL	X	X	I
Phragmites australis subsp. australis	Giant reed	Non-Native - Invasive	N/A	E	I	I	
Pontederia cordata	Pickerelweed	Native	9	E	I	I	
Potamogeton amplifolius	Large-leaf pondweed	Native	7	S	X	X	
Potamogeton berchtoldii	Slender pondweed	Native	7	S	X		
Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	S	X	I	X
Potamogeton friesii	Fries' pondweed	Native	8	S			X
Potamogeton gramineus	Variable-leaf pondweed	Native	7	S		X	X
Potamogeton illinoensis	Illinois pondweed	Native	6	S	X	X	X
Potamogeton natans	Floating-leaf pondweed	Native	5	S		X	
Potamogeton pusillus	Small pondweed	Native	7	S		X	
Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	S	X	X	X
Potamogeton strictifolius	Stiff pondweed	Native	8	S	X		
Potamogeton zosteriformis	Flat-stem pondweed	Native	6	S	X	X	X
Ranunculus aquatilis	White water crowfoot	Native	8	S	X		
Sagittaria latifolia	Common arrowhead	Native	3	E	I		
Schoenoplectus acutus	Hardstem bulrush	Native	5	E	X	X	I
Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	E	I	I	
Spirodela polyrhiza	Greater duckweed	Native	5	FF	X	X	
Stuckenia pectinata	Sago pondweed	Native	3	S	X	X	X
Typha spp.	Cattail spp.	N/A	N/A	E	I	I	
Utricularia vulgaris	Common bladderwort	Native	7	S		X	X
Vallisneria americana	Wild celery	Native	6	S	X	X	X
Wolffia spp.	Watermeal spp.	Native	N/A	FF	X		

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

In 2021, aquatic plants were found growing out to a maximum depth of 17 feet in Round Lake, 17 feet in Grass Lake, and 18 feet in Pine Lake. Over the survey years, the maximum depth of plant growth has been relatively similar on a lake-by-lake basis, fluctuating by 5 feet in Grass Lake and 3 feet in Pine Lake (Figure 3.4-2). Round Lake shows a bit wider range of 8 feet, with 2021 having the shallowest depth of plants recorded across survey years. Water clarity is typically the driver of the maximum depth that plants can grow at, as some plants require wavelengths of light that get filtered out with increased color, suspended solids, or algae growth. Water level fluctuations can also impact the maximum depth at which plants grow, as the littoral zone shifts.

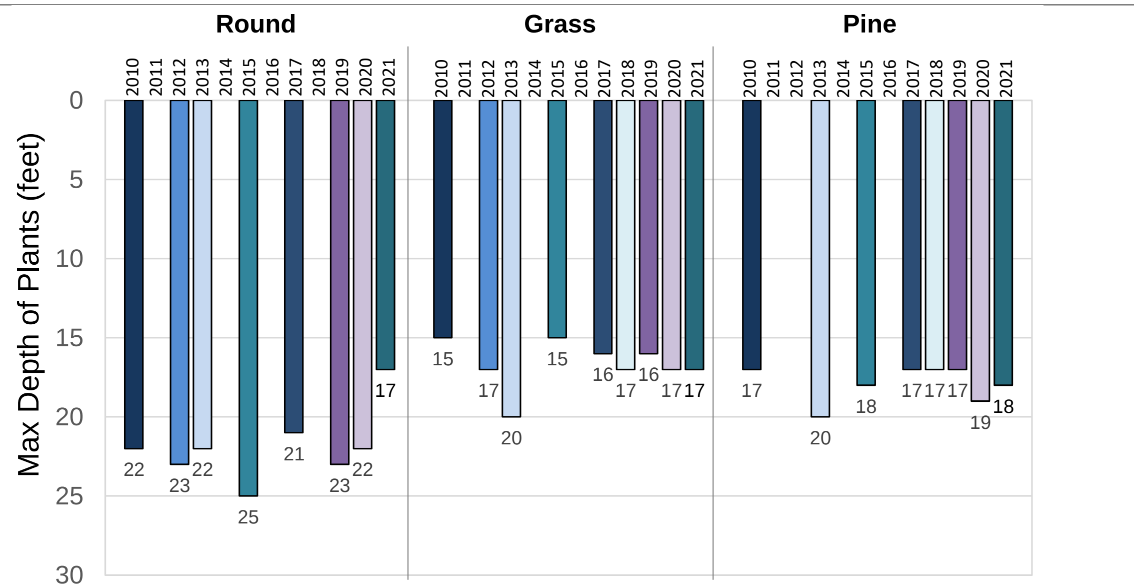


Figure 3.4-2. Maximum depth at which aquatic plants were found growing in the Cloverleaf Lakes. Created using data from the aquatic plant point-intercept surveys.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, and management, all of which influence aquatic plant community composition. Like terrestrial plants, aquatic plants vary in their preference for a particular substrate type; some species are usually only found growing in soft sediments, others only course substrates like sand, while some are more generalists and can be found growing in either. Lakes with varying types of substrates generally support a higher number of aquatic plant species because of the different habitat types that are available.

The sediment within littoral areas of the Cloverleaf Lakes is very conducive for supporting lush aquatic plant growth. Data from the 2021 point-intercept survey indicate that the majority of the sampling locations within the littoral zone of Round and Pine lakes contained fine organic sediment (muck). Round Lake contained 100% organic sediment, while Pine Lake contained 60% organic sediment, 39% sand, and 1% rock (Figure 3.4-3). Only Grass Lake showed a higher proportion of sand (55%), with the remainder being organic sediment. As discussed within the Water Quality Section (3.1), the Cloverleaf Lakes are classified as *marl lakes*, or lakes with alkaline, hardwater and noticeable deposits of carbonates on all substrates and in the sediments. While soft sediments usually support the highest plant biomass, the marl-based sediments in the Cloverleaf Lake are likely lacking in essential nutrients for supporting a higher rate of aquatic plant production. Marl lakes generally have low aquatic plant diversity, with most of the production occurring from a few species that are better adapted to this environment which is often limited in free carbon dioxide, phosphorus, and other nutrients that are required to sustain higher growth rates (Rich et al. 1971).

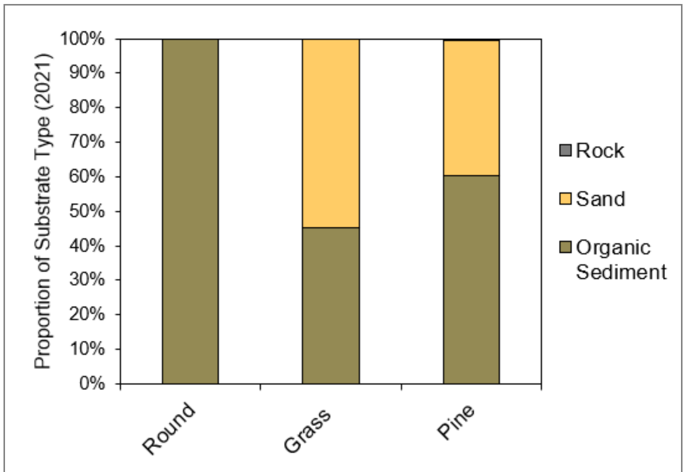


Figure 3.4-3. Cloverleaf Lakes proportion of substrate types within littoral areas. Created using data from the 2021 aquatic plant point-intercept survey.

The littoral frequency of occurrence of aquatic vegetation in 2021 ranged from 68% in Pine Lake to 90% in Round Lake (Figure 3.4-4). Figure 3.4-4 also shows a semi-quantitative analysis of the abundance of aquatic plants through looking at total rake fullness (TRF) ratings (i.e., how full of plants is the sampling rake at each location). Round Lake contained the highest proportion of the highest density rating of TRF = 3, illustrating a higher aquatic plant abundance compared to the other two lakes. More detailed information about aquatic plant biomass and changes over time can be found in each respective lake-specific section.

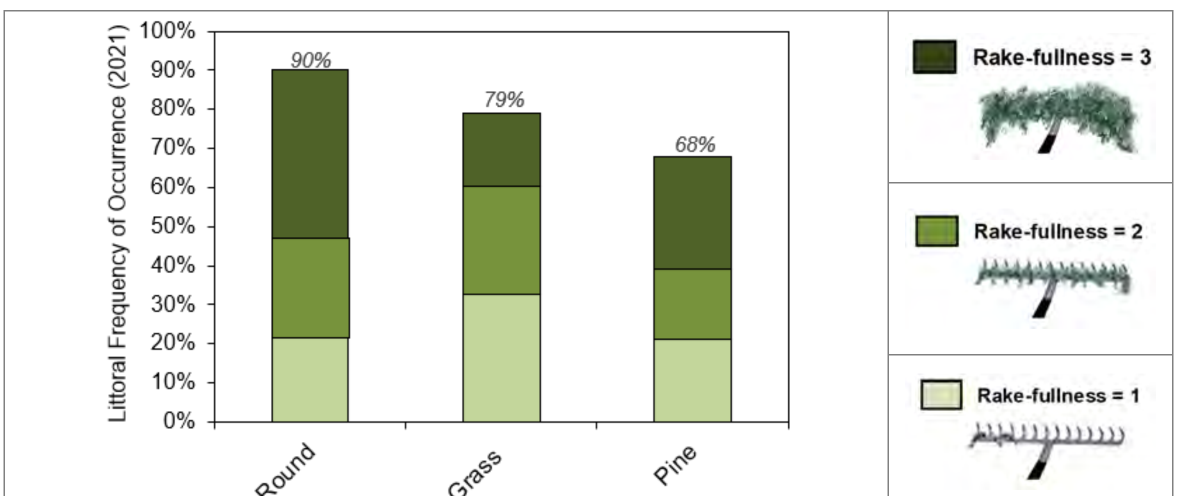


Figure 3.4-4. Cloverleaf Lakes 2021 littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF).

Grass Lake contained the highest number of native aquatic plants within the chain with 27 species being located on the rake. All three lakes contained a higher number of native plant species than both the ecoregion (16) and state (19) medians (Figure 3.4-5). The most frequently encountered species within the chain of lakes in 2021 are listed in Figure 3.4-6 below.

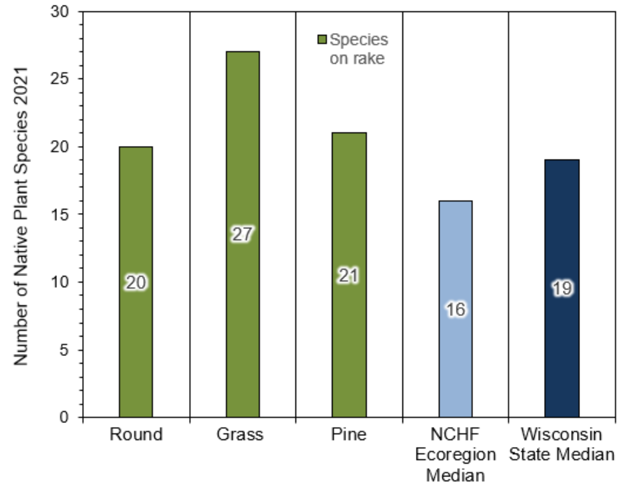


Figure 3.4-5. Species richness in the Cloverleaf Lakes. Created using data from 2020 point-intercept surveys.

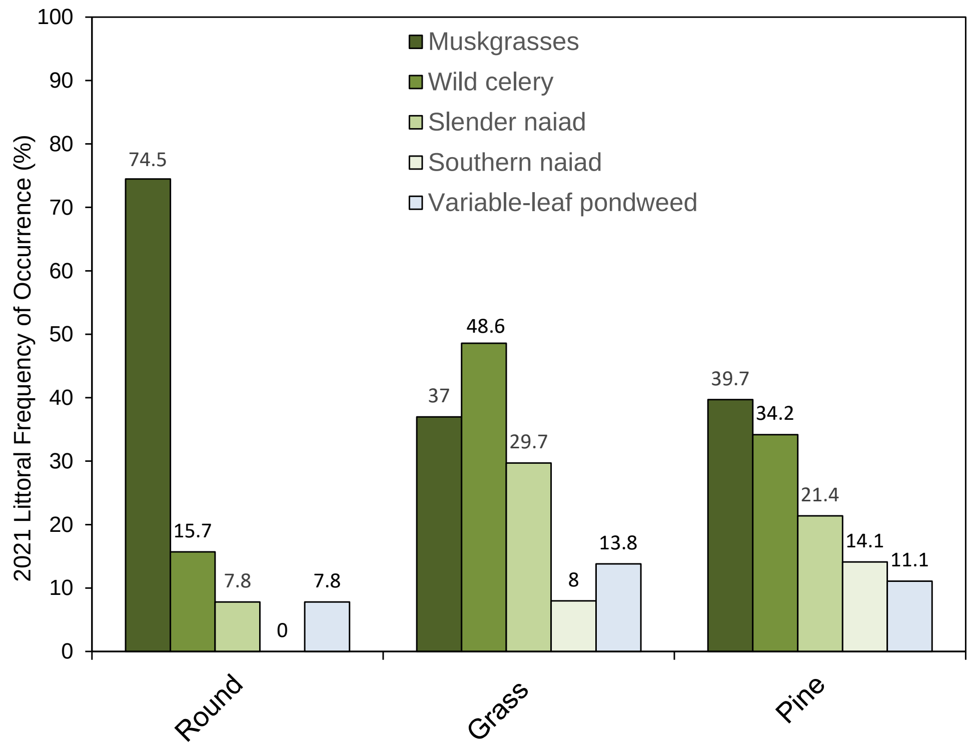
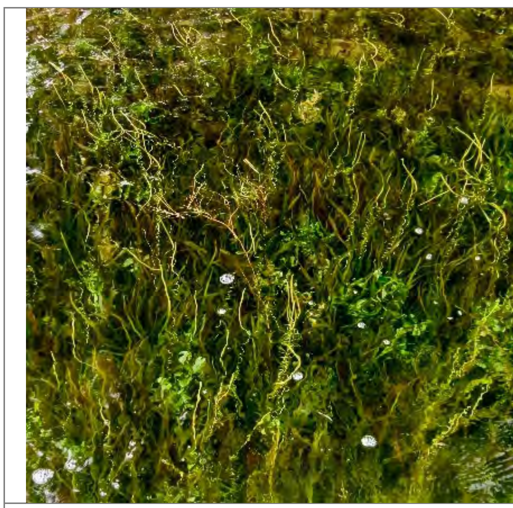


Figure 3.4-6. Frequency of occurrence at littoral depths for several Cloverleaf plant species. Created using data from 2020 aquatic plant point-intercept surveys.

Muskgrasses (*Chara* spp.) are a genus of macroalgae, of which there are ten documented species that occur in Wisconsin (Photograph 3.4-5). In 2021, muskgrasses had a very high littoral frequency of approximately 75% in Round Lake, and 37% and 40% in Grass and Pine, respectively. Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes and these macroalgae have been found to be more competitive against vascular plants (e.g., pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel & Kufel, 2002); (Wetzel, 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate encrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops, 2002). Muskgrasses can be easily identified by their strong skunk-like odor. As well as providing a food source for waterfowl, muskgrasses often serve as a sanctuary for small fish and other aquatic organisms.

Photograph 3.4-5. Aquatic macroalgae, muskgrasses (*Chara* spp.)

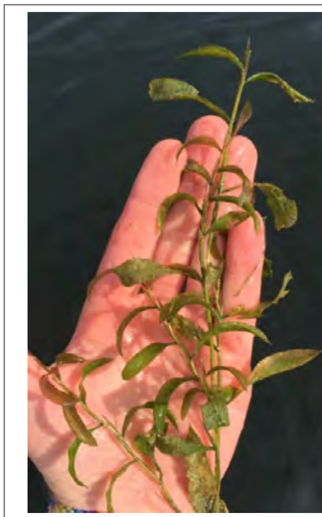
Wild celery (*Vallisneria americana*) produces long, grass-like leaves which extend in a circular fashion from a basal rosette (Photograph 3.4-7). To keep the leaves standing in the water column, lacunar cells in the leaves contain gas making them buoyant. Towards the late-summer when wild celery is at its peak growth stage, it is easily uprooted by wind and wave activity. It can then pile up on shorelines depending on the predominant wind direction. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Cloverleaf Lakes ecosystem. Wild celery was found to be the most frequently encountered aquatic plant in Grass Lake in 2021, with a littoral frequency of occurrence (LFOO) of about 49%. Pine Lake had an LFOO of about 34% for wild celery in 2021 (Figure 3.4-6).



Photograph 3.4-7. Wild celery

Photograph 3.4-8. Slender naiad (left) and southern naiad (right).

Slender naiad (*Najas flexilis*) and southern naiad (*Najas guadalupensis*) are morphologically similar species and can sometimes be difficult to differentiate in the field (Photograph 3.4-8). Both of these species were relatively common in Grass and Pine lakes, while only slender naiad was located in Round Lake in 2021. Slender naiad is an annual which produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman et al. 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Southern naiad, although native to North America, has in some lakes been observed exhibiting aggressive growth in recent years. While southern naiad provides shelter for smaller fish and invertebrates and is a food source for some duck species, it can dislodge from sediments and form surface mats that interfere with navigation, recreation, and aesthetics. This level of growth of southern naiad has not been observed in the Cloverleaf Lakes. The frequencies of these species appear to fluctuate widely from year to year in the Cloverleaf Lakes, and these changes are displayed and discussed further in the lake-specific vegetation sections.



Photograph 3.4-9. Variable-leaf pondweed

Variable-leaf pondweed (*Potamogeton gramineus*) was the fourth most common native plant in Grass Lake, with a higher LFOO (~14%) than in the other two lakes. As its name suggests, the leaves and overall size of this species can vary widely in shape and size depending on growing conditions. Variable-leaf pondweed is found throughout Wisconsin and requires higher-quality environmental conditions to persist.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. Aquatic plant populations are known to fluctuate over time in response to a number of factors including climactic conditions, water clarity, water levels, predation, and aquatic plant management activities such as herbicide treatment (Freedman & Lacoul, 2006). Adding to the complexity of factors which affect aquatic plant community dynamics, human-related disturbances such as the application of herbicides for non-native plant management, mechanical harvesting, watercraft use, and pollution runoff also affect aquatic plant community composition (Asplund & Cook, 1997) (Freedman & Lacoul, 2006).

Since 1940, the ice-out date on Pine Lake has been recorded (Figure 3.4-7). In years with a cold spring, the ice-out dates have been as late as the last week in April with the latest ice-out occurring on May 1, 2018. The earliest ice-out occurred on March 18, 1966. The length of the growing season, as influenced by the ice-out conditions could impact the aquatic plant growth in the lake.

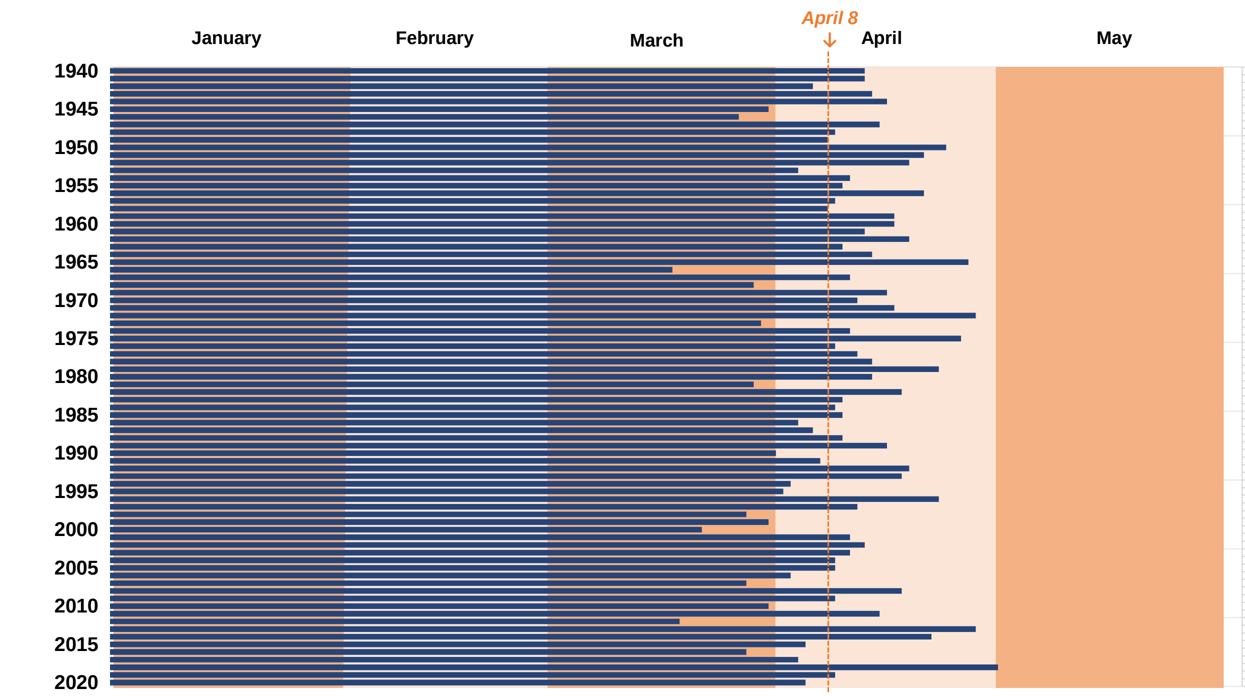


Figure 3.4-7. Pine Lake ice-out dates. Data provided by the CLPA.

As explained above in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, *relative* frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For example, while wild celery was found at about 49% of the sampling locations in Grass Lake in 2021, its relative frequency of occurrence is 22%. Explained another way, if 100 plants were randomly sampled from Grass Lake 22 of them would be wild celery. More detailed information about the relative frequency of aquatic plant species within the Cloverleaf Lakes can be found within each lake-specific section.

Figure 3.4-8 shows the average number of native plant species found per sampling site during each of the surveys on the Cloverleaf Lakes. While this number is different each year, overall, the values by lake have remained relatively stable over time for Round and Pine lakes. Grass Lake however appears to show a slight decline over time.

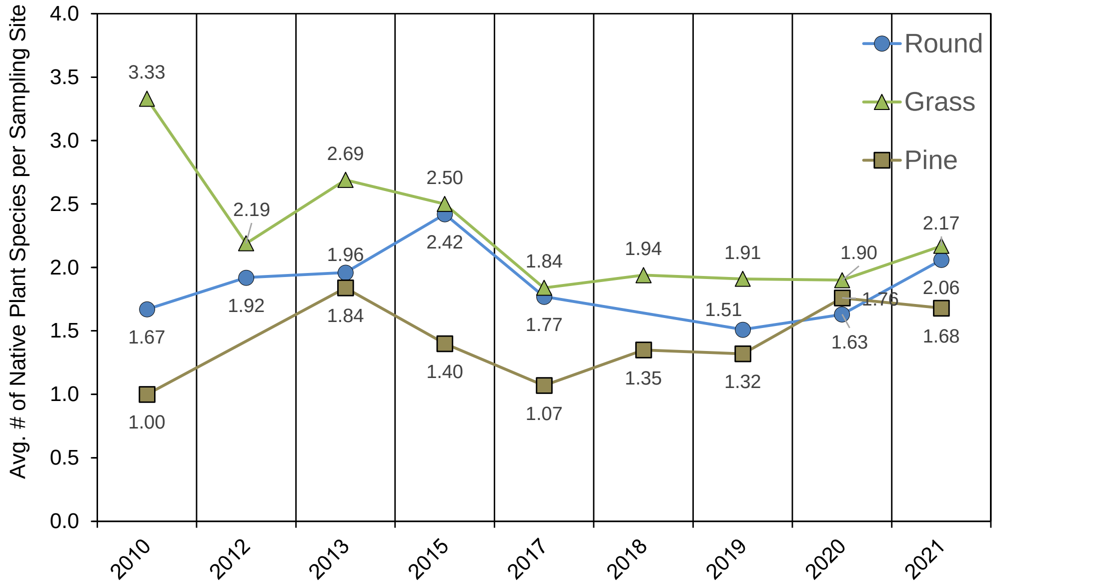


Figure 3.4-8. Average number of native species per sampling site for the Cloverleaf Lakes. Created using data from point-intercept surveys.

Some of the species present within the Cloverleaf Lakes are indicative of high-quality conditions. Data collected from the aquatic plant surveys show that the average conservatism value for Round Lake falls below both the ecoregion (5.8) and state (6.3) medians across all years. Average conservatism values for Grass and Pine lakes fall either slightly below, or somewhere in between the ecoregion and state medians across all years (Figure 3.4-9). This indicates that the majority of the plant species found in the chain are not considered sensitive to environmental disturbance and their presence signifies near average environmental conditions.

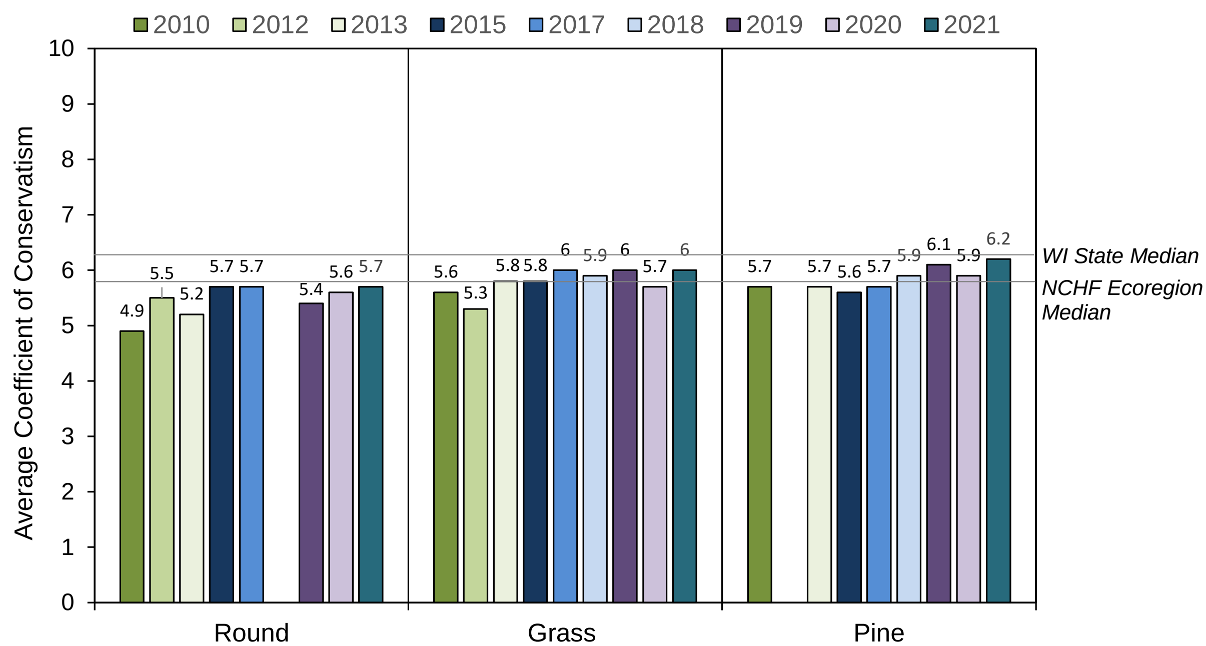


Figure 3.4-9. Average coefficient of conservatism values. NCHF= North Central Hardwood Forests Ecoregion.

Multiplying the average conservatism value by the square root of the species richness for each lake produces its Floristic Quality Index (FQI). As discussed previously, the calculations used for the FQI are based on the aquatic plant species that were encountered on the rake during the point-intercept survey and does not include incidental species. Speaking specifically in regards to 2021, Round Lake's FQI value fell in between the state and ecoregion medians, while Grass and Pine Lake fell above both medians (Figure 3.4-10). An example equation is given below for the calculation of Grass Lake's 2021 FQI value:

FQI = Average Coefficient of Conservatism (6.0) * √ Number of Native Species (27)
FQI = 31

When a lake, like Round and Grass, contains a high number of native aquatic plant species, one may assume their aquatic plant communities have high species diversity. However, as discussed earlier, species diversity is also influenced by how evenly the plant species are distributed within the community.

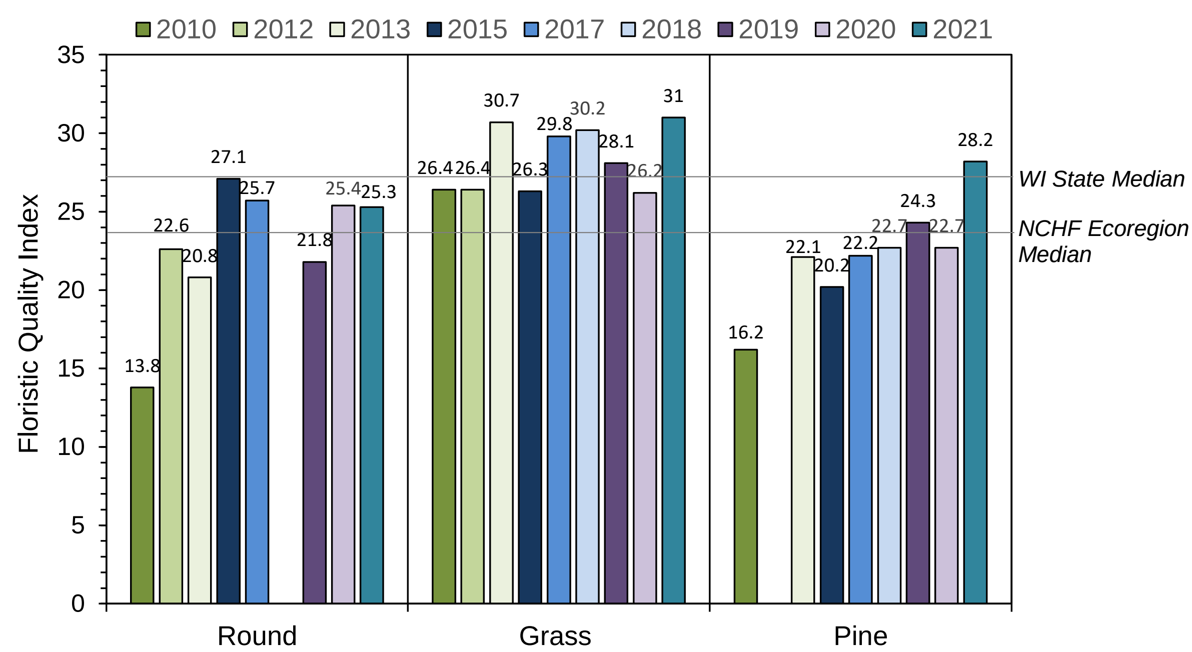


Figure 3.4-10. Cloverleaf Lakes Floristic Quality Assessment. Analysis following (Nichols, 1999) where NCHF = North Central Hardwood Forests Ecoregion.

The diversity of the aquatic plant community in the Cloverleaf Lakes has also varied across survey years (Figure 3.4-11). In 2021, the Simpson's diversity value for Round Lake fell right in between the ecoregion (0.84) and state (0.86) median values, while Grass and Pine lakes fell above both medians. Lakes with diverse aquatic plant communities have higher resilience to environmental disturbances and greater resistance to invasion by non-native plants. 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.

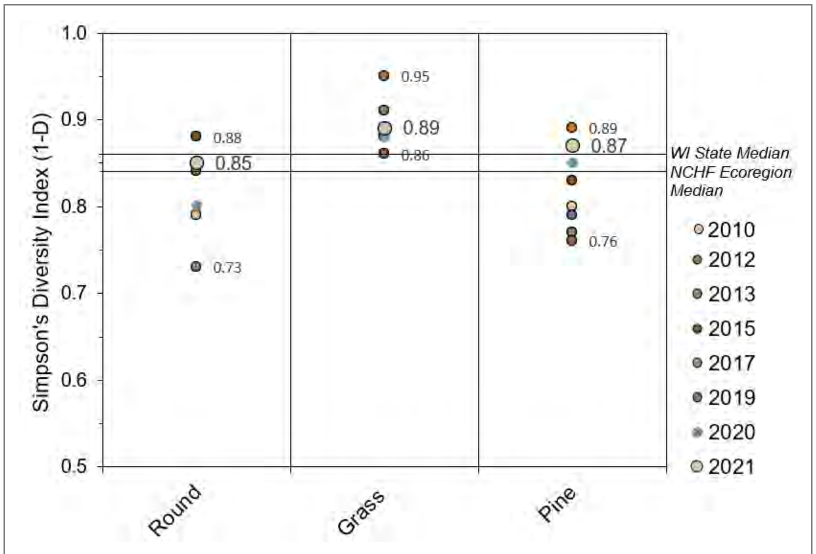


Figure 3.4-11. Species diversity index for the Cloverleaf Lakes. Created using data from the aquatic plant surveys.

The quality of the Cloverleaf Lakes' plant community is also indicated by the incidence of emergent and floating-leaf plant communities that occur in near-shore areas around the lake. The 2020 community map shows a total of approximately 25.8 acres of these types of plant communities within the three lakes (Figure 3.4-12 and Maps 2-4). Grass Lake had the highest occurrence of these community types, likely due to its more littoral nature as well as having a less uniform (round) shape than the other two lakes. These floating-leaf and emergent species provide valuable structural habitat for invertebrates, fish, and other wildlife. These communities also stabilize lake substrate and shoreland areas by dampening wave action from wind and watercraft.

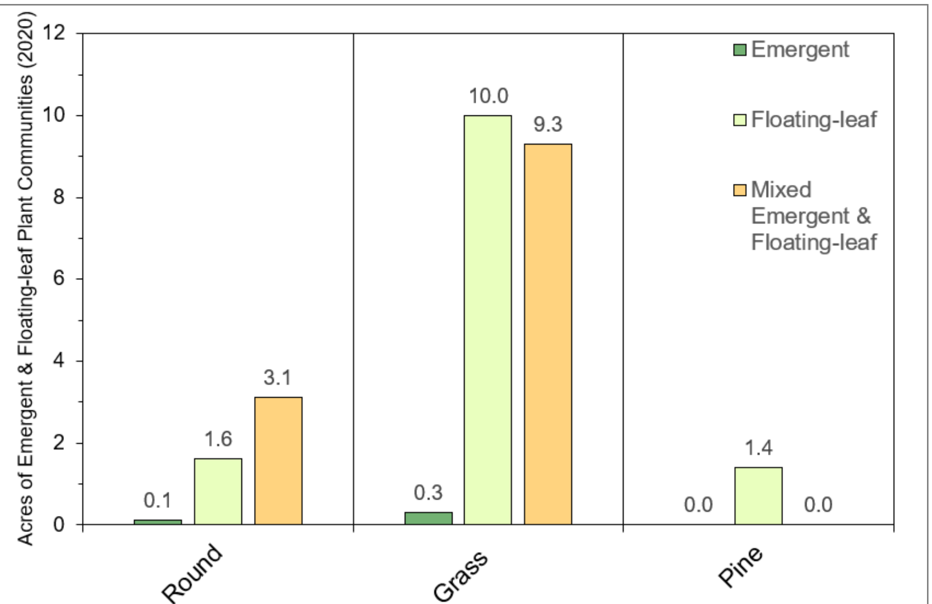


Figure 3.4-12. Cloverleaf Lakes acreage of plant community types. Created from 2020 community mapping survey data.

This 2020 community mapping survey was the first time a complete inventory, including acreage, had been recorded for the emergent and floating-leaf species within the Cloverleaf Lakes. Because the community map represents a 'snapshot' of these important plant communities, a replication of this survey in the future will provide a valuable understanding of the dynamics of these communities within the Cloverleaf Lakes. This is important because these communities are often negatively affected by recreational use and shoreland development. (Radomski & Goeman, 2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Non-Native Aquatic Plants in the Cloverleaf Lakes

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 submergent exotics, curly-leaf pondweed and Eurasian watermilfoil, and two emergent exotics, purple loosestrife and pale-yellow iris, are the primary targets of this extra attention.

Except for the emergent and floating-leaf community data discussed in Figure 3.4-12, all the aquatic plant data discussed so far was collected as part of point-intercept surveys. The subsequent materials will also incorporate data from AIS mapping surveys. Additional explanation about how these two surveys differ is discussed below.

Point-Intercept Surveys

The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations and using a rake sampler to identify all the plants at each location. The point-intercept survey can be applied at various scales. The point-intercept survey is most often applied at the whole-lake scale. These data from the Cloverleaf Lakes were discussed in the previous sub-section (Section 3.4). If a smaller area is being studied, a modified and finer-scale point-intercept sampling grid may be needed to produce a sufficient number of sampling points for comparison purposes. This sub-sample point-intercept survey methodology is often applied over management areas such as herbicide application sites. This type of sampling occurred in 2021 in association with the herbicide spot treatment in Grass Lake.

AIS Mapping Surveys

While completing the point-intercept survey, it is common to see a particular plant species, such as EWM or CLP, very near the point-intercept sampling location but not yield it on the rake sampler. Particularly in low-density colonies such as those designated by Onterra as *highly scattered* and *scattered*, large gaps between AIS plants may exist resulting in these species not being present at a particular pre-determined point-intercept sampling location in that area. While the point-intercept survey is a valuable tool to understand the overall plant population of a lake or a target area, it does not offer a full account (census) of where a particular species exists in the lake. A species-specific mapping survey, such as an EWM or CLP mapping survey, approximates a census of where that species exists in the surveyed boundaries.

Photograph 3.4-10. EWM mapping survey on a Waushara County, WI lake. Photograph credit Onterra.

During an AIS mapping survey, the entire littoral area of the lake is surveyed through visual observations from the boat (Photograph 3.4-10). Field crews supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The EWM population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies greater than 40 feet in diameter are mapped using polygons (areas) and are qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to AIS locations that were considered as *small plant colonies* (less than 40 feet in diameter), *clumps of plants*, or *single or few plants*.

Overall, each survey has its strengths and weaknesses, which is why both are utilized in different ways as part of this overall project.

Curly-leaf pondweed (*Potamogeton crispus*)

Curly-leaf pondweed (CLP) is typically at peak growth early in the growing season (Photograph 3.4-11). The advanced growth in spring gives the plant a significant head start over native vegetation. In certain lakes, CLP can become so abundant that it hampers recreational activities within the lake. In instances where large CLP populations are present, its mid-summer die-back can cause significant algal blooms spurred from the release of nutrients during the plants' decomposition (James et al. 2002). However, in some lakes, mostly in northern Wisconsin, CLP appears to integrate itself within the community without becoming a nuisance or having a measurable impact to the ecological function of the lake.

Photograph 3.4-11. Curly-leaf pondweed

The theoretical goal of CLP management is to kill the plants each year before they are able to produce and deposit new turions. Plants can be killed by physical removal (i.e., hand-pulling) or through herbicide treatment. Not all of the turions produced each year sprout new plants the following year; many lie dormant in the sediment to sprout in subsequent years. This results in a sediment turion bank being developed. Normally a control strategy for an established CLP population includes multiple years (5 or more) of controlling the same area to deplete the existing turion bank within the sediment. In instances where a large turion base may have already built up, lake managers and regulators question whether the repetitive annual herbicide strategies may be imparting more strain on the environment than the existence of the invasive species.

CLP was first verified in Round and Grass lakes in 1992 and in Pine Lake in 2010. Regular monitoring of CLP has taken place over the years and small spot-treatments for CLP control were conducted in Grass and Round lakes in 2006-2008 and 2010. CLP has shown up on the rake during point-intercept surveys, but only in very low frequencies. A number of directed Early-Season Mapping Surveys have been conducted from 2010-2019, with only low CLP occurrences being located each year. Map 5 shows the footprint of where CLP was located during the past decade within the system.

Despite being present in the system for almost three decades, CLP has not been observed at population levels that impact navigation/recreation, nor threatening the integrity of the ecosystem. Because of this, no management actions targeting CLP are being considered at this time.

Hybrid/Eurasian watermilfoil (*Myriophyllum spicatum*)

Life cycle information about Eurasian watermilfoil (EWM) was previously discussed in the Aquatic Plants Primer section. EWM was first verified in Round Lake in 1992, then in Grass and Pine lakes in 1994. It was later confirmed in 1994 through DNA analysis that the Cloverleaf Lakes contained a hybrid (HWM) variety of EWM, which is a cross between EWM and the native, northern watermilfoil (*Myriophyllum sibiricum*). More samples were sent for analysis in 2012 and 2015, again being confirmed to be HWM. The terms EWM and HWM may be used interchangeably throughout this report. Many past management actions have taken place in an effort to control EWM/HWM in the Cloverleaf Lakes. A summary of these actions can be found in Table 3.4-4 which was compiled using available past treatment reports.

The Late-Season AIS Survey is conducted late in the growing season when EWM is typically at its peak growth. Map 6 shows the entire HWM footprint from 2010-2021, including the point-based occurrences. The latest Late-Season HWM Mapping Survey occurred in mid-August of 2021 and the findings can be seen in Figure 3.4-14 and Map 7. Two small, low-density areas of HWM were mapped in Round Lake in 2021, totaling 0.4 acre. Following the 2018 herbicide treatment in Round Lake, only point-based occurrences had been mapped there in 2019 and 2020. In Pine Lake, a total of 0.02 acre of HWM was mapped, marking a decrease in HWM acreage compared to 2020. In 2021, herbicide spot-treatments occurred in Grass Lake - those HWM results will be discussed in further detail below. More detailed information about recent HWM monitoring results and management in the Cloverleaf Lakes can be found in the *2018-2020 Final AIS Monitoring & Control Strategy Assessment Report*.

Table 3.4-4. Management actions on the Cloverleaf Lakes 2004-present.

	Round	Grass	Pine	Grass & Round Treated for CLP
2004	68.0			
2005	41 acres treated/ 2 acres hand-harvested			
2006	20.0			X
2007	19.5			X
2008	5.9			X
2009	4.2		2.1	
2010	9.2			5 acres
2011	11.85			
2012	4.6	24.5	2.48	
2013		6.5	65.7	
2014				
2015	1.9		1.5	
2016	3.96	32.0	77.1	
2017				
2018	4.6	0.27		
2019		1.2	0.6	
2020	1202 lbs.			
2021		6.8		

- 2,4-D Whole-lake Herbicide Treatment
- 2,4-D Herbicide Spot-Treatment
- Fluridone Whole-lake Herbicide Treatment
- DASH/Hand-Harvesting
- Combination of Herbicides for CLP Spot-Treatment
- ProcellaCOR Spot-Treatment with Whole-Lake Potential

Using data from the point-intercept surveys that have been completed over the years on the Cloverleaf Lakes, the littoral frequency of occurrence of HWM can be compared for each of the lakes (Figure 3.4-13). The red dashed lines in the figure indicate whole-lake herbicide treatments that have taken place for the lake noted; spot-treatments are not shown. As can be seen in the figure, HWM is reduced following treatment in the lakes indicated, with a rebound

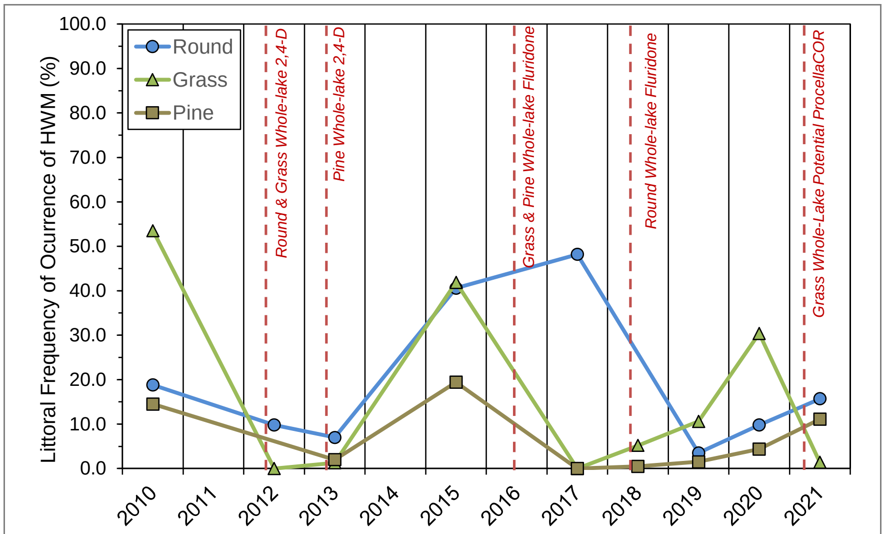


Figure 3.4-13. Littoral frequency of occurrence of EWM/HWM in the Cloverleaf Lakes. Created using data from 2010-2021 point-intercept surveys.

starting to occur only a year or two after the treatment. These rebounds appear to happen at different rates in each lake, with Round and Grass lakes reaching higher frequencies than seen in Pine Lake. Research has indicated that hybrid EWM may have a higher tolerance, or resistance, to some aquatic herbicides such as 2,4-D, which presents complications for its management.

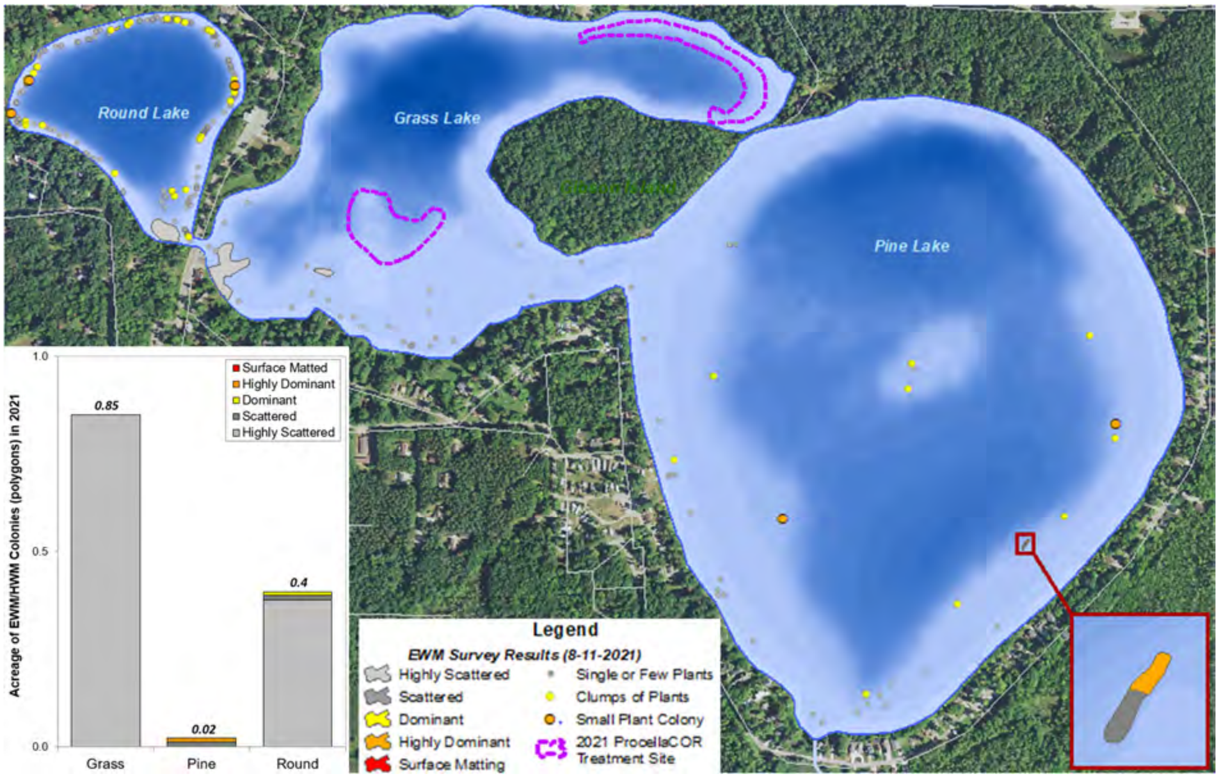


Figure 3.4-14. Late-Summer 2021 EWM/HWM mapping survey results in Cloverleaf Lakes.

WDNR Long-Term EWM Trends Monitoring Research Project

Starting in 2005, WDNR Science Services began conducting annual point-intercept aquatic plant surveys on a set of unmanaged lakes to understand how EWM populations vary over time. This was in response to commonly held beliefs of the time that once EWM becomes established in a lake, its population would continue to increase over time. This information is presented here to understand how unmanaged systems in this ecoregion compare to the Cloverleaf Lakes.

Like other aquatic plants, EWM populations are dynamic and annual changes in EWM frequency of occurrence have been documented in many lakes, including those that are not being actively managed for EWM control (no herbicide treatment or hand-harvesting program). Figure 3.4-15 shows the EWM populations of three unmanaged EWM lakes in the Northern Central Hardwood Forests ecoregion. To clarify, these lakes have not conducted herbicide treatments or any other forms of strategic EWM management. The EWM population of Montana Lake (Oconto-Marinette counties) has been variable over time, whereas the EWM population of Crystal Lake (Marquette County) has been extremely stable at around 20% during the timeframe of study. After first being detected in 2005, the EWM population of Crooked Lake (Adams County) was below 3% for at least 10 years, then increased to its highest frequency of 13.2% in 2021 after being in the lake for 16 years.

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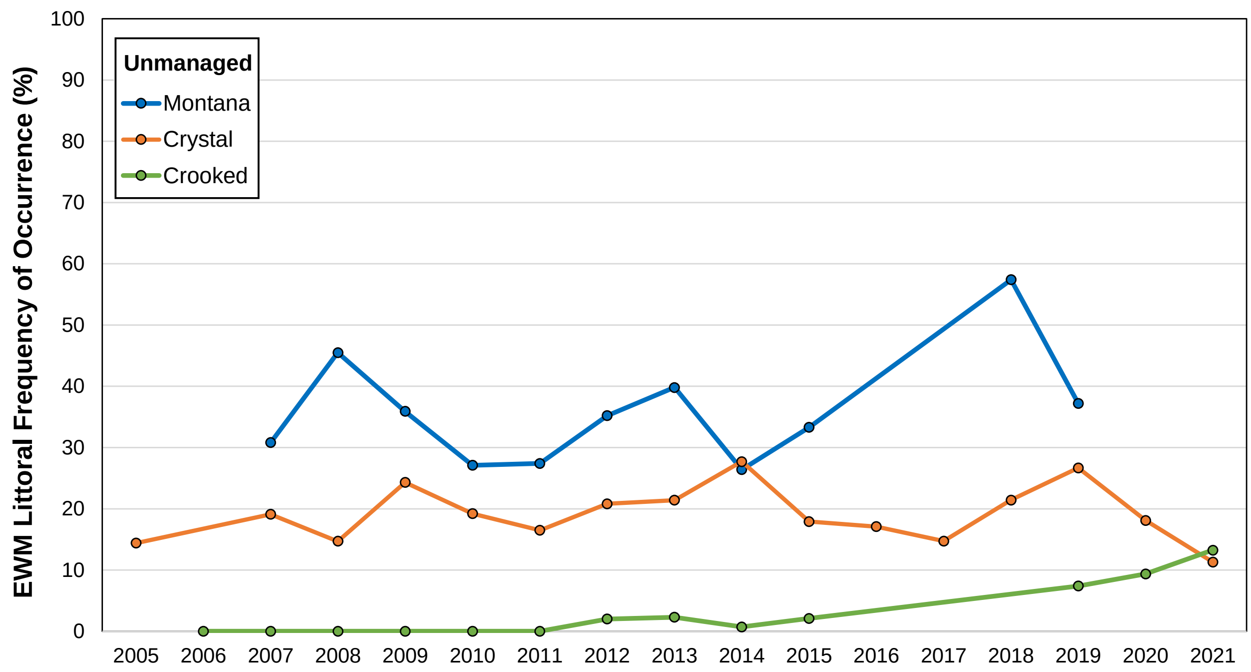


Figure 3.4-15. Littoral frequency of occurrence of Unmanaged EWM populations in the Northern Central Hardwood Forests ecoregion. Data provided by and used with permission from WDNR.

The Science Behind the "So-Called" Super Weed (Nault, 2016)

In 2015, the WDNR investigated the most recent point-intercept data from almost 400 Wisconsin Lakes that had confirmed EWM populations. These data show that approximately 65% of these lakes had EWM populations of 10% or less (Figure 3.4-16). At these low population levels, there is not likely to be impacts to recreation and navigation, nor changes in ecological function. At the time of this writing, the Cloverleaf Lakes' most recent point-intercept survey (2020) yielded HWM at 9.8% in Round Lake, 30.4% in Grass Lake, and 4.4% in Pine Lake, of the littoral sampling locations. Only approximately 15% of the lakes in this study had EWM populations of 30% or higher. This may be due to the fact that the EWM population in some lakes may never reach that level or that management activities may have been enacted to suppress the EWM population to lower levels. It also may be that once lakes reach high populations, as is currently observed in Grass Lake, aggressive management occurs to lower the population.

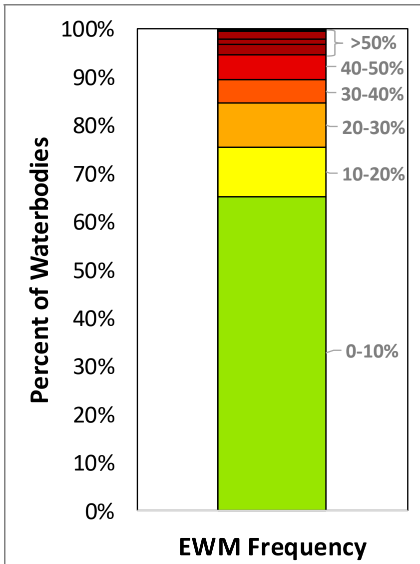


Figure 3.4-16. EWM littoral frequency of occurrence in 397 WI lakes with EWM populations. Data provided by and used with permission from WDNR.

Grass Lake 2021 ProcellaCOR Spot-treatment

The *2018-2020 Final AIS Monitoring & Control Strategy Assessment Report* (Feb 2021, Onterra) outlined a preliminary 2021 HWM management strategy that included a trial herbicide treatment in Grass Lake utilizing ProcellaCOR™, a relatively new aquatic herbicide that has shown promise in spot-treatment use scenarios in recent years in Wisconsin. During the winter of 2020-2021, the CLPA participated in discussions between Onterra ecologist/planners and the regional WDNR lake coordinator (Brenda Nordin) to develop a preliminary 2021 trial herbicide spot treatment using ProcellaCOR™ in two locations within Grass Lake. The HWM in these locations consisted of the some of the highest density colonies, and were located in high-use parts of the lake.

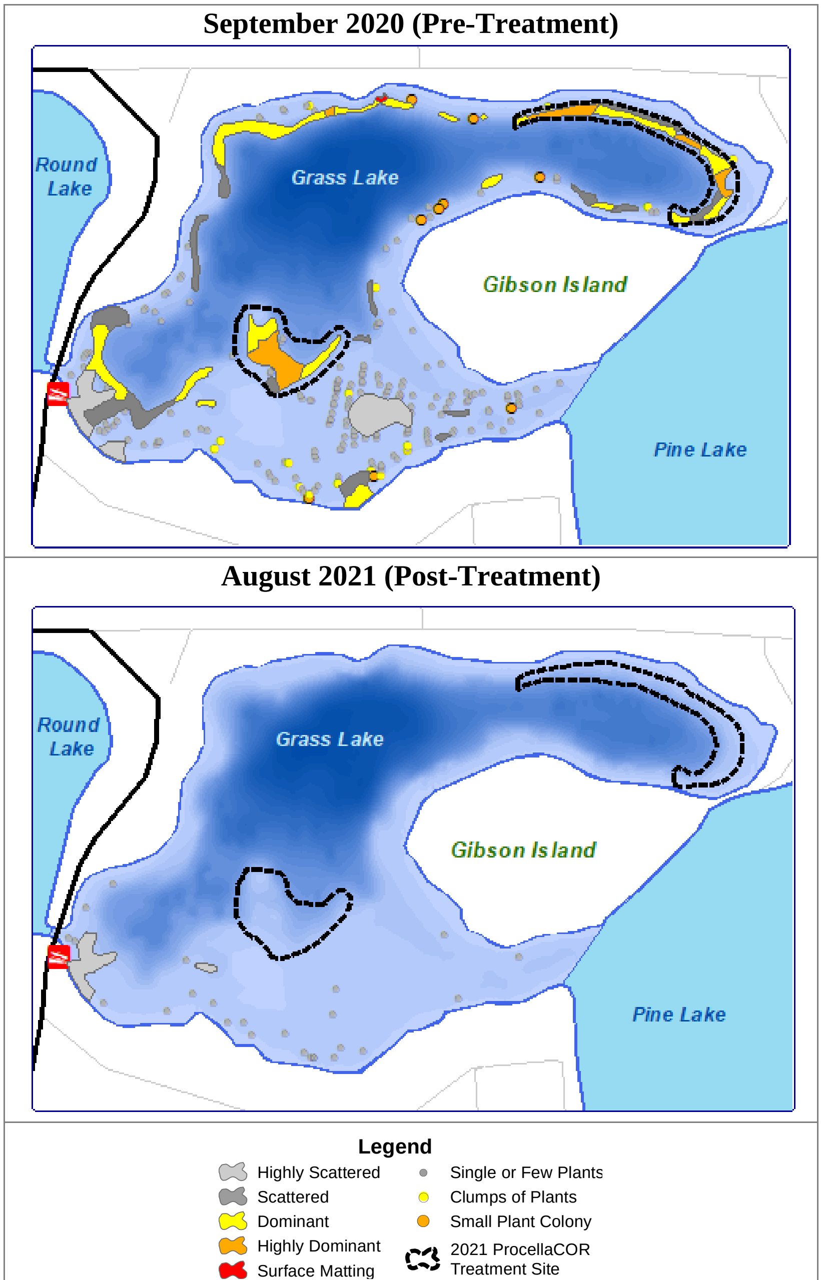


Figure 3.4-17. Eurasian watermilfoil population before (September 2020) and after (August 2021) a June 2021 herbicide treatment in Grass Lake.

Ultimately, the CLPA elected to move forward with the proposed treatment strategy which included applying ProcellaCOR to two sites totaling 6.8 acres in Grass Lake (Figure 3.4-17, top frame). Calculations indicated a potential whole-lake concentration of 0.26 ppb of the active ingredient in ProcellaCOR – florpyrauxifen-benzyl. Based on past monitoring of other treatments with this chemistry, Onterra expected some amount of HWM reductions outside of the herbicide application area, particularly adjacent to and between the two application areas.

A qualitative monitoring assessment of the herbicide treatment is made by comparing the late-season HWM mapping survey results from before and after the herbicide treatment. Figure 3.4-17 displays the HWM mapping survey results from September 2020 (pre-treatment) and August 2021 (year-of-treatment) and indicates a high level of initial HWM control. No HWM was located within the application areas or the immediate vicinity (Figure 3.4-17, bottom frame). A reduction in the lake-wide HWM population is also evident when comparing the two mapping surveys. This analysis may be replicated during 2022 to understand the year-after-treatment results.

A quantitative assessment of the 2021 herbicide treatment was completed through the completion of pre- and post-treatment sub point-intercept surveys within the two herbicide application areas. The pretreatment sub-sample point-intercept survey was completed on June 10, 2021 and the survey was replicated on August 11, 2021 in order to understand the selectivity of the herbicide treatment. A total of 71 sampling locations spaced 20 meters apart were sampled directly within the herbicide application area. Because of their morphological similarity and often difficulty in differentiating between them, the occurrences of slender and southern naiads (*Najas* spp.) were combined for this analysis.

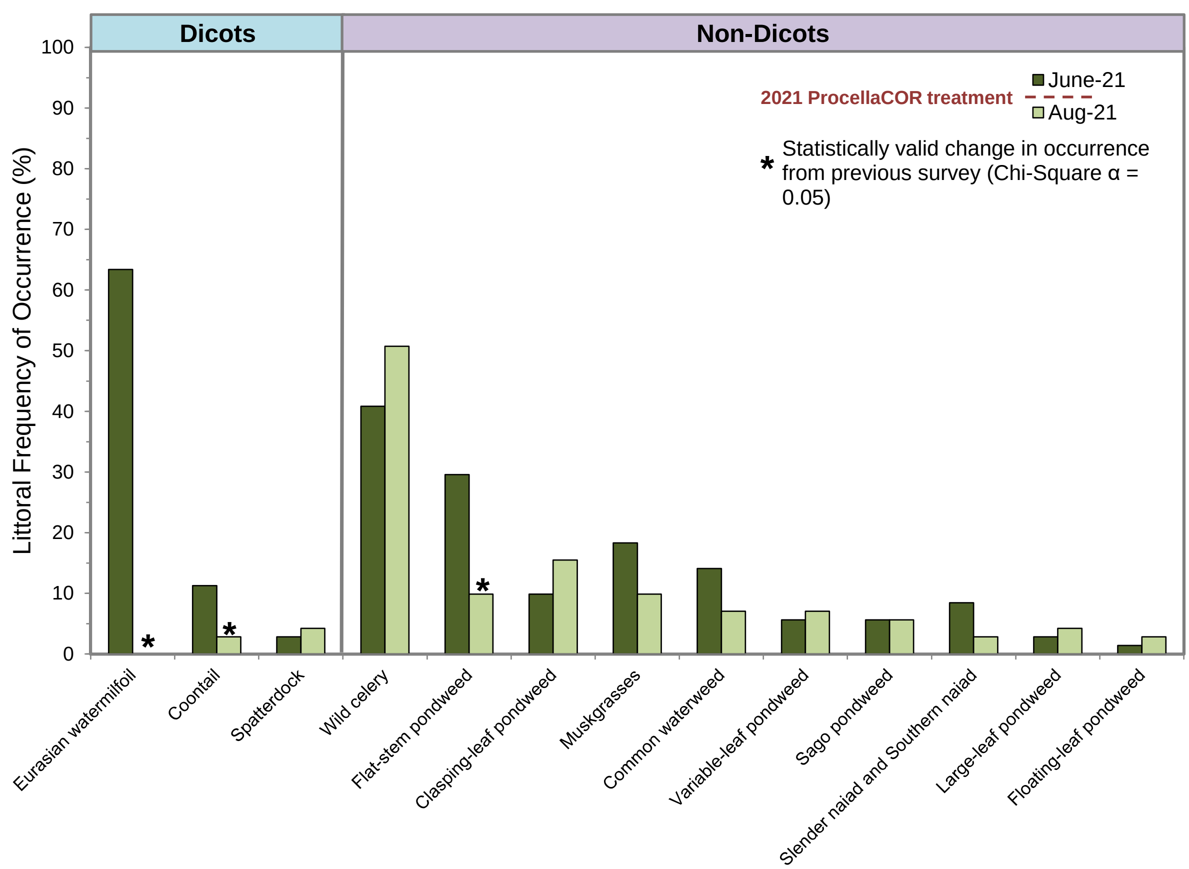


Figure 3.4-18. Littoral frequency of occurrence of aquatic plants from a sub-sample point-intercept survey collected before (June 2021) and after (August 2021) a ProcellaCOR herbicide treatment in Grass Lake. Includes all species that exhibited a 2% or greater occurrence in at least one survey. Asterisk represents statistically valid change in occurrence from previous survey. N=71

No HWM was located in the post-treatment survey compared to a 63.4% littoral frequency of occurrence documented pre-treatment (100% reduction, Figure 3.4-18). Coontail (*Ceratophyllum demersum*, -75.0%) and flat-stem pondweed (*Potamogeton zosteriformis*, -66.7%) exhibited statistically valid declines in occurrence between the pre- and post-treatment surveys. Coontail has been found to be somewhat susceptible to ProcellaCOR treatments based on monitoring that has been conducted in Wisconsin in recent years while flat-stem pondweed has not shown to be impacted in other monitoring projects. Several other native species that were present within the treatment sites did not exhibit a statistical change in occurrence between the two surveys.

Aquatic plants were also monitored on a whole-lake scale in Grass Lake during 2021 through the completion of a whole-lake point-intercept survey. An investigation into these data serves to determine the potential of impacts to the lake-wide aquatic plant population from the 2021 herbicide treatment. Coontail exhibited a statistically valid decrease in occurrence within the sub-sample point-intercept survey discussed above. The whole-lake point-intercept survey shows the population of coontail to have decreased from 4.4% in 2020 to 0.7% in 2021, an 83.7% decline (Figure 3.4-19). This decline in population between the two surveys was not statistically valid based on a chi-square analysis (a = 0.05). The 0.4% occurrence of coontail in 2021 is the lowest recorded occurrence for this species in any point-intercept survey dating back to 2010.

Flat-stem pondweed populations also exhibited a valid decrease in occurrence within the sub-sample point-intercept survey data discussed above. In the whole-lake point-intercept survey within Grass Lake, flat-stem pondweed exhibited an occurrence of 6.5% in 2021 compared to 6.7% in 2020 (Figure 3.4-19). This change in occurrence was not statistically valid.

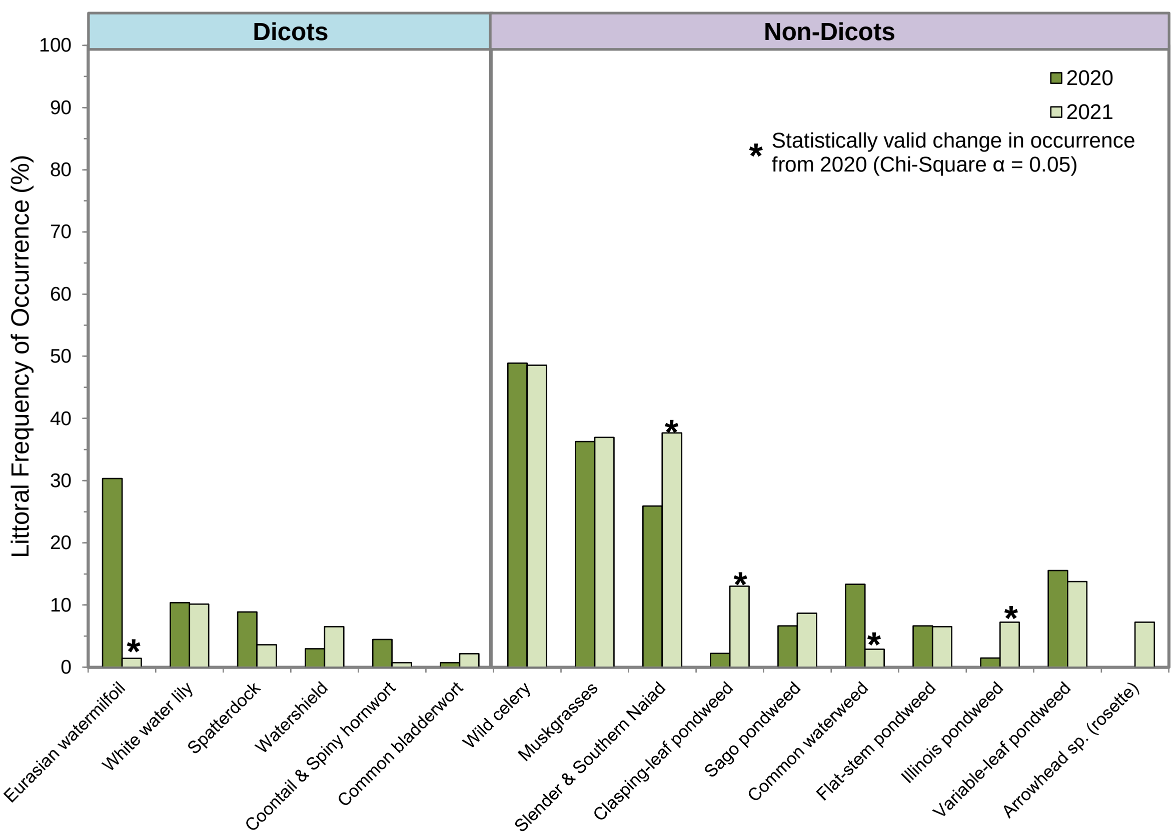


Figure 3.4-19. Littoral frequency of occurrence of aquatic plants from whole-lake point-intercept surveys in 2020 and 2021 in Grass Lake. Includes all species that exhibited a 2% or greater occurrence in at least one survey. Asterisk represents statistically valid change in occurrence from previous survey.

Common waterweed (-78.3%) was the only native species that exhibited a statistically valid decrease in occurrence between 2020-2021 in the Grass Lake whole-lake point-intercept survey (Figure 3.4-19). Within the sub-sample point-intercept survey, common waterweed decreased from a 14.1% occurrence in 2020 to 7.0% in 2021; however, this change was not statistically valid.

Three native species exhibited statistically valid increases in occurrence between 2020 and 2021 including clasping-leaf pondweed, Illinois pondweed, and the combined occurrences of slender and southern naiads (Figure 3.4-19).

Although environmental factors can naturally influence year-to-year aquatic plant growth, it is believed that the herbicide treatment was the main driver responsible for the decreased HWM population throughout much of Grass Lake. Ongoing research and case studies continue to investigate the herbicide concentrations that are measured in lakes following a treatment using ProcellaCOR to gain further understanding of the impact of lake-wide or basin-wide treatments with this chemistry. Of the approximately 20 ProcellaCOR herbicide treatments that Onterra has been monitoring since 2019, nearly all have shown impacts to EWM/HWM beyond the targeted area, similar as to what was observed following the 2021 treatment on Grass Lake.

The 2021 herbicide treatment was also accompanied with herbicide concentration monitoring to understand the concentration of the herbicide in the hours and days after application. These data were collected as planned by a trained volunteer from the CLPA and included collecting water samples from specific locations in Grass Lake at various time intervals following the treatment. The herbicide concentration monitoring plan associated with the treatment was developed by Onterra and the WDNR. Samples were collected from two sites placed directly within the herbicide application area as well as the deep hole sampling location which is located in between the two application areas. Samples were collected at different time intervals spanning three hours after treatment through seven days after treatment. Upon completion of the sampling, the samples were shipped to EPL Bio Analytical Services in Niantic, Illinois for analysis. This lab was identified by the WDNR as being able to detect the florpyrauxifen-benzyl at lower levels than the herbicide manufacturer's facility – 1 part per billion (ppb).

The EPL Lab reports the concentration in parts per billion of the initial parent active ingredient in ProcellaCOR (SX-1552) as well as an acid metabolite (SX-1552-A) which is the immediate by-product that it breaks down into. Figure 3.4-20 displays the concentrations of florpyrauxifen-benzyl from samples collected at the three monitoring locations. The application rates of the herbicide are displayed as dashed red and orange lines near the top of the graph. The concentrations of florpyrauxifen-benzyl were initially higher in samples collected at site G2 as compared to G1 (Table 3.4-5). This is likely due to the more protected nature of the B-21 application area compared to the more exposed setting within the lake at the A-21 application area. Samples collected at 3 HAT measured 4.34 ppb at site G2, compared to 0.096 ppb at the same time interval at site G1. All samples measured below 0.1 ppb by 24 HAT. Detectable levels of herbicide were present at site G1 at 96 HAT, while none was detected at site G2 at the same interval.

In an effort to understand the lake-wide herbicide concentration following dispersion and dissipation away from the herbicide application area, samples were also collected from near the center of Grass Lake at the deep hole location (site G3). Concentrations at site G3 are expected to be reflective of the lake-wide concentration following treatment. Three samples were analyzed from site G3 which were collected at 24, 48, and 96 HAT. The herbicide concentration was measured at 0.174 ppb at 24 HAT from the deep hole sampling location, which is slightly lower than the calculated potential whole-lake concentration of 0.26 ppb. Concentrations were nearly uniform between the three sampling locations at 48 HAT. Herbicide was not detected at site G3 during the last sampling interval collected at 168 HAT or 7 days after treatment.

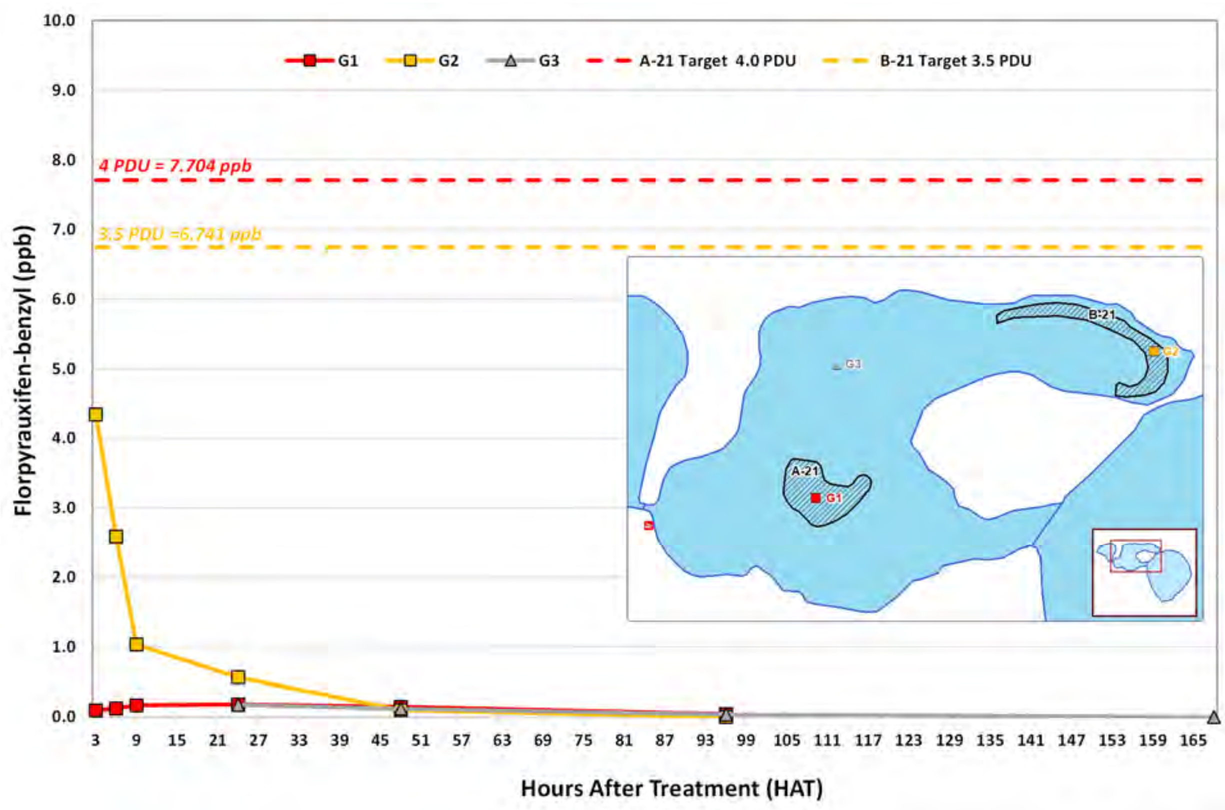


Figure 3.4-20. Florpyrauxifen-benzyl (SX-1552) concentrations measured at three monitoring locations within Grass Lake following a June 2021 ProcellaCOR herbicide treatment.

Table 3.4-5. Florpyrauxifen-benzyl (SX-1552) concentrations measured at three monitoring locations within Grass Lake following a June 2021 ProcellaCOR herbicide treatment.

Florpyrauxifen-benzyl (SX-1552) HAT (ppb)							
	3	6	9	24	48	96	168
G1	0.096	0.124	0.167	0.180	0.146	0.042	
G2	4.340	2.588	1.031	0.564	0.099	0.000	
G3				0.174	0.118	0.035	0.000

Concentrations of the acid metabolite (SX-1552-A) were also initially higher at site G2 than G1 through 24 HAT (Figure 3.4-21, and Table 3.4-6). It is important to note that the y-axis on Figure 3.4-20 differs by a full order of magnitude compared to Figure 3.4-19 (1 ppb versus 10 ppb). Concentrations at site G2 were initially near 0.3 ppb during the first 24 HAT before decreasing to approximately 0.2 ppb at 48 HAT and 96 HAT. Concentrations at site G1 were initially below 0.1 ppb through 24 HAT before increasing to 0.129 at 48 HAT and 0.146 at 96 HAT.

Samples collected at site G3 ranged from 0.050 ppb at 24 HAT increasing to 0.156 ppb at the last sampling interval collected on 168 HAT or one week after treatment. At 96 HAT, concentrations were approximately the same between site G1 and G3 whereas, concentrations were slightly higher at site G2.

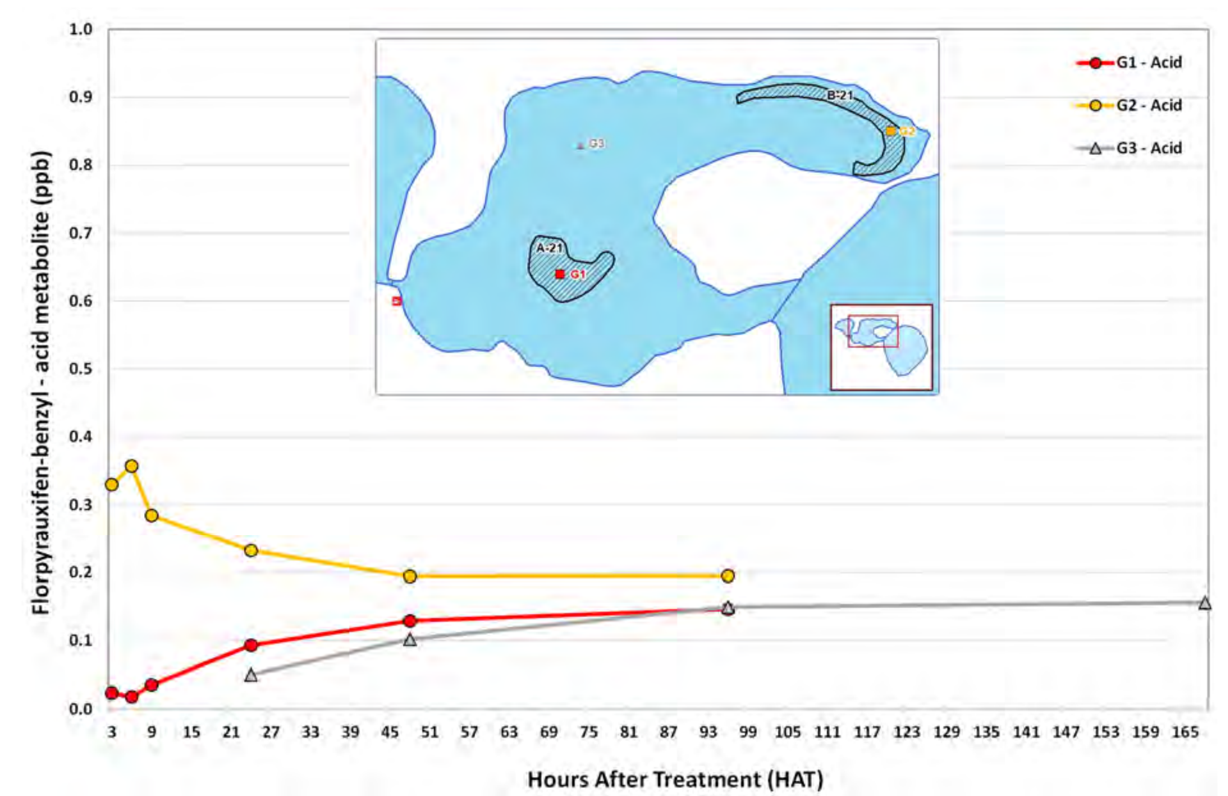


Figure 3.4-21. Florpyrauxifen-benzyl – acid metabolite (SX-1552-A) herbicide concentration monitoring results from a (ProcellaCOR™) treatment in Grass Lake in 2021. .

Table 3.4-6. Florpyrauxifen-benzyl – acid metabolite (SX-1552-A) concentrations measured at three monitoring locations within Grass Lake following a June 2021 ProcellaCOR herbicide treatment.

Florpyrauxifen-benzyl - Acid (SX-1552-A) HAT (ppb)							
	3	6	9	24	48	96	168
G1 - Acid	0.023	0.018	0.035	0.093	0.129	0.146	
G2 - Acid	0.330	0.357	0.284	0.232	0.194	0.195	
G3 - Acid				0.050	0.102	0.150	0.156

The 2021 herbicide treatment shows a high level of initial HWM control with modest detectable impacts to native species. The 2021 treatment will meet lake manager's expectations for control if the HWM population reduction is found to extend beyond the year of treatment and into year-after-treatment (2022). A replication of the late-summer HWM mapping survey and the sub point-intercept survey in 2022 would serve to provide a better understanding of the longevity of control from the 2021 treatment.

Starry Stonewort (*Nitellopsis obtusa*)

Starry stonewort (*Nitellopsis obtusa*; SSW; Photograph 3.4-12) is a non-native, invasive macroalgae that was first observed in the United States in 1978 within the St. Lawrence River. Interestingly, this species receives special protections in its native range due to low population numbers. Starry stonewort was discovered in a southeastern Wisconsin lake in 2014, and has now been verified within 14 inland lakes within five counties. Starry stonewort was also found in Sturgeon Bay in 2016 and subsequent investigations indicate this species is present in coastal areas of Lake Michigan and Green Bay.

Starry stonewort was located at six point-intercept survey sampling locations within Pine Lake during a 2021 survey conducted by Onterra staff (Figure 3.4-22). Specimens were confirmed by WDNR staff and later sent to the New York Botanical Garden for additional genetic confirmation and understanding. This finding represents the first known population of this species in Shawano County.

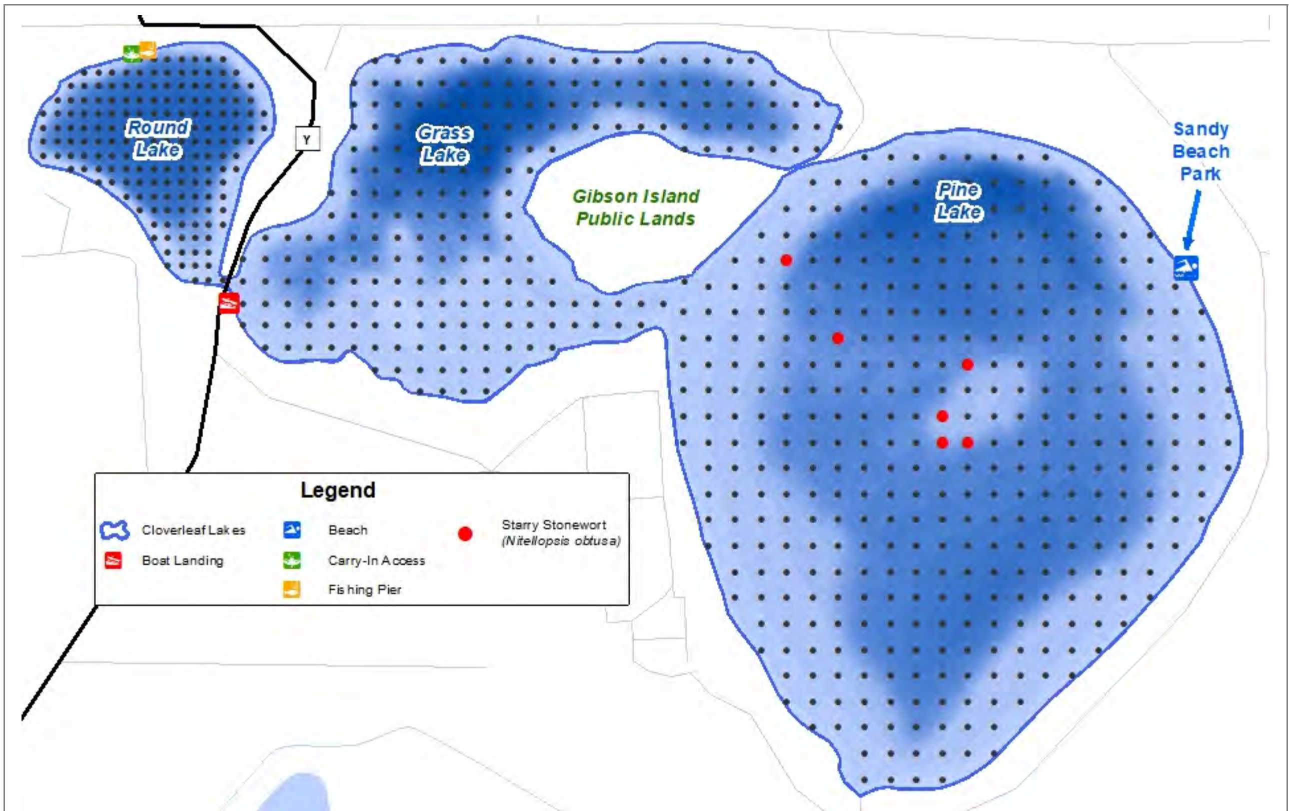
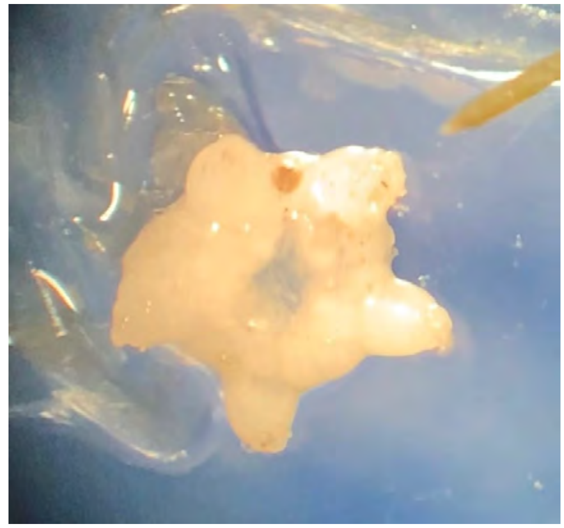


Figure 3.4-22. Locations of starry stonewort from 2021 Pine Lake point-intercept survey.

Like other invasive species, starry stonewort has been shown to dominate aquatic plant communities, in some cases growing to nuisance levels and hindering recreation. However, this species does not act invasively in all situations. Preliminary data from surveys indicate that frequency can vary across lakes, with some lakes experiencing rapid increase in SSW frequency after discovery, while other lakes have seen a much slower rate of expansion. To date, there have not been any effective chemical management strategies for SSW. Copper-based algaecides can temporarily suppress SSW populations (months), but have been shown to be ineffective at long-term control. While control methods attempted to date in Wisconsin have demonstrated a lack of control efficacy, the WDNR is working towards developing and testing new management strategies.



Photograph 3.4-12. Starry stonewort documented from Cloverleaf Lakes. Non-native, invasive macroalgae. Photo credit Onterra from Pine Lake in 2021.

Pale-yellow iris

Photograph 3.4-13. Pale-yellow iris in shoreland area. Photo credit Onterra.

Pale yellow iris (*Iris pseudacorus*) is a large, showy iris with bright yellow flowers (Photograph 3.4-13). 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 is typically in flower during the second half of June. The foliage of pale-yellow iris and northern blue flag iris (a valuable native species) is too similar to make a definitive identification based off of the foliage alone. Positive identification needs to come from the flowers or the seed pods, which develop after the flower is pollinated. Pale-yellow iris was observed in two locations around the perimeter of Round Lake and in several locations in Grass and Pine lakes during the 2020 surveys (Figure 3.4-23). It is not known exactly how long pale-yellow iris has been present in the Cloverleaf Lakes, but has been mapped by Onterra as far back as 2013 in all three lakes. As discussed in the AIS Section (3.5), the current NR 40 classification for pale-yellow iris is *restricted*. This species was first recorded in Wisconsin in 1938 and now has scattered populations throughout the state. The best control method at this time is hand-pulling, including the underground rhizomes. More information on the basis of the *restricted* classification for this species can be found in the following WDNR literature review:

https://dnr.wisconsin.gov/sites/default/files/topic/Invasives/LR_Iris_pseudacorus.pdf.

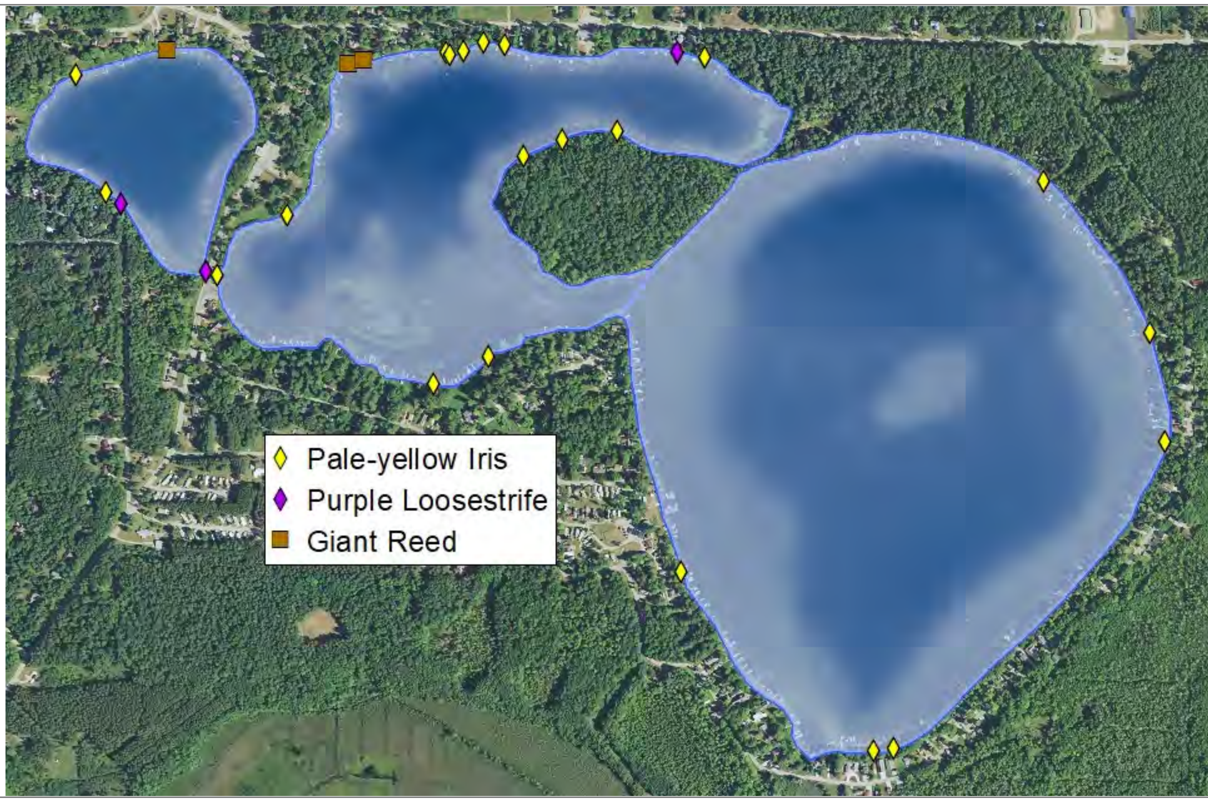


Figure 3.4-23. Locations of pale-yellow iris, purple loosestrife, and giant reed in the Cloverleaf Lakes in 2020.

Purple Loosestrife

Purple loosestrife (*Lythrum salicaria*) is a perennial herbaceous plant native to Europe that was likely brought over to North America as a garden ornamental (Photograph 3.4-14). This plant escaped from its garden landscape into wetland environments where it is able to outcompete native plants for space and resources. First detected in Wisconsin in the 1920's, it has now spread to all of the state's 72 counties. Purple loosestrife largely spreads by seed, but also can vegetatively spread from root or stem fragments. Purple loosestrife was mapped in the Cloverleaf Lakes for the first time in 2020 during the community-mapping survey, but was likely present before this year. Only a few occurrences were observed in Round and Grass lakes, while none was seen in Pine Lake (Figure 3.4-23). If purple loosestrife is to be cut or pulled, the ideal timing is from late-June to early-August when it is in flower, so easily identified, but before it produces seeds. Purple loosestrife produces many tiny seeds which can be easily spread when the plant is shaken. If removal takes place after the plant has gone to seed, the flower spikes must first be carefully bent over a bag and cut off into the bag so as not to spread the seeds. The rest of the plant can then be removed (MN DNR, 2020). At the time of this report, the current NR 40 classification for purple loosestrife is *restricted*. While populations are relatively widespread throughout the state, early detection and removal in new areas is much

Photograph 3.4-14. Purple loosestrife. Photo credit Onterra.

less expensive than letting a population spread and having to control it later by chemical or mechanical means. Due to its prolific seeding, attempts must continue to be made to control this species. Additional information can be found in the following WDNR literature review:

https://dnr.wisconsin.gov/sites/default/files/topic/Invasives/LR_Lythrum_salicaria.pdf

Giant reed

Giant reed (*Phragmites australis* subsp. *australis*) is a non-native perennial grass that can grow up to 20 feet tall. Its seeds are easily dispersed by wind and water, and it also spreads by rhizome "runners" or fragments. Once introduced, it can take over rapidly, creating dense stands that outcompete native plants. Invasive *Phragmites* can alter wetland hydrology, increase fire hazard potential, and degrade wildlife habitat due to its dense growth and monoculture tendency (USDA, 2012). While 2020 marked the first time giant reed had been formally mapped in any of the Cloverleaf Lakes, Onterra had taken photos of a small stand of it in 2017 (Photograph 3.4-15). In 2020, one occurrence of giant reed was observed in Round Lake and two occurrences were mapped in Grass Lake, with none being found in Pine Lake. Giant reed can closely resemble the native variety, common reed (*Phragmites australis* subsp. *americanus*), earlier in the growing season, so care should be taken to get a positive ID before any control measures would take place. The current NR 40 classification for giant reed is *prohibited* in western counties of the state, and *restricted* in the eastern counties; making it restricted in Shawano County. Its resiliency and size and density to which it grows makes it an important species to continue to attempt to control.

Photograph 3.4-15. Giant reed in the Cloverleaf Lakes in 2017. Photo credit Onterra.

Watercress

Watercress (*Nasturtium officinale*) is a species native to Eurasia that was intentionally introduced in the U.S. circa 1831 for cultivation, and its first sighting in the Great Lakes area was in 1847 (Cao, 2021). Watercress is a semi-aquatic perennial herb that grows along the edges of cold lakes and slow-moving streams and rivers. This species is considered naturalized throughout North America, but has been observed in some places growing invasively, even altering or blocking water flow in extreme cases. In many cases, however, watercress will have little impact on natural communities or ecosystems. Unlike the non-native species discussed above, watercress is not a restricted or regulated species in Wisconsin because of its common use as a food product. During the 2020 point-intercept survey, watercress was pulled up on the rake at one sampling point that was

Photograph 3.4-16. Watercress growing on the fringe of Round Lake in 2020. Photo credit Onterra.

closest to the small stream inlet to Round Lake. After this finding, upon closer inspection, numerous watercress plants were observed growing in the saturated sediments alongside the stream opening. If desired, hand-pulling is currently the only acceptable removal method for this species. Watercress is unregulated under NR 40 due to it being a leafy green consumed by humans. Regulated species are subject to a ban on transport, possession, and transfer, so the listing of this species could remove it as a food source; therefore, it is unlisted.

Stakeholder Survey Responses to Aquatic Vegetation within the Cloverleaf Lakes

As discussed in section 2.0, the stakeholder survey asks many questions pertaining to perception of the lakes, how they may have changed over the years, and their management. Figures 3.4-24 - 3.4-26 display the responses of Cloverleaf Lakes' stakeholders to questions regarding their level of support for different aquatic plant management actions. Most survey respondents indicated that they are in complete support of both aquatic herbicide use and hand-harvesting/DASH efforts for the management of HWM within the lakes. For those with concerns about the use of aquatic herbicides, survey respondents' greatest concerns were with potential impacts to native species and human health. For those concerned about hand-harvesting/DASH, respondents were most concerned about it not being effective, and costing too much.

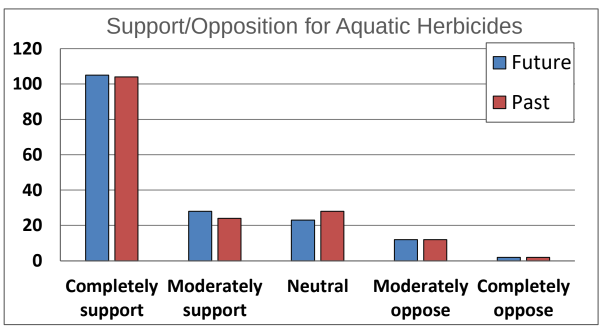


Figure 3.4-24. Stakeholder survey responses to Questions #27-28. *What is your level of support or opposition for the past and future use of aquatic herbicides to treat Eurasian watermilfoil in the Cloverleaf Lakes?*

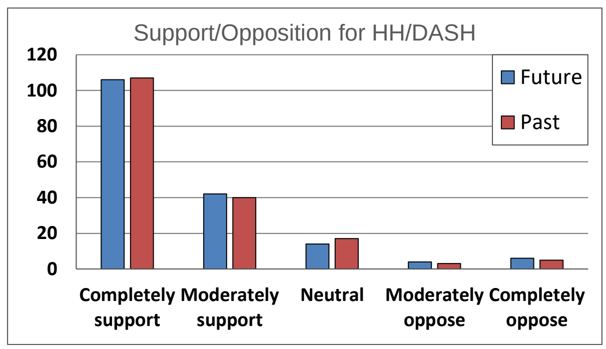


Figure 3.4-25. Stakeholder survey responses to Questions #30-31. *What is your level of support or opposition for the past and future use of hand-harvesting and DASH to target Eurasian watermilfoil in the Cloverleaf Lakes?*

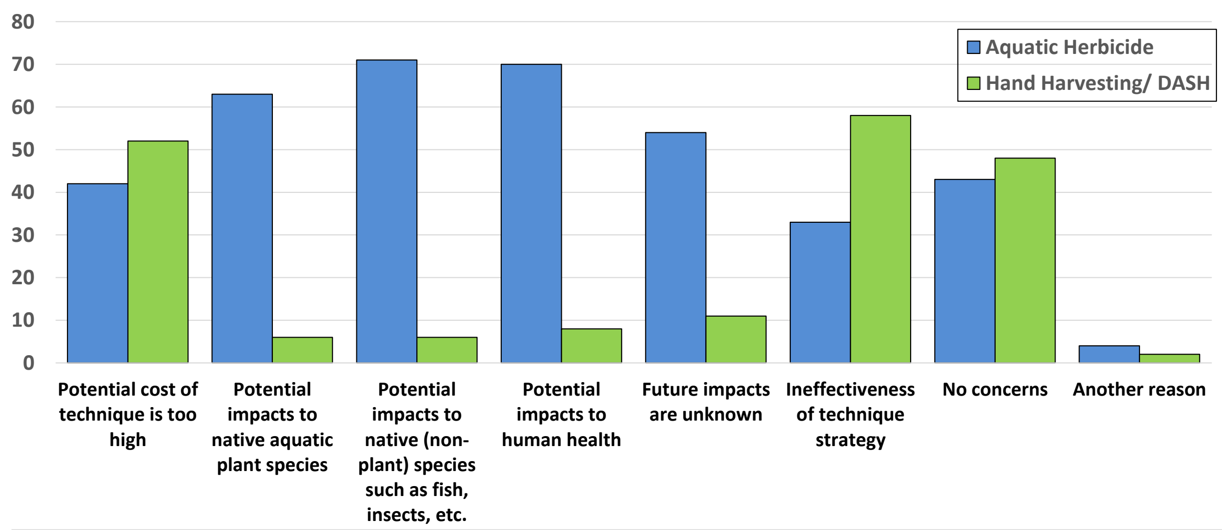


Figure 3.4-26. Stakeholder survey responses to Question #32. *What concerns, if any, do you have for the future use of aquatic herbicides and hand-harvesting/DASH to target Eurasian watermilfoil in the Cloverleaf Lakes?*

3.5 Aquatic Invasive Species in the Cloverleaf Lakes

Wisconsin Administrative Code NR 40, also known as the "invasive species rule," was put in place to identify, classify, and control invasive species in the state. Species and their corresponding classifications are recommended by a Species Assessment Group (SAG), which is an advisory group to the WI Invasive Species Council. The Council can then recommend the addition or revision of a species to the WDNR for incorporation into the list of regulated species. The SAG is made up of individuals from various sectors representing topic experts and stakeholder groups. Species are evaluated utilizing the five following assessment categories: current status and distribution, establishment potential, damage potential, socio-economic value, and prevention & control potential. Based on the assigned ratings for these categories, each species is given a classification of either prohibited, restricted, or unregulated. *Prohibited* species are ones which have been determined to have good establishment potential but have either not yet been located in the region of the listing, or exist in very low abundance. *Restricted* species on the other hand are ones which have already established themselves in the state or region of listing and are in a position to potentially cause significant environmental and/or economic harm. Non-native species which are *unregulated* does not mean they are necessarily any less invasive, but that they may have beneficial uses, or are integrated into the environment to a degree where control or eradication is no longer feasible. More information about NR 40 can be found on the following website: https://dnr.wisconsin.gov/topic/Invasives/terminology.html Onterra and the WDNR have confirmed that there are twelve AIS present in the Cloverleaf Lakes (Table 3.5-1).

Table 3.5-1. AIS present within Cloverleaf Lakes

Type	Common name	Scientific name	Location within the report	NR 40 Classification
Plants	Hybrid/Eurasian watermilfoil	*Myriophyllum spicatum*	Section 3.4 – Non-native Aquatic Plants	Restricted
	Curly-leaf pondweed	*Potamogeton crispus*	Section 3.4 – Non-native Aquatic Plants	Restricted
	Pale-yellow iris	*Iris pseudacorus*	Section 3.4 – Non-native Aquatic Plants	Restricted
	Purple loosestrife	*Lythrum salicaria*	Section 3.4 – Non-native Aquatic Plants	Restricted
	Giant Reed restricted	*Phragmites australis* subsp. *australis*	Section 3.4 – Non-native Aquatic Plants	Restricted (Prohibited in other areas of WI)
	Watercress	*Nasturtium officinale*	Section 3.4 – Non-native Aquatic Plants	Unregulated
	Starry stonewort	*Nitellopsis obtusa*	Section 3.4 – Non-native Aquatic Plants	Prohibited
Invertebrates	Zebra mussel	*Dreissena polymorpha*	Section 3.1 – Water Quality	Restricted
	Banded mystery snail	*Viviparus georgianus*	Section 3.5 - Below	Restricted
	Chinese mystery snail	*Cipangopaludina chinensis*	Section 3.5 - Below	Restricted
	Rusty crayfish	*Orconectes rusticus*	Section 3.5 - Below	Prohibited
Fish	Common carp	*Cyprinus carpio*	Section 3.5 - Below	Restricted

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in the Cloverleaf Lakes within the anonymous stakeholder survey. Figure 3.5-2 displays the aquatic invasive species that stakeholder survey respondents believe are in the Cloverleaf Lakes. Only the species actually present are discussed below or within their respective locations listed in Table 3.5-1. While it is important to recognize which species stakeholders believe to present within their lake, it is more important to share information on the species present and possible management options. More information on these invasive species or any other AIS can be found at the following links:

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

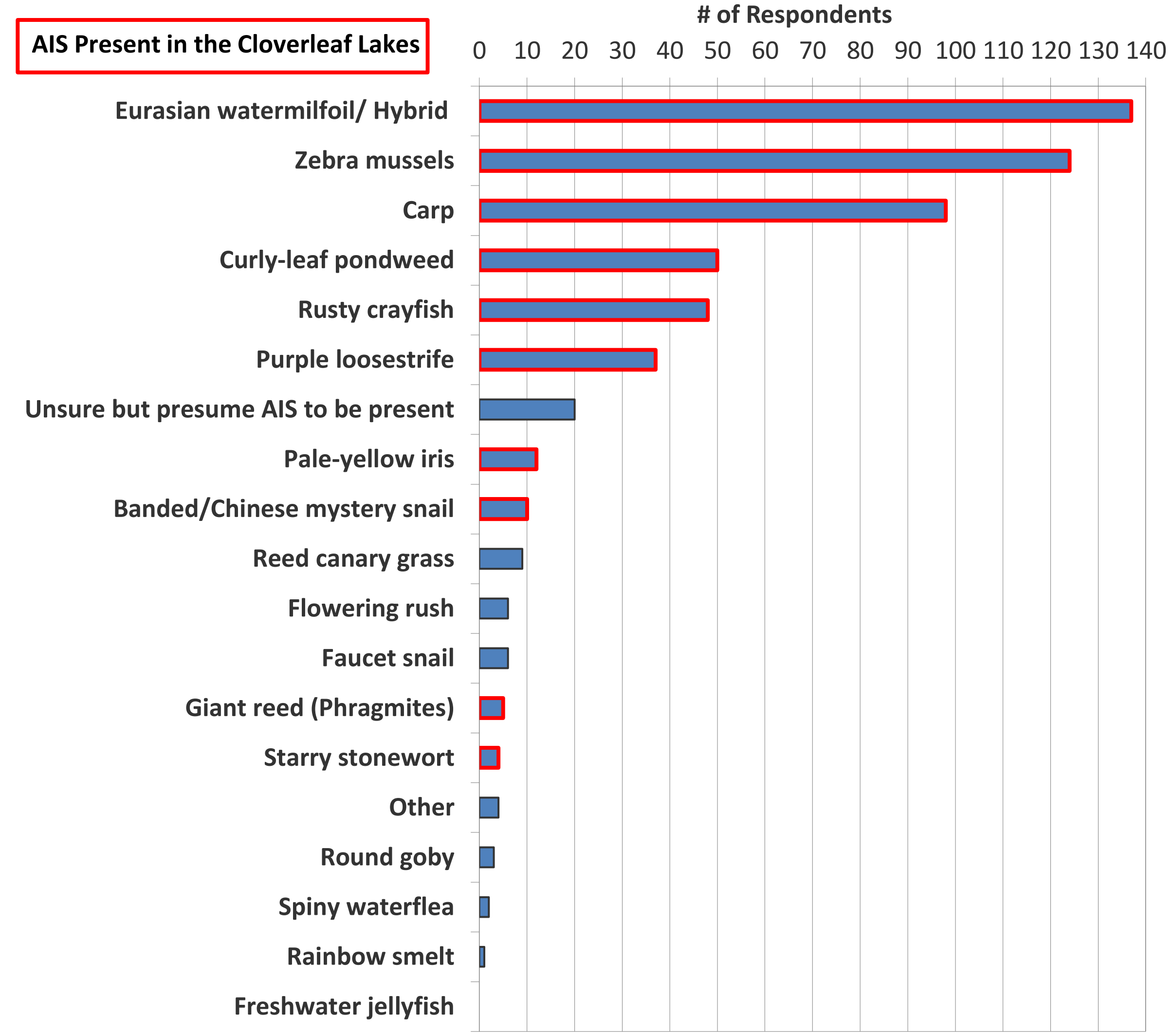


Figure 3.5-2. Stakeholder survey response Question #25. Which aquatic invasive species do you believe are in the Cloverleaf Lakes? Please note starry stonewort was not known from Cloverleaf Lakes until after the stakeholder survey was conducted.

Aquatic Animals

Rusty Crayfish

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

Mystery snails

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

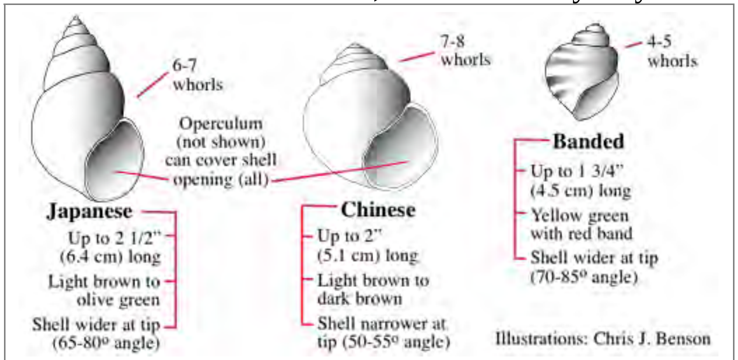


Figure 3.5-1. Identification of non-native mystery snails. Courtesy of Minnesota Sea Grant: (*http://www.seagrant.umn.edu/ais/mysterysnail*).

3.6 Fisheries Data Integration

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

The Cloverleaf Chain Fishery

Energy Flow of a Fishery

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.6-1.

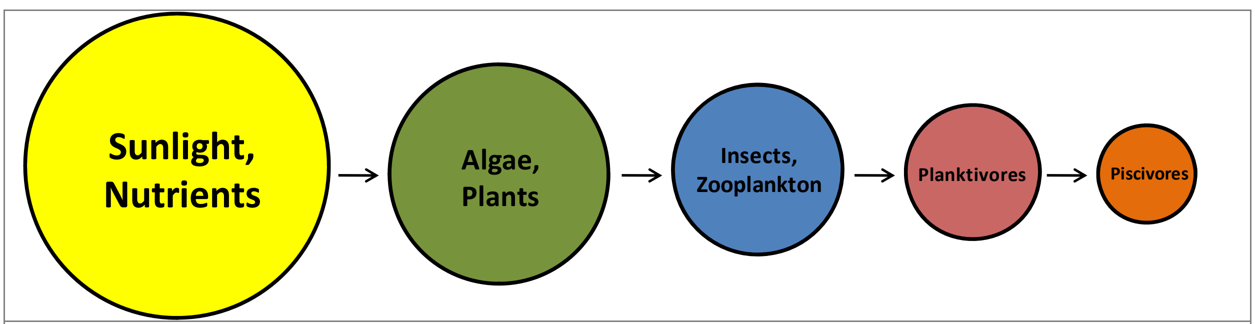


Figure 3.6-1. Aquatic food chain. Adapted from (Carpenter, Kitchell, & Hodgson, 1985).

As discussed in the Water Quality section, the Cloverleaf Chain is a mesotrophic system, meaning it has a moderate amount of nutrients and thus a moderate amount of primary productivity. This is relative to an oligotrophic system, which contains fewer nutrients (less productive) and a eutrophic system, which contains more nutrients (more productive). Simply put, this means the Cloverleaf Chain should be able to support an appropriately sized population of predatory fish (piscivores) when compared to eutrophic or oligotrophic systems. Table 3.6-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional species documented in past WDNR surveys of the Cloverleaf Chain include bluntnose minnow (*Pimephales notatus*), bowfin (*Amia calva*), banded killifish (*Fundulus diaphanus*), blackchin shiner (*Notropis heterodon*), brook silverside (*Labidesthes sicculus*), common shiner (*Luxilis cornutus*), golden shiner (*Notemigonus crysoleucas*), green sunfish (*Lepomis cyanellus*), Iowa darter (*Etheostoma exile*), lake chubsucker (*Erimyon sucetta*), mimic shiner (*Notropis volucellus*), tadpole madtom (*noturus gyrinus*), and white sucker (*Catostomus commersonii*). The invasive common carp (*Cyprinus carpio*) is also present in the Cloverleaf Chain, see Section 3.5 for more information.

Table 3.6-1. Gamefish present in the Cloverleaf Chain with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	**Max Age (yrs)**	**Spawning Period**	**Spawning Habitat Requirements**
Black Bullhead (*Ameiurus melas*)	5	April - June	Matted vegetation, woody debris, overhanging banks
Black Crappie (*Pomoxis nigromaculatus*)	7	May - June	Near *Chara* or other vegetation, over sand or fine gravel
Bluegill (*Lepomis macrochirus*)	11	Late May - Early August	Shallow water with sand or gravel bottom
Brown Bullhead (*Ameiurus nebulosus*)	5	Late Spring - August	Sand or gravel bottom, with shelter rocks, logs, or vegetation
Largemouth Bass (*Micropterus salmoides*)	13	Late April - Early July	Shallow, quiet bays with emergent vegetation
Muskellunge (*Esox masquinongy*)	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.
Northern Pike (*Esox lucius*)	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves
Pumpkinseed (*Lepomis gibbosus*)	12	Early May - August	Shallow warm bays 0.3 - 0.8 m, with sand or gravel bottom
Rock Bass (*Ambloplites rupestris*)	13	Late May - Early June	Bottom of course sand or gravel, 1 cm - 1 m deep
Walleye (*Sander vitreus*)	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms
Yellow Bullhead (*Ameiurus natalis*)	7	May - July	Heavy weeded banks, beneath logs or tree roots
Yellow Perch (*Perca flavescens*)	13	April - Early May	Sheltered areas, emergent and submergent veg

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.6-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.6-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

The mark-recapture data collected between these two surveys is placed into a statistical model to calculate the population estimate of a fish species. Fisheries biologists can then use this data to make recommendations and informed decisions on managing the future of the fishery.

Photograph 3.6-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.6-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. the Cloverleaf Chain was stocked periodically from 1985 to 2019 with muskellunge and walleye (Table 3.6-2 and 3.6-3). Additionally, in 2017, 900 large fingerling northern pike were stocked.

Photograph 3.6-2. Muskellunge fingerling.

Future stocking efforts of walleye is expected to be consistent following the Cloverleaf Chains' inclusion in the Wisconsin Walleye Initiative. The Initiative was made possible by the governor's office, Department of Natural Resources and statewide partners to maintain the walleye population in Wisconsin's lakes and improve walleye fisheries in lakes capable of sustaining the sportfish (WDNR, 2014). Lakes chosen to be included are selected based upon anticipated fingerling survival, natural reproduction opportunities, public access, tribal interest (for ceded territory lakes) and potential impacts to tourism (WDNR, 2014). Stocking rates are randomly assigned to chosen lakes and stocked every other year to avoid competing year classes. Beginning in 2013 and odd years thereafter the Cloverleaf Chain was selected to receive the stocking rate of 10 extended growth walleye/acre as funding allows (WDNR, 2014).

Table 3.6-2. Stocking data available for muskellunge in the Cloverleaf Chain (1985-2019).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
2019	MUSKELLUNGE	-	LARGE FINGERLING	316	12
2017	MUSKELLUNGE	-	LARGE FINGERLING	316	12
2014	MUSKELLUNGE	UPPER WISCONSIN RIVER	LARGE FINGERLING	316	9.8
2010	MUSKELLUNGE	UPPER WISCONSIN RIVER	LARGE FINGERLING	193	13.2
2008	MUSKELLUNGE	UPPER WISCONSIN RIVER	LARGE FINGERLING	640	10.3
2006	MUSKELLUNGE	UPPER WISCONSIN RIVER	LARGE FINGERLING	140	10.8
2004	MUSKELLUNGE	UNSPECIFIED	LARGE FINGERLING	638	10.5
2002	MUSKELLUNGE	UNSPECIFIED	LARGE FINGERLING	640	10.1
2000	MUSKELLUNGE	UNSPECIFIED	LARGE FINGERLING	450	11.4
1992	MUSKELLUNGE	UNSPECIFIED	FINGERLING	646	11
1991	MUSKELLUNGE	UNSPECIFIED	FINGERLING	640	10.9
1989	MUSKELLUNGE	UNSPECIFIED	FINGERLING	640	11
1987	MUSKELLUNGE	UNSPECIFIED	FINGERLING	1920	9
1985	MUSKELLUNGE	UNSPECIFIED	FINGERLING	840	12

Table 3.6-3. Stocking data available for walleye in the Cloverleaf Chain (1985-2019).

Year	Species	Strain (Stock)	Age Class	# Fish Stocked	Avg Fish Length (in)
2019	WALLEYE	MISSISSIPPI HEADWATERS	LARGE FINGERLING	3,183	8
2017	WALLEYE	MISSISSIPPI HEADWATERS	LARGE FINGERLING	3,172	3.3
2015	WALLEYE	LAKE MICHIGAN	LARGE FINGERLING	3,184	7.8
2008	WALLEYE	MISSISSIPPI HEADWATERS	SMALL FINGERLING	11,290	1.5
2006	WALLEYE	LAKE MICHIGAN	SMALL FINGERLING	15,985	1.4
2004	WALLEYE	LAKE MICHIGAN	SMALL FINGERLING	15,990	1.4
2000	WALLEYE	UNSPECIFIED	SMALL FINGERLING	11,000	1.7
1998	WALLEYE	UNSPECIFIED	SMALL FINGERLING	8,850	1.7
1997	WALLEYE	UNSPECIFIED	LARGE FINGERLING	11,000	2.7
1996	WALLEYE	UNSPECIFIED	FINGERLING	14,954	1.6
1994	WALLEYE	UNSPECIFIED	FINGERLING	16,303	3.6
1992	WALLEYE	UNSPECIFIED	FINGERLING	8,120	3
1989	WALLEYE	UNSPECIFIED	YEARLING	4,500	10
1987	WALLEYE	UNSPECIFIED	FINGERLING	33,150	7
1985	WALLEYE	UNSPECIFIED	FINGERLING	14,100	2

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water) was the fourth most important reason for owning property on or near the Cloverleaf Chain (Question #17). Figure 3.6-2 displays the fish that the Cloverleaf Chain stakeholders enjoy catching the most, with bluegill/sunfish crappie, and largemouth bass being the most popular. Approximately 79% of these same respondents believed that the quality of fishing on the lake was either excellent, good, or fair (Figure 3.6-3). Approximately 90% of respondents who fish the Cloverleaf Chain believe the quality of fishing has remained the same or gotten worse since they first started to fish the lake (Figure 3.6-4).

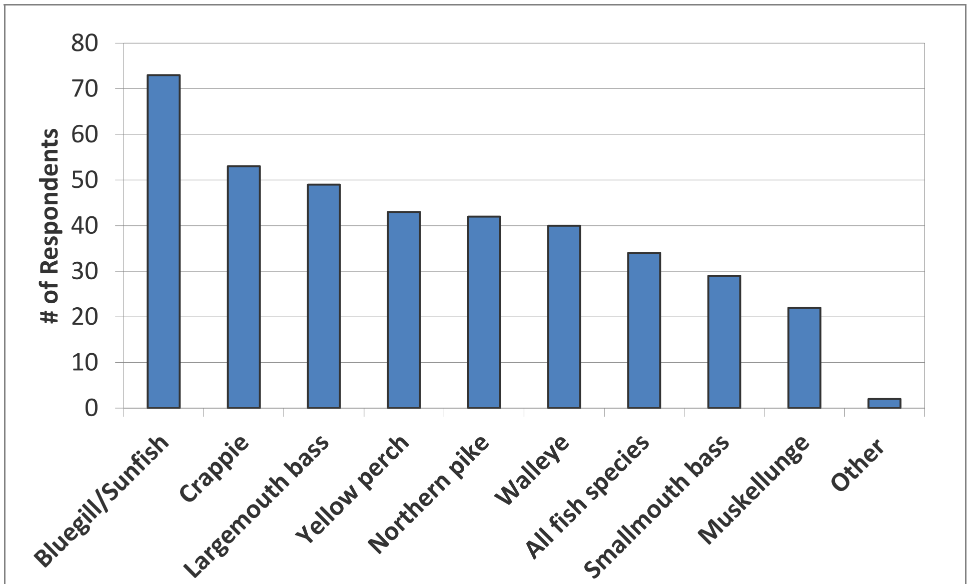


Figure 3.6-2. Stakeholder survey response Question #9. What species of fish do you like to catch on the Cloverleaf Chain?

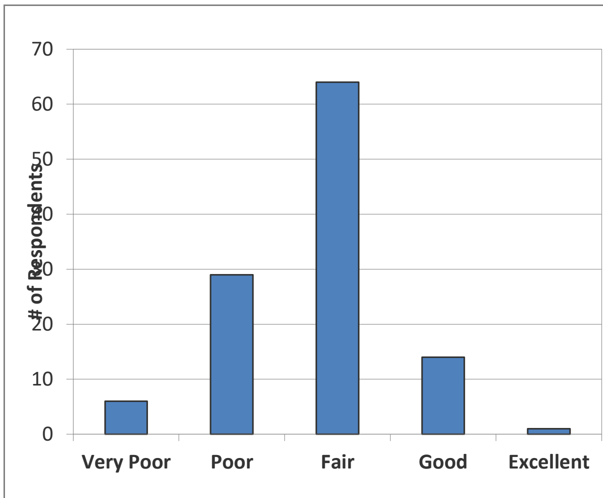


Figure 3.6-3. Stakeholder survey response Question #10. How would you describe the current quality of fishing on the Cloverleaf Chain?

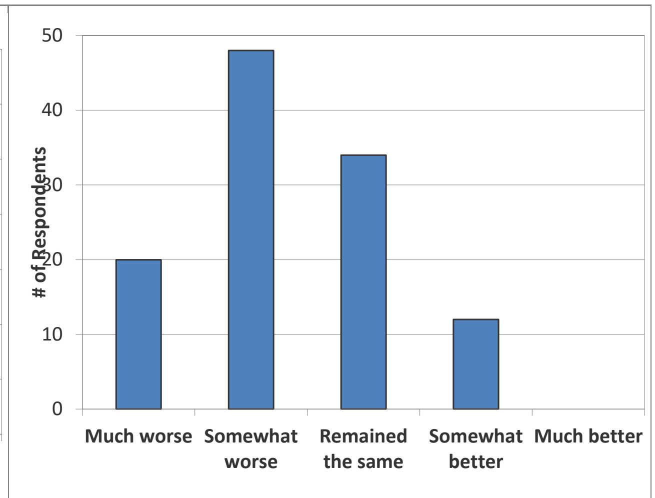


Figure 3.6-4. Stakeholder survey response Question #11. How has the quality of fishing changed on the Cloverleaf Chain since you started fishing the lake?

Fish Populations and Trends

Utilizing the fish sampling techniques mentioned above and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. One method used in calculating the numbers captured is catch per unit effort (CPUE). This number provides a standardized way to compare fish abundances between years when the amount of fishing effort (number of nights' fyke nets are set) differs. When comparing within the same year, CPUE indexes are compared to statewide data by percentiles (Neibur 2015). For example, if a CPUE is in the 90th percentile, it is higher than 90% of the other CPUEs in the state (Neibur 2015). Ultimately this data shows a healthy population of fish from moderate to high abundances. This is one example of how data is analyzed by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on the Cloverleaf Chain represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch largemouth bass on the Cloverleaf Chain (Figure 3.6-2). Brief summaries of gamefish with fishable populations in the Cloverleaf Chain are provided based off of the report submitted by WDNR fisheries biologist Jason Breeggemann following the fisheries survey completed in 2017 (Appendix E).

Walleyes are a valued sportfish in Wisconsin. No natural reproduction of walleye occurs within the Cloverleaf Chain and populations are completely dependent on stocking. Since being included in the Wisconsin Walleye Initiative in 2013, the Cloverleaf Chain has received extended growth walleye fingerlings at a rate of approximately 10 fish per acre every odd year. Data from a comprehensive fisheries survey completed in 2017 shows low walleye densities with all but one fish captured being greater than 20 inches. It is likely that the influx of smaller fish captured in 2017 are results of the 2013 and 2015 stocking events. Continued walleye stocking will be needed to maintain the low density, put-grow-take fishery that is currently present.

Muskellunge, like walleye, are also a valued sportfish of the Cloverleaf Chain. No natural reproduction of muskellunge occurs in the Cloverleaf Chain, so consistent stocking events have occurred since the 1980s to maintain the population. During the 2017 survey, 34 muskellunge were captured in fyke nets. The average size of these fish was high, with 97% of fish captured measuring 35 inches or greater. The largest individual captured measured approximately 47.5 inches. The Cloverleaf Chain is currently listed as a class B muskellunge fishery, meaning anglers can expect good fishing but quality and success rates may be less than prime waters. However, the size and growth structures of muskellunge in the Cloverleaf Chain more closely resemble that of some class A waters. A mark-recapture survey was conducted in 2017 and 2018 to calculate a population estimate of muskellunge within the Cloverleaf Chain (Figure 3.6-5). From the data collected, a population estimate of 82 fish (0.25 fish/acre) was generated. This is within the goal set by biologists of 0.1-0.3 fish per acre. The DNR recommends stocking events of one fish per acre to occur every 2-3 years to maintain this population (Jason Breeggemann personal comm. 2021).

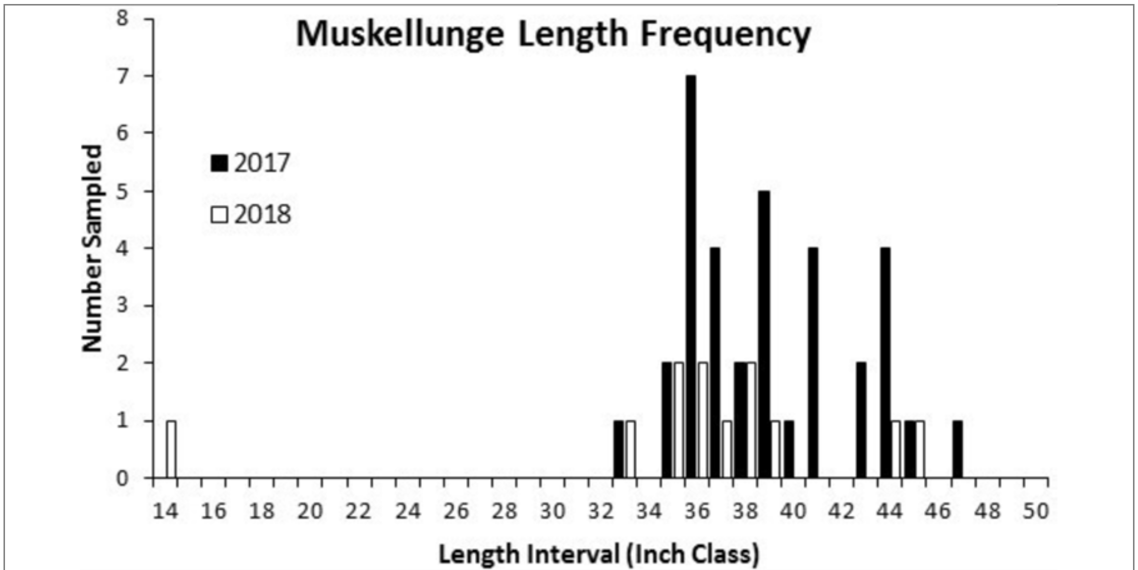


Figure 3.6-5. Results from the 2017-2018 mark-recapture survey on the Cloverleaf Chain. Figure extracted from 2018 spring netting summary report (Appendix E)

Largemouth bass are common within the Cloverleaf Chain. Data from the 2017 comprehensive survey shows healthy and balanced numbers across multiple year classes of largemouth bass. Sizes ranged from four to 16.5 inches. However, biologists did note slower than average growth metrics for largemouth bass in the Cloverleaf Chain. This, paired with high densities, may be the reason no bass larger than 16.5 inches were captured. High bass densities are beneficial for keeping high panfish populations in check.

Northern Pike are present in the Cloverleaf Chain. The population is comprised mostly of smaller individuals. In 2017, 94 northern pike were captured with an average size of 16.6 inches. Due to this, northern pike was given a low size and abundance rating. Stocking events of northern pike fingerlings in 2014 and 2017 took place in an effort to bolster populations.

Panfish

The panfish present on the Cloverleaf Chain represent different population dynamics depending on the species. Abundant panfish populations are present but are lacking numbers of quality sized fish. The results for the stakeholder survey show anglers prefer to catch bluegill, pumpkinseed, and crappie on the Cloverleaf Chain (Figure 3.6-2). Brief summaries of panfish with fishable populations in the Cloverleaf Chain are provided based off of the WDNR fisheries survey completed in 2017 (Appendix E).

Bluegill were the most abundant panfish captured during the 2017 electrofishing survey. In total, 990 bluegills were captured with an average size of 5.8 inches. Bluegill showed a balanced size structure, but few fish greater than seven inches were captured. In addition, a subsample of fish were sampled to assess growth rates. On average, it took almost six years for bluegill to reach 6.5 inches. Ranking in the 39th percentile, this is considered a slow-moderate growth rate. In 2016, a special panfish regulation took effect in efforts to increase both the growth rates and size structure of bluegill. In total, 25 panfish can still be kept, but only five of these fish can be bluegill or pumpkinseed greater than 7 inches in length. In addition, increased stocking of predatory fish has occurred in an effort to decrease the amount of smaller panfish.

Black crappie are commonly found in the Cloverleaf Chain as well. In 2017, crappies were sampled at moderate-high densities but the size structure was only ranked in the 5th percentile. Few fish measured greater than eight inches and fish between four and five inches dominated the catch. These fish, likely from a very strong 2015 class, should now be of harvestable size and contributing to the fishery.

Pumpkinseed are common within the Cloverleaf Chain. In total, 316 pumpkinseeds were captured in the 2017 survey. Fish between four and six inches accounted for the majority of fish caught, with no fish larger than 7.5 inches being captured. Pumpkinseeds fall within the special bluegill regulation.

Yellow perch are present in the Cloverleaf Chain but densities and size structure remain low. In 2017, perch measuring four-seven inches accounted for the majority of fish captured. No perch measuring greater than nine inches were captured. It should be noted that perch are difficult to catch with electrofishing and fyke netting techniques. Both of these methods were used during the 2017 survey.

Common Carp

Since the introduction of common carp (*Cyprinus carpio*), an invasive species which originates from Eurasia, to waterbodies in the United States and other countries around the world, numerous studies have documented the deleterious effects these fish have on lake ecosystems. Common carp can survive in a wide range of waterbody conditions, but they reach their greatest densities in shallow, eutrophic systems like Beaver Dam Lake (Weber & Brown, 2011). Because of their ability to reach extreme densities, they are considered to be one of the most detrimental invasive species to waterbodies they inhabit (Weber & Brown, 2011).

Following the introduction of common carp to a waterbody, studies have documented declines in submersed aquatic vegetation and increases in total phosphorus and suspended solids, and a shift from a clear, submersed aquatic plant-dominated state to a turbid, algae-dominated state (Bajer & Sorensen, 2015). Common carp directly increase nutrients within the water by physical resuspension of bottom sediments through foraging and spawning behavior as well as through excretion (Fischer & Krogman, 2013). Common carp foraging behavior also creates more flocculent sediments which are more prone to resuspension from wind. In addition, sediments are also more prone to wind-induced resuspension as aquatic vegetation declines through physical uprooting and decline in light availability due to increases in water turbidity (Lin & Wu, 2013). Zooplankton which feed on algae also decline as their refuge from predators within aquatic vegetation disappears. Common carp create a positive feedback mechanism: the direct physical resuspension and uprooting of vegetation indirectly increases the susceptibility of bottom sediments to wind-induced resuspension, and the increased turbidity further decreases aquatic vegetation.

Cloverleaf Chain Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra in 2020, 97% of the substrate sampled in the littoral zone of Round Lake were soft sediments and 3% composed of rock. In Grass Lake, 79% of the substrate was of soft sediments and 21% was composed of sand. In Pine Lake, 77% of substrate was of soft sediments and 23% was composed of sand.

Fish Habitat Structures

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


Photograph 3.6-3. Examples of fish sticks (left) and half-log habitat structures. (Photos by WDNR)

Fish cribs are a type of fish habitat structure placed on the lakebed. These structures are more commonly utilized when there is not a suitable shoreline location for fish sticks. Installing fish cribs may also be cheaper than fish sticks; however, some concern exists that fish cribs can concentrate fish, which in turn leads to increased predation and angler pressure. Having multiple locations of fish cribs can help mitigate that issue.

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.6-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan, & Haynes, 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (Neuswanger & Bozek, 2004). A walleye spawning reef was installed on the north side of Pine Lake in the 1980's, however successful natural reproduction of walleye has not been recorded (Olson, 2003).

Placement of a fish habitat structure in a lake may be exempt from needing a permit if the project meets certain conditions outlined by the WDNR's checklists available online:

(https://dnr.wi.gov/topic/waterways/Permits/Exemptions.html)

If a project does not meet all of the conditions listed on the checklist, a permit application may be sent in to the WDNR and an exemption requested.

If interested, the Cloverleaf Lakes Protective Association may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for the Cloverleaf Chain.

For specific fishing regulations on all fish species, anglers should visit the WDNR website (*www.http://dnr.wi.gov/topic/fishing/regulations/hookline.html)* or visit their local bait and tackle shop to receive a free fishing pamphlet that contains this information.

Table 3.6-4. WDNR fishing regulations for the Cloverleaf Chain (As of January 2021).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	5 or fewer can be bluegill or pumpkinseed over 7"	Open All Year
Largemouth bass	5	14"	May 2, 2020 to March 7, 2021
Muskellunge and hybrids	1	40"	May 23, 2020 to December 31, 2020
Northern pike	5	None	May 2, 2020 to March 7, 2021
Walleye, sauger, and hybrids	3	The minimum length is 15", but walleye, sauger, and hybrids from 20" to 24" may not be kept, and only 1 fish over 24" is allowed.	May 2, 2020 to March 7, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10	None	Open All Year

A 2003 habitat survey conducted by DNR biologists designated six sensitive habitat areas around the Cloverleaf Chain (Map 1). Priority should be placed in protecting these areas, which provide cover and prime spawning habitat for almost all fish species within the Cloverleaf Chain. Two of the largest areas, located in Grass Lake, were the shoreline surrounding Gibson island as well the island of emergent plants on the southern part of the lake (Olson, 2003). The Pine Lake sunken island is also identified as an area critical to spawning panfish.

Mercury Contamination and Fish Consumption Advisories

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

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

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

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

Figure 3.6-8. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Fishery Management & Conclusions

Several habitat and management goals are in place in the Cloverleaf Chain. Continued muskellunge and walleye stocking is recommended to maintain low-moderate density populations. Stocking of large fingerling walleyes instead of smaller fingerlings is recommended to increase survival rates as well. The special panfish regulation put in place in 2016 is to be evaluated during the next comprehensive survey, which is tentatively planned for 2021. Biologists hope that with lower densities and protection of some larger individuals, overall bluegill size structure will start to improve. Lastly, continued monitoring of northern pike populations is recommended. Two pike stocking events were completed in 2014 and 2017 in addition to increased protections of shoreline and emergent habitat. Protection and enhancement of these areas will not only benefit the northern pike population, but the fish community of the Cloverleaf Chain as a whole.

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill three objectives;

1) Collect baseline data to increase the general understanding of the Cloverleaf Lakes ecosystem.
2) Collect detailed information regarding invasive plant species within the lake, with the primary emphasis being on Eurasian watermilfoil.
3) Collect sociological information from Cloverleaf Lakes stakeholders regarding their use of the lake and their thoughts pertaining to the past and current condition of the lake and its management.

The three objectives were fulfilled during the project and have led to a good understanding of the Cloverleaf Lakes ecosystem, the folks that care about the lakes, and what steps can be taken by the CLPA to protect and enhance the system.

CLPA's participation in the Citizens Lake Monitoring Network program has allowed for the availability of consistent water quality data. Cloverleaf Lakes contains *excellent* water quality compared to other deep headwater drainage lakes. The Cloverleaf Lakes are marl lakes which means they naturally possess a large amount of calcium in their water. These types of lakes naturally have very hard water and are low in nutrients, e.g. phosphorus, resulting in clear water which often gives the lakes a turquoise color. The high amount of calcium in the water combines with phosphorus and coprecipitates to the lake bottom. This mechanism reduces phosphorus levels in the water and thus reduces algal growth. Submerged plants are usually covered with a "crust" of this calcium carbonate, and the nearshore sediments are often gray in color.

The Cloverleaf Lakes are classified as mesotrophic lakes, meaning they have a moderate amount of overall productivity. Water clarity, total phosphorus, and chlorophyll-a parameters are all similar to mean values of other deep headwater drainage lakes. The water clarity of Cloverleaf Lakes is minimally impacted by staining organic compounds called tannins, and likely enhanced due to the presence of zebra mussels. Trend analysis indicates an increase in nutrients over time, likely as a result of increased human activity in the lake and watershed. This was also corroborated by looking at nutrient levels in sediment cores from pre-European colonization.

The Cloverleaf Lakes are within the Wolf River Watershed, and have a direct watershed of around 1,800 acres. This means for every acre of the Cloverleaf Lakes, there is about 7 acres of land draining to it. The watershed has a moderately high amount of agriculture lands, which export more phosphorus to the lake than other land cover types. A sanitary district surrounds the lakes, which is helpful to keep phosphorus inputs to the lake down. This fact may make some folks complacent on conducting other nutrient reduction strategies, such as extremely important shoreland protection and enhancement activities.

Cloverleaf Lakes is a regionally popular destination for anglers that target plentiful panfish, bass, and muskellunge. Riparian stakeholder respondents believe the fishery is currently *fair* and that the fishery has *remained the same* or has become *somewhat* worse since they first started fishing the lake. Fisheries surveys are planned to occur by the WDNR to occur in 2022.

Approximately 44 different species of plants were located within and along the margins of the Cloverleaf Lakes during the last comprehensive assessment, much higher than most Wisconsin systems. Cloverleaf Lakes contains a wide range of habitats, including sandy shoals, sediment-rich backwater bays, and deep drop-offs. Different aquatic plant species favor each of these habits and results in the high species richness. A statistical measurement of aquatic plant diversity indicates that there is just under a 90% chance of the next plant species encountered being different from the previous one. Aquatic plants grow out to waters that are roughly 18 feet in Pine and Grass Lakes, and out to 22 or more feet in Round Lake, depending on the conditions that year. Not surprisingly, the Cloverleaf Lake's aquatic plant population is highly dominated by muskgrasses, which typically proliferate in clear, high-calcium lakes such as those found in the Chain. These macro-algae are important for sediment stabilization, which is extremely important to help minimize the impacts from high amounts of recreation that periodically occur on the system.

A non-native macro-algae, starry stonewort, was first discovered from the Cloverleaf Lakes as part of this project. Preliminary data from Wisconsin Lakes indicate that the frequency aquatic invasive species can vary across lakes, with some lakes experiencing rapid increase in starry stonewort (SSW) frequency after discovery, while other lakes have seen a much slower rate of expansion. To date, there have not been any effective chemical or manual removal management strategies for SSW. The CLPA will continue to monitor this species in their lake and keep apprised new research into technologies that may effectively manage SSW in the future.

The CLPA, in conjunction within WDNR grants, have invested a large amount of money managing the hybrid Eurasian watermilfoil (HWM) population of Cloverleaf Lakes, primarily with herbicides but also incorporating strategic hand-removal operations in recent years. The herbicide strategies employed during this time period were considered the *Best Management Practices (BMPs*) of the time. However, some of these management actions have gone out of favor as new research and information has become available. Onterra believes some of the largest advances in BMPs in regards to EWM management was gained as a part of a cooperative research project between the WDNR, US Army Corps of Engineers Research and Development Center (USACE), and private consultants. The CLPA was involved with this research project and should be commended for their valuable role in improving herbicide management across the Midwest.

As a part of this management planning project, the CLPA has been educated on the updated BMPs of managing HWM with herbicides. This includes using newer herbicides that are more effective under short concentration and exposure time scenarios (e.g. ProcellaCOR). This also includes understanding the area of potential impact (AOPI) that the herbicide will ultimately dilute into. The CLPA has outlined criteria for when different types of management actions would be considered for the Cloverleaf Lakes.

Through the process of this lake management planning effort, the CLPA has learned much about their system, both in terms of its positive and negative attributes. The CLPA continues to be tasked with properly maintaining and caring for this resource. It is particularly important to protect high quality aspects of the Cloverleaf Lakes ecosystem.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented below was created through the collaborative efforts of the CLPA Planning Committee and ecologist/planners from Onterra. The Implementation Plan represents the path CLPA 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 Cloverleaf Lake 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 constant review and adjustment depending on the condition of the lake, the availability of funds, level of volunteer involvement, and the needs of the stakeholders.

The Aquatic Plant Management-related aspects of the Implementation Plan provided here outlines separate management goals and actions that together form the CLPA's Integrated Pest Management strategy on the Cloverleaf Lakes. Integrated Pest Management (IPM) is an approach to manage a species that utilizes a combination of methods that are more effective when applied collectively as part of defined strategy than when conducted separately. This long-term vision considers all available control practices such as:

- Prevention
- Biological control
- Biomanipulation
- Nutrient management
- Habitat manipulation
- Pesticide application
- Water level manipulation
- Mechanical removal
- Feasibility planning
- Population monitoring
- Substantial modification of cultural practices

While the CLPA Board of Directors 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 or an individual director/coordinator. The CLPA Board of Directors will be responsible for determining whether the formation of sub-committees and or directors is needed to achieve the various management goals.

Management Goal 1: Increase the CLPA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action:	Participate in annual Wisconsin Lakes and Rivers Convention
Timeframe:	Annually
Facilitator:	Board of Directors
Description:	Wisconsin is unique in that there is a long-standing partnership between a governmental body, a citizen-based lake lobbying and protection association, and the state's primary educational outreach program. That unique group is the Wisconsin Lakes Partnership and its three members, the Wisconsin Dept. of Natural Resources, Wisconsin Lakes, and the UW-Extension Lakes Program, facilitate many lake-related events throughout the state. The primary event is the Wisconsin Lakes Partnership Convention held each spring in Stevens Point. This is the largest citizen-based lakes conference in the nation and is specifically suited to the needs of lake associations and associations. It is an exceptional opportunity for lake group members to learn about lake management and monitoring; network with other lake groups, agency staff, and lake management contractors; and learn how to effectively operate a lake association/association. The CLPA will encourage 1-3 members annually attend the convention. Following the attendance of the convention, the members will report specifics to the board of directors regarding topics that may be applicable to the management of the Cloverleaf Lakes and operations of the CLPA. The attendees will also create a summary in the form of a newsletter article and if appropriate, update the association membership at the annual meeting. Information about the convention can be found at: https://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/programs/default.aspx In addition to the state-wide conference, local counties occasionally hold more focused conferences where CLPA would attempt to have representation present.

Management Action:	Routinely educate and communicate with all lake stakeholders
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	The CLPA will make the education of lake-related issues a priority. One of the first tasks would be to disseminate the information contained within this *Comprehensive Management Plan*, allowing it to be better understood by association members. To accomplish this task, a committee plans to highlight key topics from the plan and share educational materials on the subjects over time. The CLPA believes that creating smaller modules of information and spreading out the delivery over time will be an effective educational initiative. As a part of the planning process, the CLPA identified key topics which they believe the association members would appreciate additional educational opportunities. These may include educational materials, awareness events, and demonstrations for lake users as well as activities which solicit local and state government support. *Example Educational Topics* • General lake ecology • Importance of natural landscapes • Aquatic invasive species identification • Shoreline habitat restoration and protection • Shoreline erosion • Litter, particularly during ice fishing • Noise and light pollution • Fishing regulations and overfishing • Minimizing disturbance to spawning fish

Management Action:	Conduct Periodic Riparian Stakeholder Surveys
Timeframe:	Periodic: Every 5-6 years
Facilitator:	Board of Directors
Description:	Formal riparian stakeholder user surveys have been performed by the association in the past, with the most-recent survey completed in 2020 as part of this project. Approximately once every 5-6 years, potentially at the time of a Plan update or prior to a large management effort, an updated stakeholder survey would be distributed to the Cloverleaf riparians. Periodically conducting an anonymous stakeholder survey would gather comments and opinions from lake stakeholders to gain important information regarding their understanding of the lake and thoughts on how it should be managed. This information would be critical to the development of a realistic plan by supplying an indication of

	the needs of the stakeholders and their perspective on the management of the lake. The stakeholder survey could partially replicate the design and administration methodology conducted during 2020, with modified or additional questions as appropriate. The survey would again receive approval from a WDNR Research Social Scientist, particularly if WDNR grant funds are used to offset the cost of the effort.

Management Action:	Periodically update lake management plan
Timeframe:	Periodic
Facilitator:	Board of Directors
Description:	The term *Best Management Practice (BMP)* is often used in environmental management fields to represent the management option that is currently supported by that latest science and policy. When used in an action plan, the term can be thought of as a placeholder with anticipation of having an evolving definition over time. The WDNR recommends *Comprehensive Lake Management Plans* generally get updated every 10 years. Implementation projects require a completion data of "no more than 10 years prior to the year in which an implementation grant application is submitted. The department may determine a longer lifespan is appropriate if the applicant can demonstrate a plan has been actively implemented and updated during its lifespan." This allows a review of the available data from the lake, as well as to consider changing BMPs for water quality, watershed, and shoreland management. This project creates a *Comprehensive Lake Management Plan* for the Cloverleaf Lakes. BMPs for aquatic plant management change rapidly, as new information about effectiveness, non-target impacts, and risk assessment emerges. To be eligible to apply for grants that provide cost share for AIS control and monitoring, "a current plan has a completion date of no more than 5 years prior to submittal of the recommendation for approval. The department may determine that a longer lifespan is appropriate for a given management plan if the applicant can demonstrate it has been actively implemented and updated during its lifespan. However, a [whole-lake] point-intercept survey of the aquatic plant community conducted within 5 years of the year an applicant applies for a grant is required." It is important to work with the regional WDNR Lakes Biologist to understand what is required at this time, as it is more subjective in comparison to the requirements of a *Comprehensive Lake Management Plan* as it relates to the specific management actions being considered.

	It is important to note that the management plan provides a framework to guide the management action, but does not include the specific control plan for a given year. A written control plan, consistent with the *Management Plan*, would be produced prior to the action outlining the management and monitoring strategy. The control plan is useful for WDNR and tribal regulators when considering approval of the action, as well as to convey the control plan to CLPA members for their understanding. Historically, the CLPA has conveyed their control plan within annual reporting, which are distributed in late winter of each year.

Management Action:	Continue CLPA's involvement with other entities that have responsibilities in managing Cloverleaf Lakes
Timeframe:	Continuation of current efforts
Facilitator:	Board of Directors
Description:	The purpose of the CLPA is to maintain, protect, and improve the quality of lakes for the landowners and those that use the lake for recreation purposes. The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are governmental while others organizations rely on voluntary participation. It is important that the CLPA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next page.
Action Steps:	
	See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Shawano County Land Services Department	County Conservationist (Scott Frank- 715.526.4632)	Oversees land & water conservation projects.	Twice a year or more as needed.	Can provide assistance with shoreland restorations and habitat improvements.
Town of Belle Plaine	Town Clerk (Kris Vomastic – belleplaineclerk@gmail.com)	Local unit of government	Annual and as needed: (belleplainewi.com)	Aspects that involve the government such as building and zoning, municipal sewer, funding opportunities, grant applications, CBCW, events, ordinances etc.
Waterways Association of Menominee and Shawano Counties (WAMSCO)	Shanda Hubertus (wamsco@gmail.com)	Local collaboration of associations and districts	Attend annual meeting, or as needed. (wamsco.org)	Relevant local information related to maintaining and restoring waterways. Sharing research, education, and resources.
Fox-Wolf Watershed Alliance	Jessica Schultz (jessica@fwwa.org)	Non-profit organization	As needed. Visit website (fwwa.org)	Working to protect and improve the Fox-Wolf River watershed
Belle Plaine Sportsman's Club	Joe Stueck – (joestueck@msn.com)	Non-profit organization	Annual and as needed: (belleplainesportsmansclub.com)	Organization of sportsman and anglers interested in habitat and population management.
Gibson Island Stewardship Committee	Chair (Joy Krubsack – jkrubsack@hotmail.com)	Town committee	Often	Promote stewardship of Gibson Island.
Wisconsin Lakes	General staff (800.542.5253)	Education, networking and assistance.	As needed. (wisconsinlakes.org)	Reps can assist on education
Wisconsin Department of Natural Resources	Fisheries biologist (Aaron Oconnell - (920) 420-9203)	Manages the fishery of the system.	Once a year, or more as issues arise.	Stocking, surveys, volunteer opportunities for improving fishery.
	Lakes Coordinator (Brenda Nordin- 920.360.3167)	Oversees management plans, grants, all lake activities.	Once a year, or more as necessary.	Information on updating a lake management plans, submitting grants r permits, and to seek advice on other lake issues.
	Warden (Clark Delzer – 920.764.0194; Mark Schraufnagel - 715.853-8686)	Oversees regulations handed down by the state.	As needed. May contact WDNR Tip Line (1.800.847.9367) as needed also.	Suspected violations, including fishing, boating safety, ordinance violations, etc.
	CLMN Director (Brenda Nordin- 920.360.3167)	CLMN training and assistance.	Twice a year or more as needed.	Training, planning of monitoring and reporting of data.
	AIS Regional Coordinator (Chris Kolasinski)	Oversees local AIS monitoring and prevention.	Twice a year or more as issues arise.	AIS training and ID, AIS monitoring techniques

Management Goal 2: Monitor Aquatic Vegetation on the Cloverleaf Lakes

Management Action:	Periodically monitor the Curly-leaf Pondweed population
Timeframe:	Periodic: every 3-4 years or when prompted
Facilitator:	Board of Directors
Description:	As discussed in the Aquatic Plant Section (3.4), CLP was first recorded from the Cloverleaf Lakes during 1992. Despite being present in the system for almost three decades, CLP has not been observed at population levels that impact navigation/recreation, nor threatening the integrity of the ecosystem In some lakes, particularly in northern Wisconsin, CLP appears to integrate itself within the aquatic plant community without becoming a nuisance or having a measurable impact to the ecological function of the lake. At this time, it appears that the CLP population of the Cloverleaf Lakes does not warrant management. The CLPA would give consideration to periodically monitoring the CLP population within the system, likely at 3-4-year intervals. In order to corresponded with the peak growth stage of this species and before it naturally dies back for the year, surveys would be completed in early- to mid-June.

Management Action:	Periodically monitor the Eurasian watermilfoil population
Timeframe:	Annual during latter part of growing season
Facilitator:	Board of Directors
Description:	As the name implies, the Late-Season EWM Mapping Survey is a professionally contracted survey completed towards the end of the growing season when the plant is at its anticipated peak growth stage, allowing for a true assessment of the amount of this exotic within the lake. For the Cloverleaf Lakes, this survey would likely take place in mid-August to the end of September, dependent on the growing conditions of the particular year. This survey would include a complete meander survey of the system's littoral zone by professional ecologists and mapping using GPS technology (sub-meter accuracy is preferred). Late Season EWM Mapping Surveys have been conducted annually since 2011, allowing for lake stakeholders to understand annual EWM populations in response to natural variation and directed management activities. These surveys are also used as the trigger within a subsequent management goal for management. The CLPA would like to continue annual EWM mapping surveys with supplemental assistance from volunteer monitors. The CLPA volunteers would

	informally survey the lake and talk to riparians about their perceived level of concerns. The volunteer monitors would convey information to the consultant prior to the Late Season EWM Mapping Survey. Depending on the results of the volunteer-based monitoring, the Late-Season EWM Mapping Survey may be reduced to a more focused part of the system. The CLPA will also investigate grant funding opportunities to help fund this survey in the future. This will likely consist of a Surface Water AIS Control Grant, which have an application deadline of November 1 of each year, with intent materials being due 60 days prior (September 2).

Management Action:	Initiate early detection monitoring program for starry stonewort
Timeframe:	Annual during latter part of growing season
Facilitator:	Board of Directors
Description:	Starry stonewort (SSW) is a non-native macro-algae that was first discovered in a southeastern Wisconsin lake in 2014, and has now been verified within 14 inland lakes within five counties. Starry stonewort was also found in Sturgeon Bay in 2016 and subsequent investigations indicate this species is present in coastal areas of Lake Michigan and Green Bay. Starry stonewort was located at six point-intercept survey sampling locations within Pine Lake during a 2021 survey conducted by Onterra staff. Preliminary data from Wisconsin Lakes indicate that SSW frequency can vary across lakes, with some lakes experiencing rapid increase in SSW frequency after discovery, while other lakes have seen a much slower rate of expansion. To date, there have not been any effective chemical management strategies for SSW. The WDNR's permitting guidance for SSW states that herbicide permits maybe considered to relieve nuisance conditions in high-traffic areas, but permits for population management will not be considered until an effective method of SSW population control is identified. The WDNR encourages monitoring of all SSW populations on inland lakes through the point-intercept survey methodology. The CLPA will work with the WDNR to initiate an early-detection monitoring project on the Cloverleaf Lakes, likely consisting of annual point-intercept survey monitoring on Pine Lake and possibly including all three Cloverleaf Lakes. The WDNR offers Early Detection and Response Grants for pioneering populations of NR40-classified *restricted* invasive species, and for NR40-classified *prohibited* species. Starry Stonewort is considered by NR40 to be a *prohibited* species and therefore eligible for these grant funds.

Management Action:	Coordinate periodic point-intercept surveys
Timeframe:	Periodic: at least every 5 years
Facilitator:	Board of Directors
Description:	The point-intercept survey provides a standardized way to gain quantitative information about a lake's aquatic plant population through visiting predetermined locations and using a rake sampler to identify all the plants at each location. At each point-intercept location within the *littoral zone*, information regarding the depth, substrate type (soft sediment, sand, or rock), and the plant species sampled along with their relative abundance (rake fullness) on the sampling rake is recorded. The WDNR indicates that conducting a point-intercept survey as described Wisconsin Department of Natural Resources Bureau of Science Services, PUB-SS-1068 2010 (Hauxwell et al. 2010) approximately once every five years will generally suffice to meet WDNR planning requirements unless large-scale aquatic plant management is taking place and more frequent monitoring is requested for the specifically targeted areas. The Cloverleaf Lakes have been actively involved with EWM/HWM management, particularly since 2010; therefore, the point-intercept survey has been conducted on most lakes almost every year during that time frame. The CLPA will ensure that a point-intercept survey is completed on each lake within a 5-year period or more frequently, depending on the scale of active management that is occurring.

Management Action:	Coordinate periodic community mapping surveys (floating-leaf and emergent colonies)
Timeframe:	Periodic: every 10 years or when prompted
Facilitator:	Board of Directors
Description:	This survey would delineate the margins of floating-leaf (e.g., water lilies) and emergent (e.g., cattails, bulrushes) plant species using GPS technology (preferably sub-meter accuracy) as well as document the primary species present within each community. Changes in the footprint of these communities can be strong and early indicators of environmental perturbation as well as provide information regarding various habitat types within the system. To continue understanding the dynamics of the emergent and floating-leaf aquatic plant communities in the Cloverleaf Lakes, a community mapping survey would be conducted approximately every 10 years as a part of an updated planning project unless a specific rationale prompts a shorter interval. Replicating this survey in the future will be particularly important for the

	bulrush island in Grass Lake that has been reportedly reducing in size and density over time.

Management Goal 3: Manage Aquatic Invasive Species and Prevent Establishment of New Aquatic Invasive Species

Management Action:	Monitor Cloverleaf Lake entry points for aquatic invasive species
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	The intent of this program is not only be to prevent additional invasive species from entering the Cloverleaf Lakes through its public access locations, but also to prevent the infestation of other waterways with invasive species that originated in the Cloverleaf Lakes. This is particularly important for containing starry stonewort, which is not known from any other nearby waterbodies. The CLPA continues to support watercraft inspections occurring on local waters. It would be most helpful to have watercraft monitors at 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 its spread. A Clean Boat Clean Waters (CBCW) watercraft inspection program has been in place on the Cloverleaf Lake since at least 2004, with greater than 400 hours of inspections occurring annually since 2010. The CLPA would like to continue operating at that level, which equates to approximately 32 hours per week during the summer. The CLPA uses a paid watercraft inspection model with partnership from the Town of Belle Plaine administrating payroll and cost share through the WDNR's streamline Clean Boats Clean Waters (CBCW) program: https://dnr.wi.gov/Aid/documents/SurfaceWater/CleanBoatsCleanWatersFactSheet.pdf Based upon modeling by the University of Wisconsin Center for Limnology, Grass Lake is on the list of the state's top 300 AIS Prevention Priority Waterbodies. This means that these lakes have a high number of boats arriving from lakes that have AIS (receiving) and a high number of boats moving from the Cloverleaf Lakes to uninvaded waters (sending). Therefore, the WDNR encourages additional supplemental prevention efforts above just watercraft inspections, offering additional grant funds for these activities for applicable lakes. Supplemental prevention efforts such as decontamination stations (e.g., pressure washer) and remote video surveillance (e.g., I-Lids™) could be funded through this program.

	The CLPA will strive to have updated signage at the Grass Lake boat landing kiosk promoting CBCW messaging. They will also consider supplemental prevention efforts as described above.

Management Action:	Actively manage EWM to keep system-wide populations low
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	As discussed within the Non-Native Aquatic Plants sub-section (4.3), there are differing management philosophies and approaches to invasive aquatic plant species. Where EWM populations already have an established footprint in the lake and are already present in most nearby waterbodies, such as in the southeast part of Wisconsin, most populations are no-longer managed for an overall lowered population. In these instances, the nuisance conditions are targeted for management and other areas are tolerated or avoided. Since first being located in the Cloverleaf Lakes, the CLPA has managed for a goal of maintaining a low chain-wide population of invasive watermilfoil within the system. The CLPA believes they have been effective with this strategy to date and would like to continue moving forward with that same philosophy. The CLPA intends to use an integrated approach of herbicide treatment and hand-harvesting (includes DASH) for managing HWM within the Cloverleaf Lakes. Because of the relatively small size of each lake within the Cloverleaf Chain, the CLPA will also embrace spot-treatment and whole-lake herbicide treatment approaches. The CLPA intends to use herbicide application as the primary tool for HWM population management, with hand-harvesting actions potentially employed as follow-up to herbicide management or for targeting EWM to reduce conditions in strategic locations. The CLPA has outlined the following threshold (trigger) for when to consider an herbicide spot treatment: • *target colonized areas of HWM with a density of dominant or greater, extending treatment areas to adjacent areas of HWM* • *prioritize high use or riparian frontage* If the CLPA's trigger is reached, they would start understanding what is considered the current best management practice (BMP) for HWM spot herbicide treatment. While some herbicide spot treatments show promise, the unpredictability of spot treatments state-wide has resulted in less favorability of this strategy with some WDNR regulators and lake managers. This is particularly true in areas of increased water exchange via flow, exposed and offshore EWM colonies, or when traditional weak-acid herbicides like 2,4-D are used.

Herbicide spot treatment techniques would only be considered if the colonies have a size/shape/location where management is anticipated to be effective. In general, this would be areas confined to bays (not exposed), broad in shape (not narrow bands), and of sufficient size to hold core concentrations and exposure times (likely at least 3 acres or larger). Future spot herbicide treatments on Cloverleaf Lakes would consider herbicides thought to be effective under short exposure situations. At the time of this writing, florpyrauxifen-benzyl (ProcellaCOR™), a combination of 2,4-D/endothall (Chinook®), and a combination of diquat/endothall (Aquastrike™) are examples of herbicides with reported short exposure time requirements that are employed for invasive watermilfoil control in Wisconsin. Advancements in research into new herbicides and use patterns will need to be integrated into future management strategies, including effectiveness, native plant selectivity, and environmental risk profile.

Protected areas targeted with spot treatments would consider additive impacts within an Area of Potential Impact (AOPI), such that if calculated lake/basin-wide levels reach potentially impactful concentrations, they are accounted for in the treatment and monitoring strategy. The CLPA has outlined the following threshold (trigger) for when to consider an intentional whole-lake treatment:

- *whole-lake point-intercept survey is approaching EWM at 20% of littoral sampling locations*
- *consecutive whole-lake treatments will not occur within 3 years*

If CLPA decides to pursue future herbicide management towards HWM, the following set of bullet points would occur:

- Early consultation with WDNR would occur.
- The preceding annual AIS monitoring report would outline the precise control and monitoring strategy.
  - Monitoring for EWM efficacy at the scale of likely impact. If the treatment is a true spot treatment, the application area should be monitored. If the Area of Potential Impact (AOPI) is larger, such as a basin or an entire lake, that AOPI should be monitored.
  - HWM efficacy would occur by comparing annual late-summer HWM mapping surveys
  - If grant funds are being used or new-to-the-region herbicide strategies are being considered, the WDNR may request a quantitative evaluation monitoring plan be constructed that is consistent with the *Draft Aquatic Plant Treatment Evaluation Protocol (October 1, 2016):*

    https://dnrx.wisconsin.gov/swims/downloadDocument.do?id=158140137 This generally consist of collecting quantitative point-intercept before the treatment (pre) and the summer following the treatment (post) at the scale of AOPI.

	- Herbicide concentration monitoring may also occur surrounding the treatment if grant funds are being used or the CLPA believes important information would be gained from the effort. • An herbicide applicator firm would be selected in late-winter and a permit application would be applied to the WDNR as early in the calendar year as possible, allowing interested parties sufficient time to review the control plan outlined within the annual report as well as review the permit application. • Unless specified otherwise by the manufacturer of the herbicide, an early-season use-pattern would likely occur. This would consist of the herbicide treatment occurring towards the beginning of the growing season (typically in June) and active growth tissue is confirmed on the target plants. A focused pretreatment survey would take place approximately a week or so prior to treatment. This site visit would evaluate the growth stage of the HWM (and native plants) as well as to confirm the proposed treatment area extents and water depths. This information would be used to finalize the permit, potentially with adjustments and dictate approximate ideal treatment timing. Additional aspects of the treatment may also be investigated, depending on the use pattern being considered, such as the role of stratification.

Management Action:	Reduce occurrence of emergent AIS along Cloverleaf Lakes shorelands
Timeframe:	Annually as volunteerism allows
Facilitator:	Board of Directors
Description:	Three primary species of non-native emergent plants have been identified from the margins of the Cloverleaf Lakes: purple loosestrife, pale-yellow iris, and phragmites grass. All three species have the capacity to displace native species and disrupt the function of important ecosystems. Likely the species of greatest threat is phragmites. This species is notoriously hard to remove from an area once established. The CLPA will prioritize removal of phragmites from the Cloverleaf shorelands with the assistance of member volunteers. The ownership of shorelines with identified plants will be contacted to receive access permission. The identified plants would be bundled together and cut above where they are bundled. These cut ends would be targeted with an appropriate herbicide (e.g. imazapyr) in the early fall when this species is more likely to be translocating towards roots and rhizomes. The use of herbicides near water or wet ground may require a permit and aquatic formulas of herbicide. More information on phragmites identification and management can be found here: https://dnr.wisconsin.gov/topic/Invasives/fact/Phragmites.html

	Purple loosestrife is the species with the second-greatest threat to the Cloverleaf Lakes, particularly wetland areas. The CLPA will also prioritize purple-loosestrife removal along the shorelines of the Cloverleaf Lakes. During approximately the third week in August, the volunteers would search the system for purple loosestrife. Plants found would be tagged with ribbon and their flower heads are removed, bagged, and properly disposed of. Follow-up herbicide applications would conducted using aquatic-approved glyphosate products. More information on purple loosestrife identification and management can be found here: https://dnr.wisconsin.gov/topic/Invasives/fact/PurpleLoosestrife.html Pale-yellow iris is a non-native plant that can get a little invasive, but often times it does along the margins of the lake. Some resource managers feel it is important to limit the population of pale-yellow iris as an effort to limit its spread. Other resource managers acknowledge its wide-scale distribution and only encourage management efforts when located in a valuable wetland. Many riparians that prefer the urbanized landscape may not mind having pale-yellow iris on their shoreline and some may feel that is better than mowed grass for the health of the lake in terms of providing some habitat and sediment stabilizing value. The CLPA will educate its membership on pale-yellow iris and the importance of native species around the lake. The CLPA will actively remove pale-yellow iris plants when found along the margins of Gibson Island. More information on pale-yellow iris identification and management can be found here: https://dnr.wisconsin.gov/topic/Invasives/fact/YellowFlagIris.html

Management Goal 4: Maintain Current Water Quality Conditions

Management Action:	Monitor water quality parameters through WDNR Citizens Lake Monitoring Network.
Timeframe:	Continuation of current effort
Facilitator:	Kevin Goodman
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 may lead to the reason of why the trend is occurring. Volunteer water quality monitoring will be completed annually by Cloverleaf Lake riparians through the Citizen Lake Monitoring Network (CLMN). The CLMN is a WDNR program in which volunteers are trained to collect water quality information on their lake. The CLPA currently monitor a single site in all three lakes (at the deep hole) under the advanced CLMN program. This includes collecting Secchi disk transparency, as well as sending in water

	chemistry samples (chlorophyll-*a*, and total phosphorus) to the Wisconsin State Laboratory of Hygiene (WSLH) for analysis. The samples are collected three times during the summer and once during the spring. It is 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). As a part of this management planning process, it has been determined that internal nutrient loading is occurring. In order to better understand the magnitude of impact of this phenomenon, the CLPA will again collect hypolimnetic phosphorus concentrations at the time of its next Plan update. In addition, the CLPA will continue to collect temperature and dissolved oxygen profiles in conjunction with the CLMN monitoring schedule and manually enter the data into SWIMS. It also must be noted that the CLMN program may be changing in the near future with sample analysis cost coverage not available annually. Recently there has been a move to have new CLMN volunteers collect samples for three years and then stop so that additional lakes can be funded. If a long-term record is desired by the CLPA then it will be important to maintain the volunteer data collection without a lapse. The CLPA board will need to review the specifics of the revised program when available and potentially modify this management action.
Action Steps:	
1.	Trained CLMN volunteer(s) collects data, enters data into SWIMS, and report results to association members during annual meeting.
2.	CLMN volunteer and/or CLPA board would facilitate new volunteer(s) as needed

Management Action:	Promote overall watershed health
Timeframe:	Initiate in 2022
Facilitator:	Board of Directors
Description:	The Cloverleaf Lakes have a relatively small watershed, but a relatively large proportion of that watershed is in row crop agriculture. This type of land cover has the potential to deliver the largest amount of phosphorus to the lake, fueling algae and plants within the system. The CLPA will work with partner organizations, such as the Fox-Wolf Watershed Alliance (FWWA) and the Waterways Association of Menominee and Shawano Counties (WAMSCO), to provide education to farmers within the watershed on best practices for impacts to downstream waterways. The CLPA will give consideration to volunteer-based monitoring of the inlet streams entering into Round and Grass Lake. The goal of this program would

	be to understand whether these point-sources are deliverable a concerning amount of nutrients to the system. The CLPA would seek regional WDNR staff in reference to this program.

Management Action:	Facilitate connecting Cloverleaf Lake Riparians with Healthy Lakes & River Grants
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program, now called the Healthy Lake and Rivers Grant program, provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality: • Rain Garden • Rock Infiltration • Diversion • Native Plantings • Fish Sticks The cost share allows $1,000 per practice, up to $25,000 per annual grant application. More details and resources for the program can be found at: https://healthylakeswi.com Partial funding for shoreland restoration activities is available through the WDNR Healthy Lakes Initiative but needs to be applied for by a qualified lake group such as the CLPA, not an individual riparian. The above Healthy Lakes practices are important and applicable to all riparian properties except the addition of fish sticks. Fish stick projects need to be implemented in accordance to approved technical requirements from the local WDNR fisheries biologist and complies with local shoreland zoning ordinances. It's important to reiterated the importance of working with the local WDNR fisheries biologist (Jason Breeggemann) prior to implementing fish stick projects to ensure the activity will be beneficial for the fish species being managed for. That being said, the Belle Plaine Sportsman's Club in cooperation with the WDNR has installed numerous fish stick projects along Gibson Island. Water levels have been relatively high on the Cloverleaf Lakes in recent years, causing riparians concern over increased shoreland erosion. While the WDNR promotes vegetated shorelines as the primary way landowners can protect their shorelines, they acknowledge that additional practices may be required in some instances. The WDNR favors properly implemented rip-

	rap/rock to satisfy this need. In these instances, the CLPA encourages shoreland buffers be added above the shoreline modification practice and will actively promote this practice to these property owners. The CLPA has made shoreline restoration a priority, assisting with many projects including approximately 25 Healthy Lakes projects in recent years. The CLPA assists with the grant application and project coordination, but all direct and indirect costs would be the responsibility of the benefiting riparian. The CLPA has set a goal to have at least 5 new Healthy Lakes projects annually. The CLPA intends to assemble a series of sample design plans for distribution to potentially interested riparians. This would include a list of plant species readily available from an established nursery that have been proven well to grow around the margins of the Cloverleaf Lakes. Further, the CLPA intends to use existing shoreland restoration locations as demonstration sites in an effort to bolster more interest in shoreland restoration practices. The CLPA may organize tours of demonstration sites for interested parties to view and ask questions.

Management Goal 5: Improve Lake and Fishery Resource

Management Action:	Request Town of Belle Plaine consider emergency slow-no-wake declaration for high water
Timeframe:	Initiate 2022
Facilitator:	Board of Directors
Description:	As discussed in the previous management action related to shoreland restoration, water levels have been relatively high on the Cloverleaf Lakes in recent years, causing riparians concern over increased shoreland erosion. High amounts of recreational use are common on the Cloverleaf Lakes. At high water levels, the impact of wave activity from motor boating on shoreland erosion increases. The CLPA would work with the Town of Belle Plaine to consider an emergency slow-no-wake ordinance when water levels exceed a predefined level.

Management Action:	Continue monitoring water levels
Timeframe:	Continuation of current effort with enhancement
Facilitator:	Board of Directors
Description:	Cloverleaf Lake riparians have conducted water level monitoring for decades, providing extremely valuable information for understanding ecological changes in the system. The CLPA supports this effort and wants to make sure it continues in the future with the data collected in a compatible fashion. The CLPA would also like to use the water level data to support the previous management action of triggering slow-no-wake boating. The CLPA is considering adding a staff gauge near the Hwy Y culvert and/or entering into the WDNR's water level monitoring program that was recently added to the Citizen's Lake Monitoring Network. The CLPA would reach out to Scott Koehnke, WDNR Water Management Specialist, for additional discussion.

Management Action:	Work with WDNR to preserve and enhance the fisheries of the Cloverleaf Lakes.
Timeframe:	Initiate in 2022
Facilitator:	Board of Directors
Description:	The Cloverleaf Lakes are a regionally important fisheries resource. The CLPA will continue to work with the Belle Plaine Sportsman's Club to promote a strong fisheries program on the Cloverleaf Lakes. As discussed in the Fisheries Data Integration Section (3.6), the Cloverleaf Lakes contain a healthy bass and muskellunge population, but likely are not a good fit for a sustainable walleye population. The CLPA, in conjunction with the Sportsman's Club, would like to work with the WDNR to better understand the role of walleye within this system and determine if additional walleye stocking and habitat improvement projects should be discontinued in lieu of focusing on improving other fish populations. Special panfish regulations were initiated on the Cloverleaf Lakes in 2016. WDNR crews intended to sample the Cloverleaf Lakes in 2022 to verify whether the new regulations are having an impact on the size structure of panfish. If the 2022 WDNR surveys document improvements in panfish size structure, the CLPA will continue to work with local fisheries managers to support continuation of the experimental harvest-limit regulations.

Management Action:	Reduce nuisance wildlife activity
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	The natural shorelines of Round Lake are ideal habitat for muskrats and beavers. If these populations are left unchecked, damage and destruction of riparian shorelines can occur and has been documented in the past. If nuisance actions occur from muskrats and beavers, the CLPA would facilitate the hiring of trappers by referring inquiries to an approved list maintained by the CLPA, and would refer safety-related nuisance problems to the Town of Belle Plaine. The CLPA board might also consider whether to return to a previous practice of helping defray costs for riparians by making funds available for the purpose of muskrat control. Vegetated and wooded natural shorelines are the best way to discourage geese from coming on to properties. But green space exists around the lake as it allows riparians to use the nearshore areas for recreation. High populations of geese can leave aesthetically unpleasing waste behind as well as damage valuable native plants and landscaping. The CLPA will promote natural shorelines as a way to discourage geese activity on the Cloverleaf Lakes. If conditions do not improve, the CLPA would consider looking into more active forms of geese control such as harvest or egg addling. Addling is the process of applying an oil to the egg to terminate embryo development but leave the egg intact so the goose does not lay additional eggs. These programs would be conducted by hired contractors in conjunction with WDNR and the US Fish and Wildlife Service.

Management Action:	Continue the Loon Watch Program
Timeframe:	Continuation of current effort with enhancement
Facilitator:	Board of Directors
Description:	The Loon Watch Program is operated through the Sigurd Olson Environmental Institute from Northland College. The purpose of the program is to provide a picture of common loon reproduction and population trends on northern Wisconsin lakes. Loon watch volunteers send in a yearly report on sightings of any loon activity, number counts, chicks observed, and markings on a lake map where loons were seen. With the decreasing size and density of the bulrush island on Grass Lake, the CLPA will consider working with Northland College to determine if artificial loon nesting platform(s) would be appropriate for this system.

Management Action:	Continue to protect and enhance Gibson Island.
Timeframe:	Continuation of current effort
Facilitator:	Board of Directors
Description:	The centerpiece of Cloverleaf Lakes is Gibson Island (actually an "island" that has a one-lane walking path isthmus). More information about this 25-acre property is included within the Introduction Section (1.0). Gibson Island contributes more than 5,000 feet of natural shoreland as well as several "fish sticks" and natural tree falls along the shore. A town Stewardship Committee oversees the property, maintaining trails and controlling invasive plants. Local citizens as well as a youth corps participate in the anti-invasives project and native plants were added on a portion of the property. The CLPA will continue to support the Gibson Island Stewardship Committee and the protection and enhancement of Gibson Island.

Management Action:	Continue to promote water safety
Timeframe:	Continuation of current effort with enhancement
Facilitator:	Board of Directors
Description:	The Town of Belle Plaine has enacted boating ordinances to "to provide for the safety, welfare, healthful conditions and enjoyment of recreational boating enthusiast and riparian landowners consistent with public rights, interests and capabilities of the waterways listed." The CLPA will continue to advertise these ordinances at the Grass Lake landing kiosk, handouts, and through word of mouth. The CLPA will also consider creating a courtesy code, which would include advised actions in addition to the laws put in through local ordinance. Examples would include providing space for wildlife, reminders not to litter, recommend non-lead fishing tackle, proper decontamination procedures for entering/exiting waters, and respect for private property. The CLPA and the Town of Belle Plaine have hired water patrol through the Shawano County Sherriff's department to enforce state laws and local ordinances on the Cloverleaf Lakes. The CLPA would like to continue this effort in the future, potentially finding ways to increase the amount of water patrols on the system that are limited by staffing availability.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the Cloverleaf Lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on the lake that would most accurately depict the conditions of the lake. Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by CLMN volunteers, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit.

All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (WSLH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

	Spring		**June**	**July**		**August**	**Fall**		**Winter**	
Parameter	**S**	**B**	**S**	**S**	**B**	**S**	**S**	**B**	**S**	**B**
Total Phosphorus	■	■	♦	■	■	♦	■	■	■	■
Dissolved Phosphorus	■	■							■	■
Chlorophyll-*a*	■		♦	■		♦	■			
Total Nitrogen	■	■	●	■		●			■	■
True Color	■			■						
Laboratory Conductivity	■	■		■	■					
Laboratory pH	■	■		■	■					
Total Alkalinity	■	■		■	■					
Hardness	■									
Total Suspended Solids	■	■					■	■		
Calcium	■									

♦ indicates samples collected as a part of the Citizen Lake Monitoring Network.
● indicates samples collected by volunteers under proposed project.
■ indicates samples collected by consultant under proposed project.

Watershed Analysis

The watershed analysis began with an accurate delineation of each lakes' 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) (USGS, 2019) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska & Kreider, 2003)

Point-Intercept Macrophyte Survey

Comprehensive surveys of aquatic macrophytes were conducted on Cloverleaf Lakes to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) (Hauxwell et al. 2010) was used to complete this study.

Floating-Leaf & Emergent Plant Community Mapping

During the species inventory work, the aquatic vegetation community types within Cloverleaf Lakes (emergent and floating-leaved vegetation) were mapped using a Trimble Pro6T Global Positioning System (GPS) receiver with sub-meter accuracy. Furthermore, all species found during the point-intercept surveys and the community mapping surveys were recorded to provide a complete species list for the lake.

AIS Mapping Surveys

During these surveys, the entire littoral area of the lake was surveyed through visual observations from the boat. Field crews may supplement the visual survey by deploying a submersible camera along with periodically doing rake tows. The AIS population is mapped using sub-meter GPS technology by using either 1) point-based or 2) area-based methodologies. Large colonies >40 feet in diameter are mapped using polygons (areas) and were qualitatively attributed a density rating based upon a five-tiered scale from *highly scattered* to *surface matting*. Point-based techniques were applied to EWM locations that were considered as *small plant colonies* (<40 feet in diameter), *clumps of plants*, or *single or few plants*

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8.0 INDIVIDUAL LAKE SECTIONS

The remainder of this plan will investigate the data on a lake-by-lake basis. Some of the text may seem redundant if one reads each lake section. However, this is intentional to ensure the information is portrayed to those who only read the chain-wide section and their individual lake-specific section.

Methodology, explanation of analysis and scientific background are contained within the Cloverleaf Lakes Chain-wide Management Plan document.

8.1.0 Round Lake Introduction

An Introduction to Round Lake

Round Lake, Shawano County, is a deep, headwater mesotrophic drainage lake with a maximum depth of 39 feet, a mean depth of 26 feet, and a surface area of approximately 28 acres. Its surficial watershed encompasses approximately 713 acres comprised mainly of forests, wetlands and row crop agriculture. Water from Round Lake flows out into Grass Lake and eventually into Pine Lake and eventually into Matteson Creek which flows into the Embarrass River. In 2020, 27 native aquatic plant species were located within the lake, of which muskgrasses (*Chara* spp.) were the most common. During the 2020 survey, six invasive plants were found in Round Lake: Eurasian watermilfoil, curly-leaf pondweed, pale-yellow iris, purple loosestrife, giant reed, and watercress.

Lake at a Glance - Round Lake

Morphometry	
Lake Type	Deep Headwater Drainage Lake
Surface Area (Acres)	28
Max Depth (feet)	39
Mean Depth (feet)	26
Perimeter (Miles)	0.9
Shoreline Complexity	1.3
Watershed Area (Acres)	713
Watershed to Lake Area Ratio	25:1

Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	13
Avg Summer Chl-α (µg/L)	4
Avg Summer Secchi Depth (ft)	9.7
Summer pH	8.6
Alkalinity (mg/L as $CaCO_3$)	166

Vegetation	
Number of Native Species	27
NHI-Listed Species	-
Exotic Species	Eurasian watermilfoil; Curly-leaf pondweed, Pale-yellow iris, Purple loosestrife, Giant reed, Watercress
Average Conservatism	5.6
Floristic Quality	25.4
Simpson's Diversity (1-D)	0.80

Descriptions of these parameters can be found within the chain-wide portion of the management plan

8.1.1 Round Lake Water Quality

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, and whether its health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, the status of a lake's water quality can be made by comparison.

Near-surface total phosphorus data for Round Lake are available from 1981, 2000, and 2005-2020 (Figure 8.1.1-1). All historical near-surface total phosphorus concentrations and the data collected as part of the lake management planning project in 2020 fall within the *excellent* category for deep, headwater drainage lakes in Wisconsin. The weighted average of summer near-surface total phosphorus concentrations using all data that are available is 12.8 µg/L, and falls below the median concentration for other deep, headwater drainage lakes in Wisconsin (17.0 µg/L) and considerably below the median concentration for all lake types within the North Central Hardwood Forests (NCHF) ecoregion (52.0 µg/L). Phosphorus concentrations have been stable during the period 2006-2020 and an increasing trend was not observed.

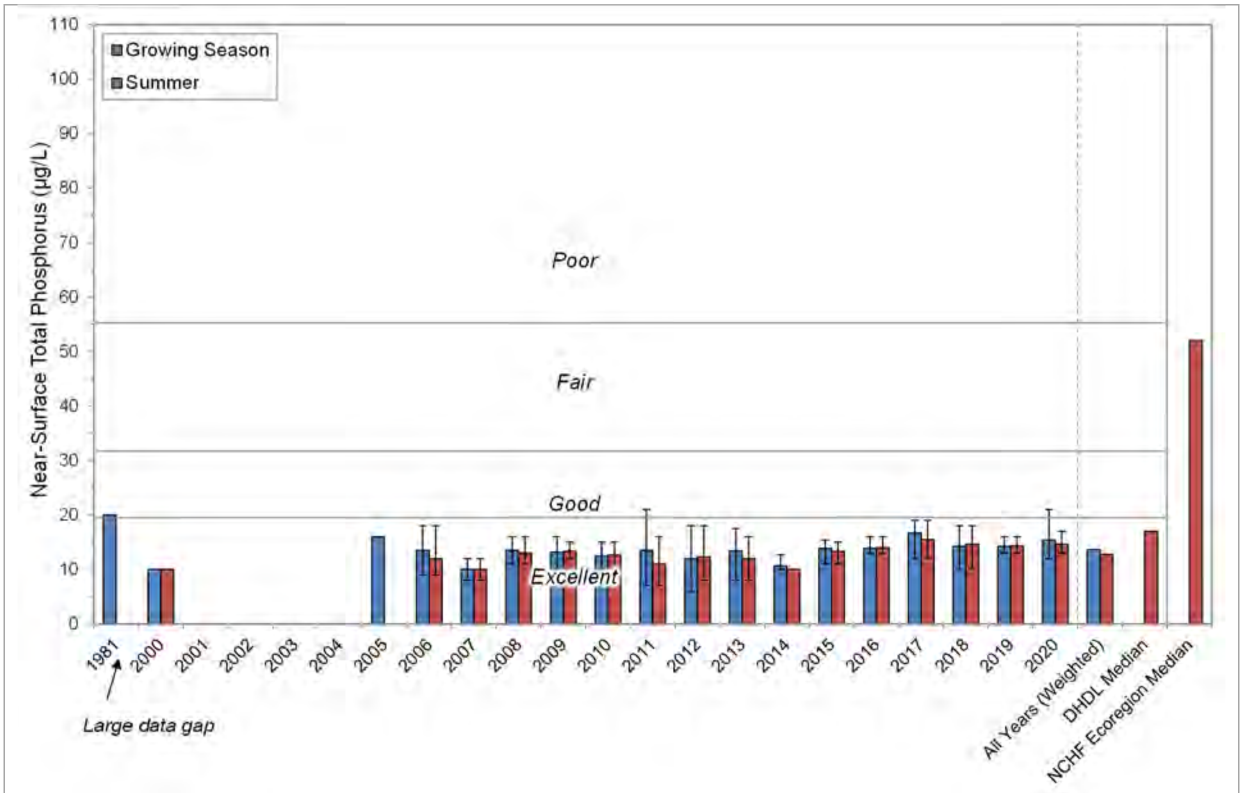


Figure 8.1.1-1. Round Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake during stratification. In lakes which experience high levels of internal nutrient loading, the near-bottom phosphorus concentrations are significantly higher than those measured near the surface.

Near-bottom total phosphorus concentrations were collected on four occasions in 1981 and on three occasions in 2020 from Round Lake (Figure 8.1.1-2). In 1981, near-bottom concentrations were only higher than near-surface concentrations on one occasion—November. In April and July 2020 bottom concentrations were much higher than the near-surface concentrations suggesting that internal loading is occurring during the ice covered period as well as when the lake is stratified during the summer. The high concentration in April 2020 is because the lake did not mix during the spring in that year. In October 2020 fall mixing was occurring so bottom and surface concentration were similar. Although phosphorus concentrations in the bottom waters in 2020 were elevated, the phosphorus concentration during fall turnover was only slightly elevated indicating that at the present time internal loading is not significant. However, the suggestion of some internal loading in 2020 compared with 1981 is a sign that internal loading could become more of a problem.

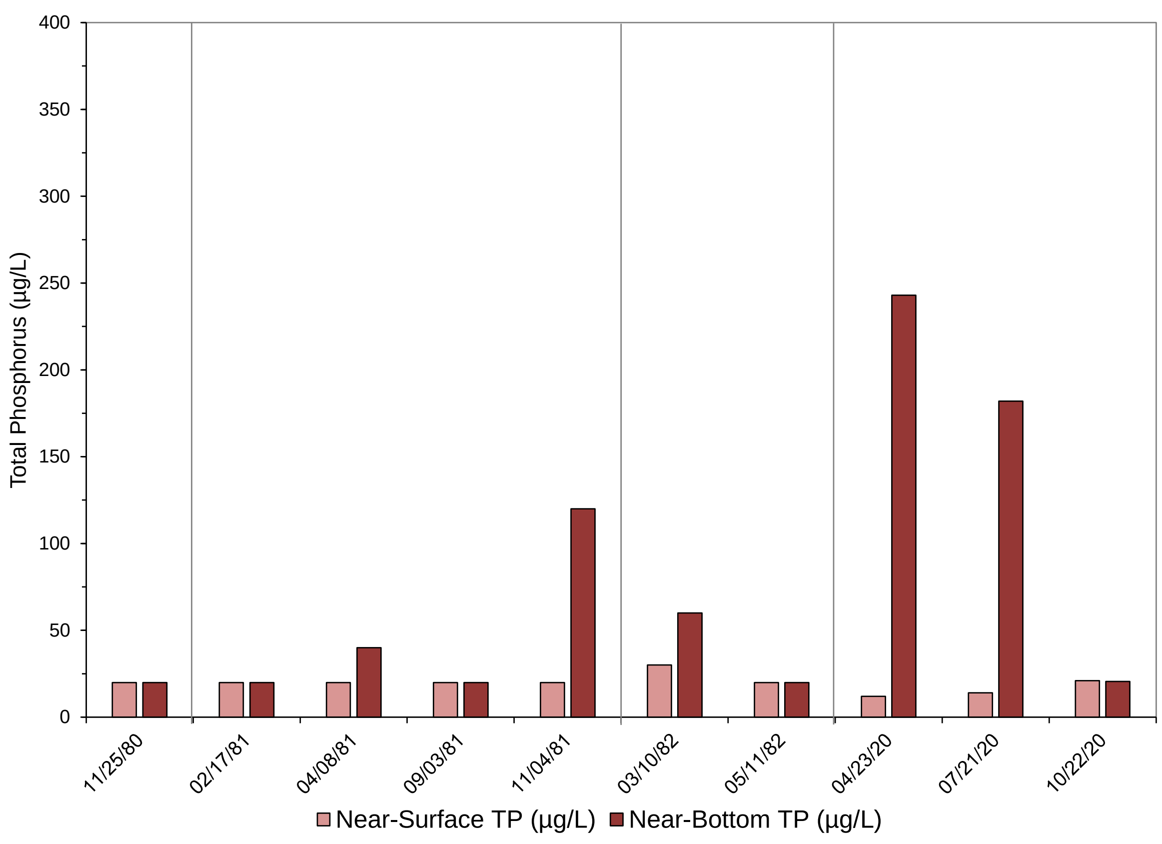


Figure 8.1.1-2. Round Lake near-bottom and corresponding near-surface total phosphorus concentrations.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Round Lake from 1981 and 2005-2020 (Figure 8.1.1-3). For the period 2006-2018, all of the mean summer concentrations were in the *excellent* range with a mean concentration of 3.5 µg/L. For the last two years (2019-20), the mean summer concentrations have increased are now in the *good* category. It is not clear why there has been an increase during the last two years as phosphorus concentration did not increase. The long-term mean summer concentration is 4.0 µg/L which is less than the median value for other deep, headwater drainage lakes in Wisconsin (5.0 µg/L) and swore much less than the median concentration for all lake types within the NCHF ecoregion (15.2 µg/L). However, the mean concentration for the last two years of 6.8 µg/L is higher than the median value for deep headwater drainage lakes in Wisconsin.

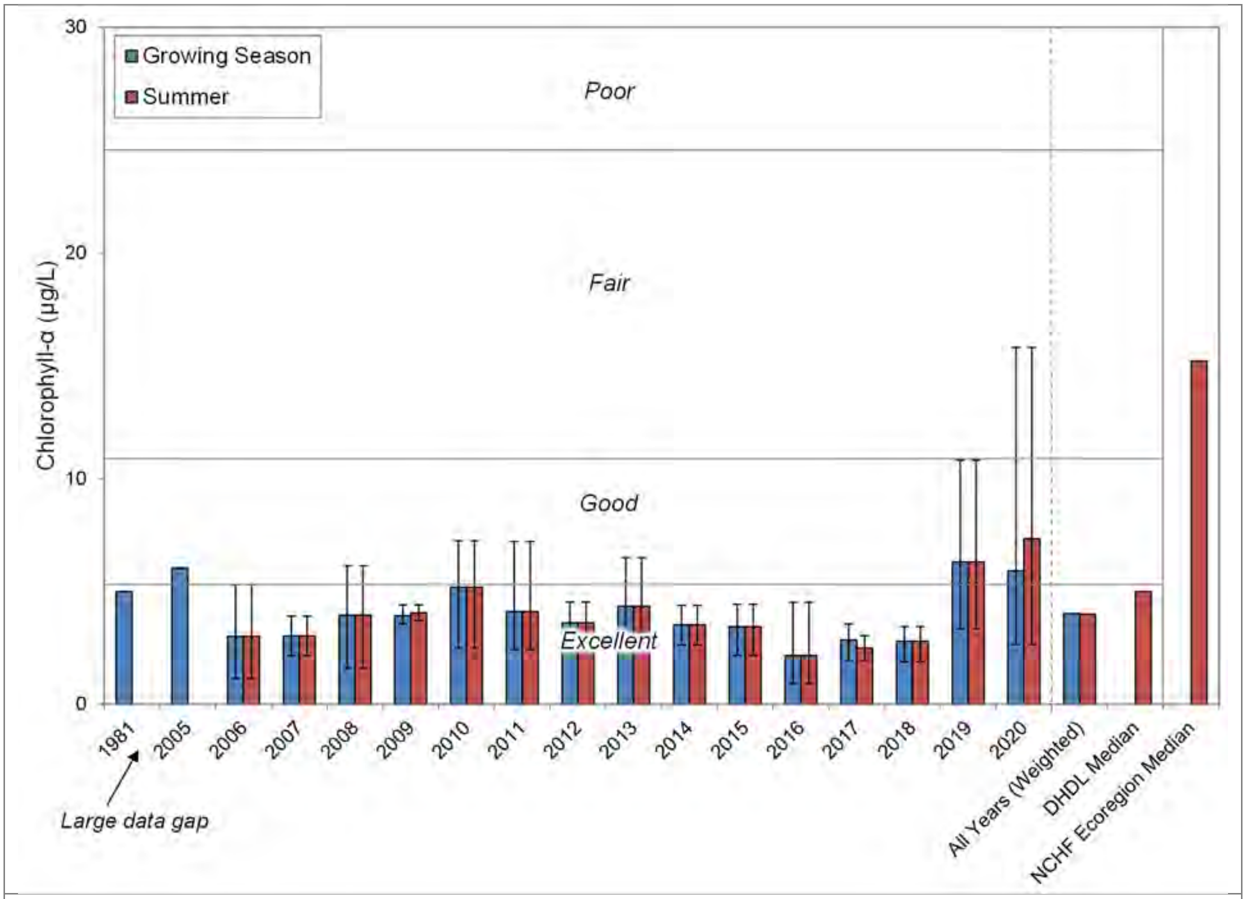


Figure 8.1.1-3. Round Lake average annual near-surface chlorophyll-*a* concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

There is a considerably longer record of Secchi disk transparency from Round Lake compared with phosphorus or chlorophyll *a*. A continuous record from 1987 to 2020 is available (Figure 8.1.1-4). For the period 1987-2000, the mean summer Secchi disk transparency (10.8 feet) fell within the *excellent* category for deep, headwater drainage lakes. However for the period 2001-2020 the summer water clarity was not as good with a mean summer Secchi disk transparency of 8.2 feet. This places the lake on the border between the excellent and good categories. This mean transparency is less than the median depth (10.8 feet) for deep headwater drainage lakes in Wisconsin but is much better than the median value (5.3 feet) for all lake types in the NCHF ecoregion.

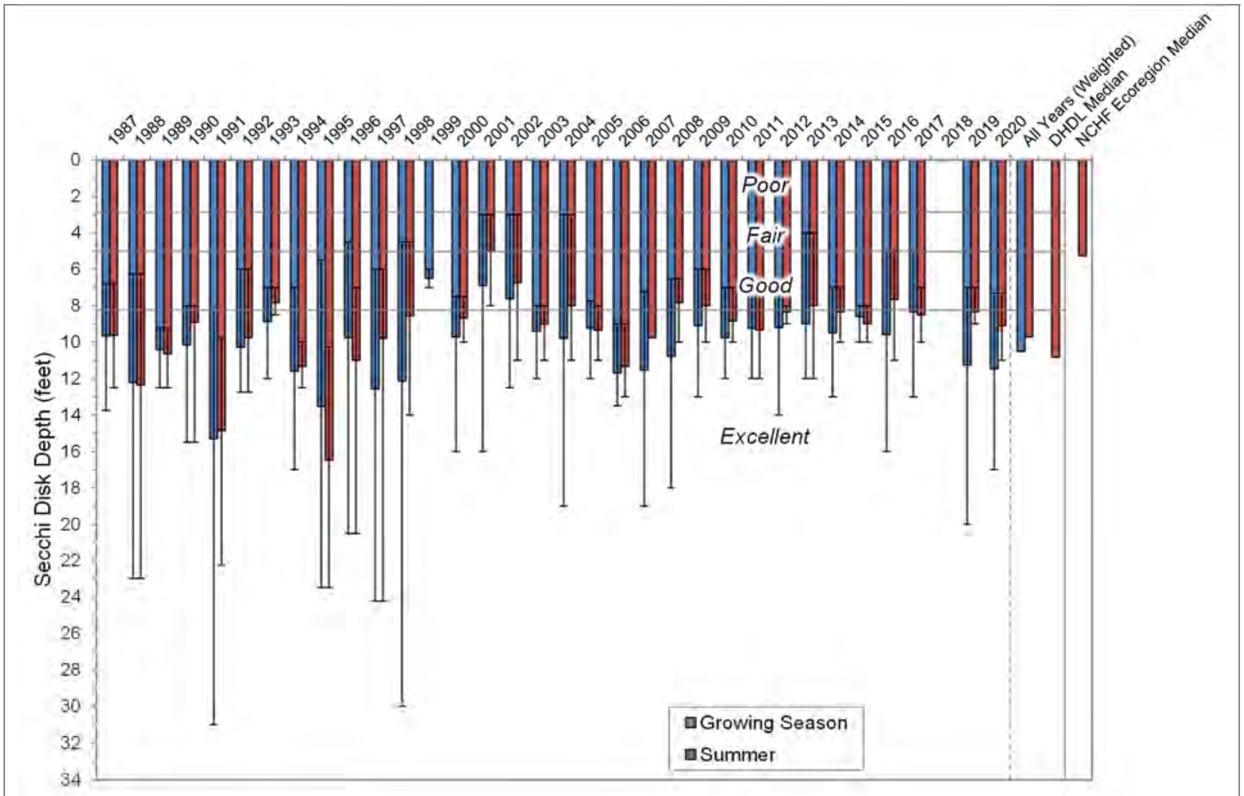


Figure 8.1.1-4. Round Lake average annual Secchi disk transparency and median Secchi disk transparencies for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Round Lake Trophic State

The Trophic State Index (TSI) values for Round Lake were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figure 8.1.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae. Historical data indicate that Round Lake was in a mesotrophic state, but with the increase in phosphorus and chlorophyll-*a* in recent years, the lake is currently in a lower eutrophic state.

Using the overall weighed TSI value, it can be said that Round Lake is a mesotrophic system. Round Lake's productivity level is comparable to other deep headwater drainage lakes in the state and less than other lakes in the Northern Lakes and Forests Ecoregion.

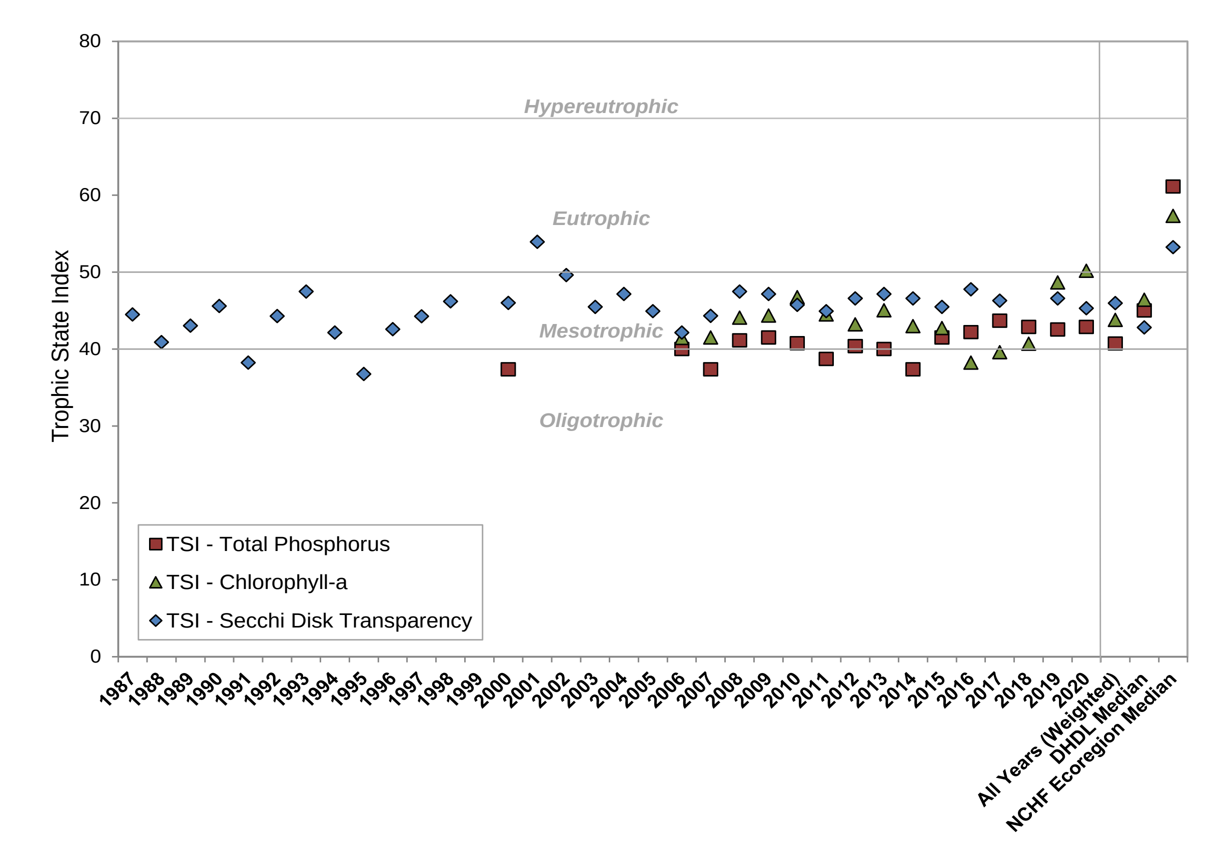


Figure 8.1.1-5. Round Lake, state-wide deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Round Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Round Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.1.1-6. Round Lake is *dimictic* meaning the lake remains stratified during the summer (and winter). Most dimictic lakes turnover in the spring and fall but this was not the case in Round Lake in the spring 2020. The lake was stratified on April 23 and the bottom waters were devoid of oxygen. This suggests the lake never mixed and is supported by the high phosphorus concentration in the near-bottom waters (8.1.1-2). With stratification, wind and water movement are not sufficient to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen. The lake was still stratified on October 22 but likely mixed prior to the onset of ice cover. On July 21, the highest oxygen concentration was in the metalimnion. This indicates that there is a significant algal community in the metalimnion. This is not uncommon in relatively small stratified lakes with excellent water clarity like Round Lake. There is sufficient light reaching the metalimnion to allow photosynthesis and since the lake is stratified the oxygen produced is not in contact with the atmosphere and is able to build up to supersaturation levels. These high levels are not harmful to other aquatic life.

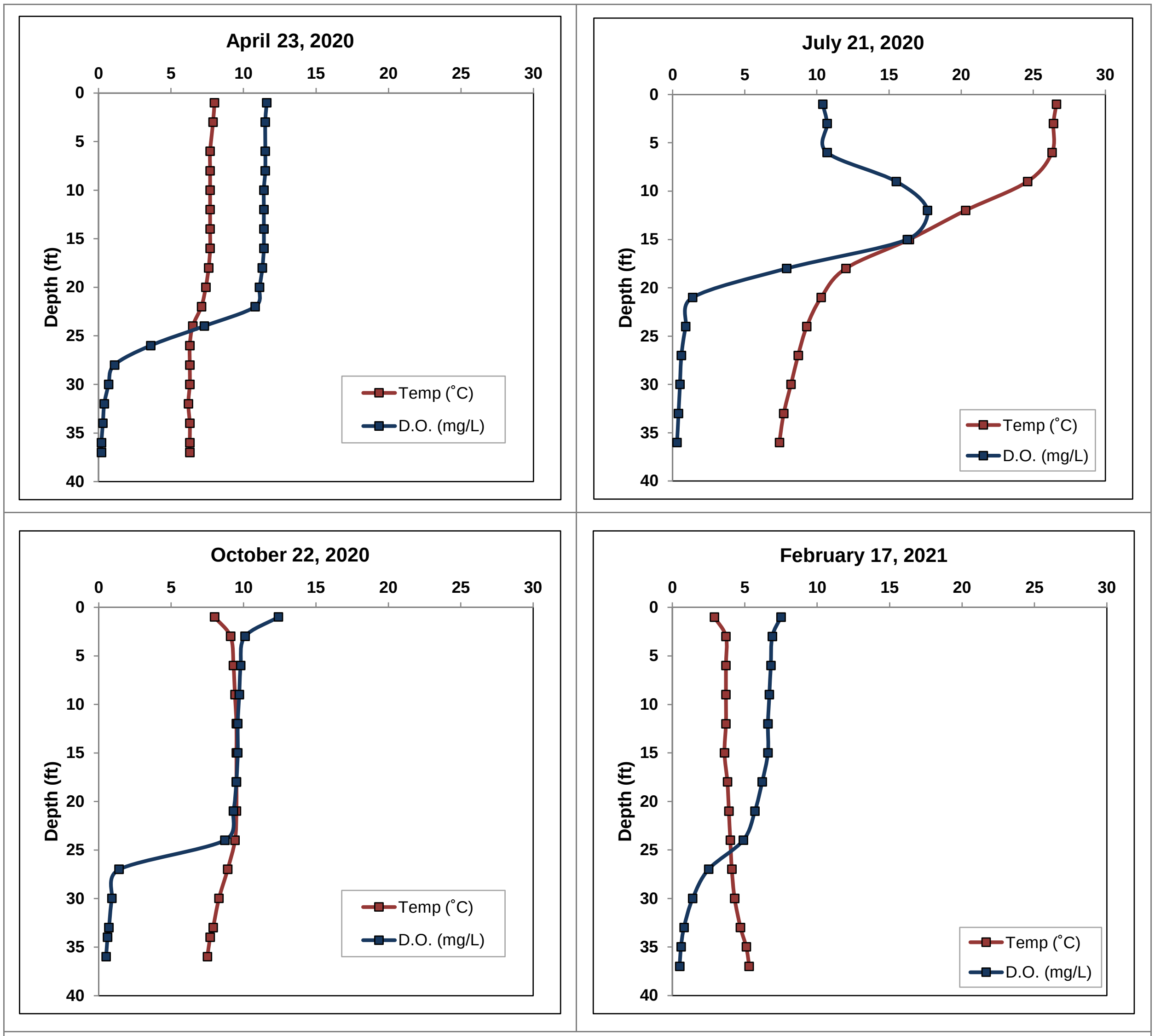


Figure 8.1.1-6. Round Lake 2020/21 dissolved oxygen and temperature profiles.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. In February 2021, Round Lake was found to support sufficient levels of dissolved oxygen under the ice throughout most of the water column. This indicates that winter fish kills are not a concern in the lake.

8.1.2 Round Lake Aquatic Vegetation

The 2021 aquatic plant point-intercept survey was conducted on Round Lake on August 11, 2021 by Onterra (Figure 8.1.2-1). Point-intercept surveys were also completed in 2010, 2012, 2013, 2015, 2017, 2019, and 2020. Taking all survey years into account, a total of 39 native aquatic plants species have been located in Round Lake (Table 8.1.2-1). Only the species which were sampled directly on the rake during the point-intercept survey are used in the analyses that follow – incidentally located species are not included. In addition, six non-native species were located in Round Lake: Eurasian watermilfoil (EWM), curly-leaf pondweed (CLP), pale-yellow iris, purple loosestrife, giant reed, and watercress. These non-native species were previously discussed at the end of section 3.4 in a subsection titled *Non-native Aquatic Plants in the Cloverleaf Lakes*.

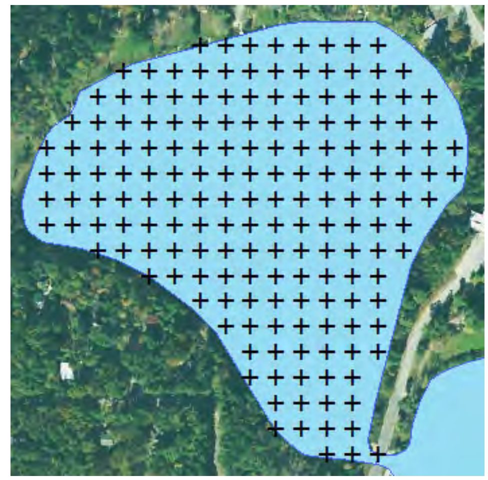


Figure 8.1.2-1. Round Lake whole-lake aquatic point-intercept survey sampling locations.

During the 2021 PI survey, aquatic plants were found growing to a depth of 17 feet in Round Lake. Of the 174 points on the sampling grid (Figure 8.1.2-1), 51 were considered to be littoral (within depths at which plants can grow). Of these point-intercept locations sampled within the littoral zone in 2021, approximately 90% contained aquatic vegetation. Aquatic plant rake fullness data (density of plants pulled up on the rake) indicates that in 2021, about 43% of the littoral sampling sites contained the highest density rating of TRF=3, 26% contained TRF=2, and 22% contained TRF=1 (Figure 8.1.2-2).

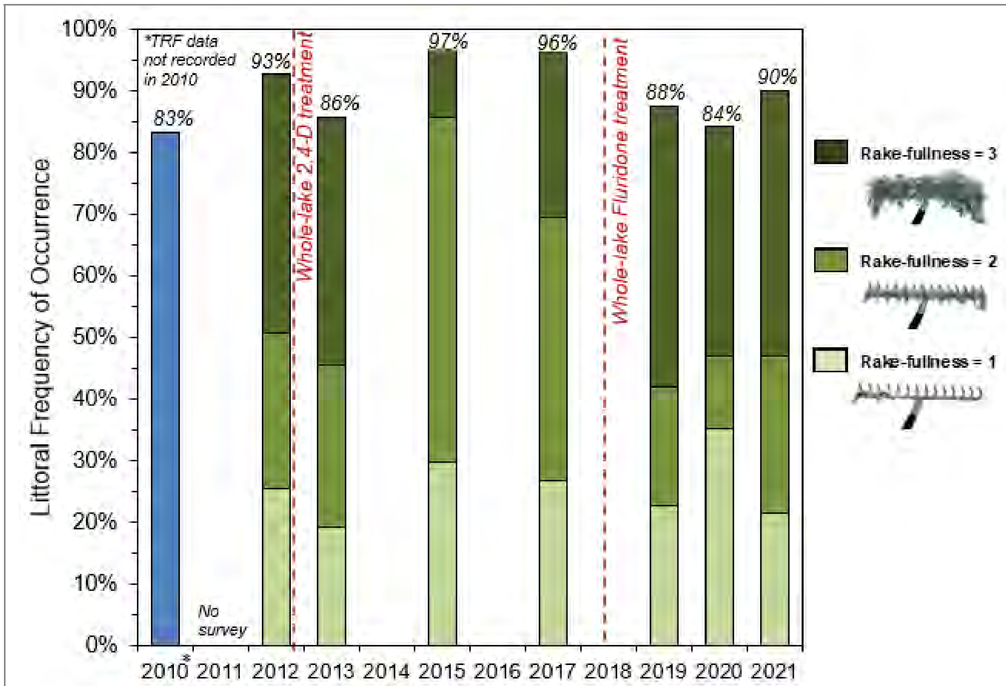


Figure 8.1.2-2. Total rake fullness ratings on Round Lake. Created using data from point-intercept surveys.

Table 8.1.2-1. Aquatic plant species located in Round Lake during the aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2012	2013	2015	2017	2019	2020	2021
Emergent	*Acorus calamus*	Sweetflag	Non-Native - Naturalized	N/A							I	
	Carex aquatilis	Long-bracted tussock sedge	Native	7							I	
	Comarum palustre	Marsh cinquefoil	Native	8	I			I				
	Eleocharis palustris	Creeping spikerush	Native	6							I	
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A							I	
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A							I	
	Phragmites australis subsp. *americanus*	Common reed	Native	5				I				
	Phragmites australis subsp. *australis*	Giant reed	Non-Native - Invasive	N/A							I	
	Pontederia cordata	Pickerelweed	Native	9							I	
	Sagittaria latifolia	Common arrowhead	Native	3							I	
	Schoenoplectus acutus	Hardstem bulrush	Native	5		X	X	X	X	X	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	X			X			I	
	Typha latifolia	Broad-leaved cattail	Native	1	I			I				
	Typha spp.	Cattail spp.	N/A	N/A	X						I	
FL	*Brasenia schreberi*	Watershield	Native	7					X		I	X
	Nuphar variegata	Spatterdock	Native	6	X	X	X	I	X	X	X	X
	Nymphaea odorata	White water lily	Native	6		X	X	X	X	X	X	X
Submergent	*Ceratophyllum demersum*	Coontail	Native	3	X	X	X	X	X		X	X
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3		X	X		X	X	X	
	Heteranthera dubia	Water stargrass	Native	6				X	X			
	Myriophyllum sibiricum	Northern watermilfoil	Native	7		X						
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X	X	X	X	X	X
	Najas flexilis	Slender naiad	Native	6			X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7		X	X	X	X			
	Nitella spp.	Stoneworts	Native	7		X		X	X	X	X	X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X						X	
	Potamogeton berchtoldii	Slender pondweed	Native	7							X	
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X					X	X	
	Potamogeton foliosus	Leafy pondweed	Native	6			X	X				
	Potamogeton gramineus	Variable-leaf pondweed	Native	7		X	X	X	X	X		X
	Potamogeton illinoensis	Illinois pondweed	Native	6		X		X	X	X	X	X
	Potamogeton pusillus	Small pondweed	Native	7		X		X		X		X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8							X	
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6			X	X	X	X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8				X	X		X	
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A					X			X
	Stuckenia pectinata	Sago pondweed	Native	3		X	X	X	X	X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X	X
S/E	*Eleocharis acicularis*	Needle spikerush	Native	5								X
	Nasturtium officinale	Watercress	Non-Native - Invasive	N/A							X	
FF	*Lemna minor*	Lesser duckweed	Native	5				X			X	X
	Lemna trisulca	Forked duckweed	Native	6		X		X				
	Lemna turionifera	Turion duckweed	Native	2		X	X			X	X	
	Spirodela polyrhiza	Greater duckweed	Native	5			X	X	X	X	X	X
	Wolffia spp.	Watermeal spp.	Native	N/A				X			X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
E = Emergent; FL = Floating-leaf; S/E = Submergent/Emergent; FF = Free-floating

Figure 8.1.2-3 shows that charophytes, wild celery, sago pondweed, white water lily, and clasping-leaf pondweed are typically the most frequently encountered native plants in Round Lake.

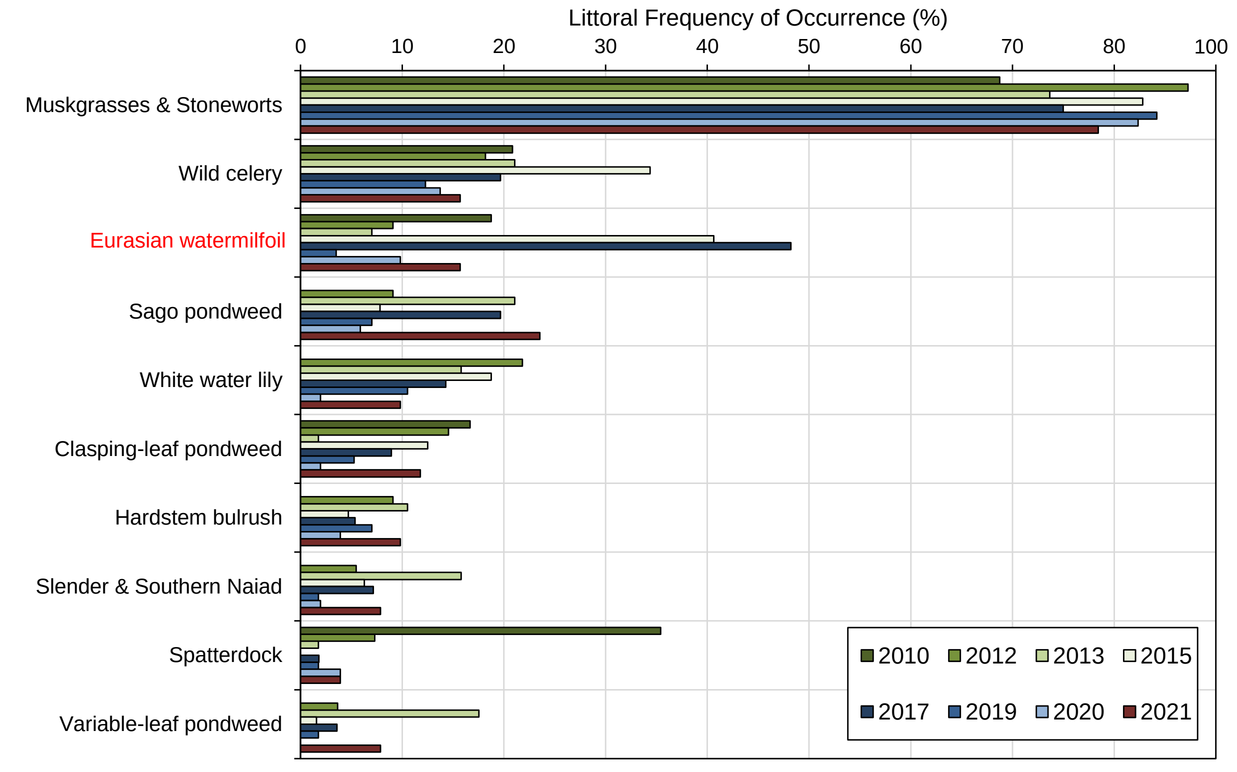


Figure 8.1.2-3. Round Lake aquatic plant littoral frequency of occurrence analysis. Chart includes the top most frequently encountered species only. Created using data from the point-intercept surveys.

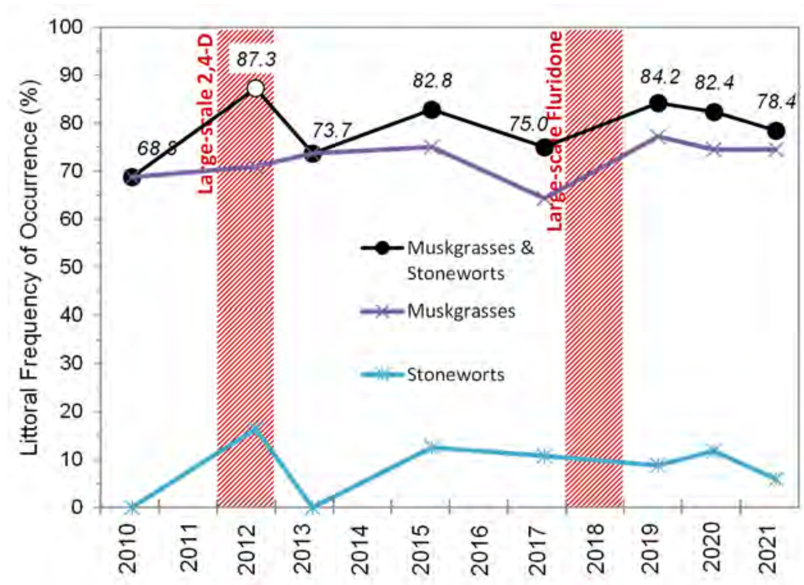
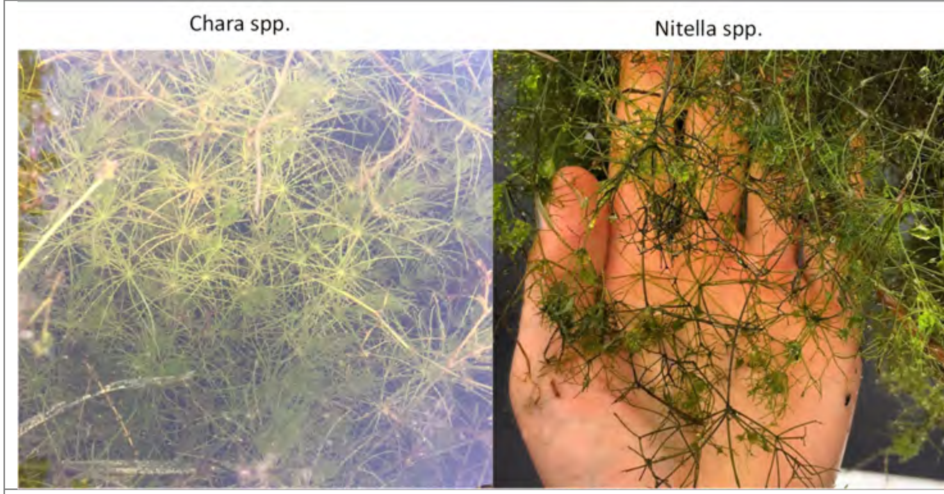


Figure 8.1.2-4. Littoral frequency of occurrence of muskgrasses and stoneworts in Round Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05). Red lines indicate whole-lake herbicide treatments that have occurred in Round Lake. Smaller-scale spot-treatments are not displayed.

Charophytes are a group of macroalgae comprised mainly of muskgrasses and stoneworts (Photograph 8.1.2-1). Muskgrasses have by far been the most frequently encountered plant during each of the point-intercept surveys over the years. Muskgrasses and stoneworts can be difficult to differentiate in the field, and their occurrences are often combined together for analyses, as seen here. Charophytes typically do better in systems with good water clarity, and their large beds help to stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate encrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops, 2002). The charophyte population within Round Lake appears to have remained relatively stable over time (Figure 8.1.2-4).



Photograph 8.1.2-1. Muskgrasses (Chara spp.), left; and stoneworts (Nitella spp.), right

Wild celery (*Vallisneria americana*) was the second most frequent species in Round Lake during the 2021 point-intercept survey (Figure 8.1.2-5, Photograph 8.1.2-2). Wild celery produces long, grass-like leaves which extend in a circular fashion from a basal rosette. To keep the leaves standing in the water column, lacunar cells in the leaves contain gas, making them buoyant. Towards the late-summer when wild celery is at its peak growth stage, it is easily uprooted by wind and wave activity. It can then pile up on shorelines depending on the predominant wind direction. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Cloverleaf Lakes ecosystem. The wild celery population in Round Lake has remained relatively stable over time, with the most recent survey years yielding the lowest frequencies.

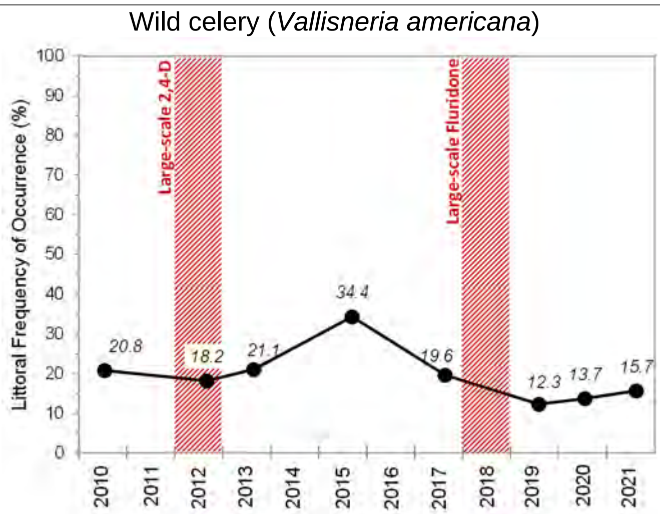


Figure 8.1.2-5. Littoral frequency of occurrence of wild celery in Round Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.1.2-2. Wild celery (*Vallisneria americana*). Photo credit Onterra.

White water lily (*Nymphaea odorata*) has been one of the next most frequent species in Round Lake when taking all survey years into account (Figure 8.1.2-6). White water lily is easy to spot with its round, notched lily pads and bright white and fragrant flowers (Photograph 8.1.2-3). Its leaves and rhizomes are eaten by some wildlife; but while floating, provide habitat for aquatic organisms as well as a place for some insects and amphibians to lay their eggs. White water lily was not recorded in 2010, but was likely present. Floating-leaf species such as this can be underrepresented during point-intercept surveys since they tend to grow in more shallow areas of lakes, closest to the perimeter, and sampling points do not always reach these areas. That being said, 2020 marked the next lowest frequency recorded for white water lily with only a 2% LFOO. Referencing the 2020 floating-leaf and emergent community map will give a better idea of where white-water lily was found in the lakes in 2020. Floating-leaved plants like white-water likely are known to be influence by water levels, particularly lack of fluctuations.

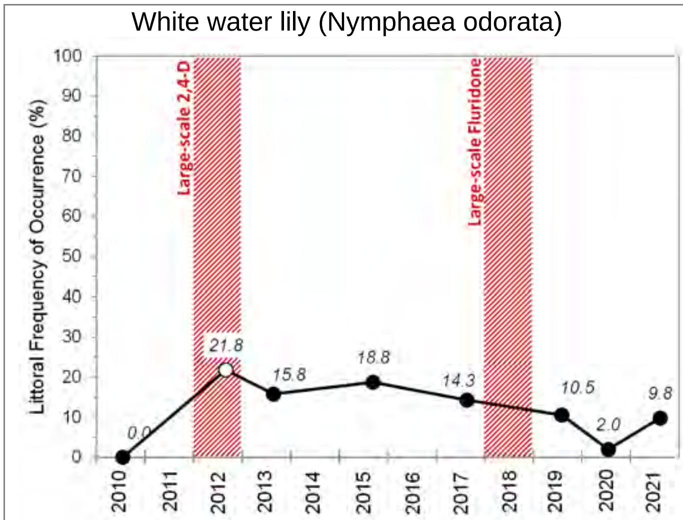
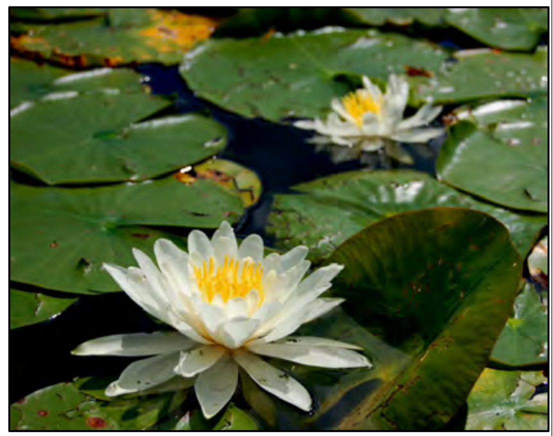


Figure 8.1.2-6. Littoral frequency of occurrence of white water lily in Round Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 8.1.2-3. White water lily (*Nymphaea odorata*). Photo credit Onterra.

Sago pondweed (*Stuckenia pectinata*) is another of the more common species in Round Lake. It is a rooted plant that can be found in a variety of waterbodies throughout Wisconsin. It is highly tolerant of low-light conditions, and is often the last rooted plant able to survive in waterbodies with extremely turbid water (Borman, Korth, & Temte, 1997). To survive in these conditions, it produces numerous needle-like leaves that spread out near or at the water's surface in a fan-shape to gather light (Photograph 8.1.2-4). Sago pondweed has been found to be one of the most valuable food resources for waterfowl, producing numerous seeds and tubers. The sago pondweed population in Round Lake has fluctuated from survey to survey, with 2021 having a statistically valid increase from 2020, marking the highest LFOO recorded to date (Figure 8.1.2-7).

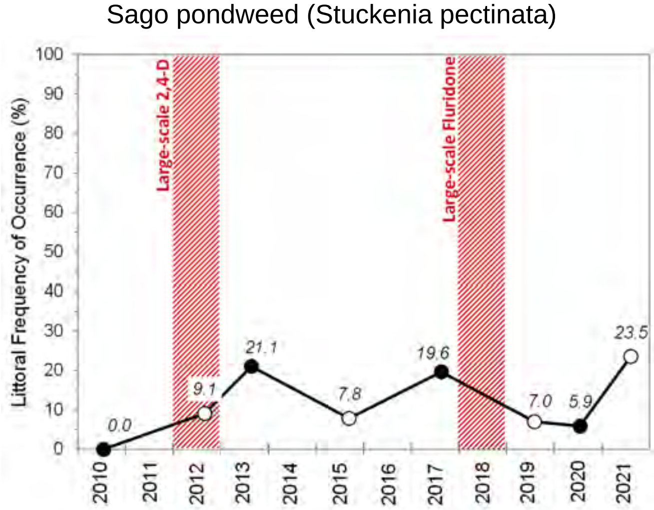
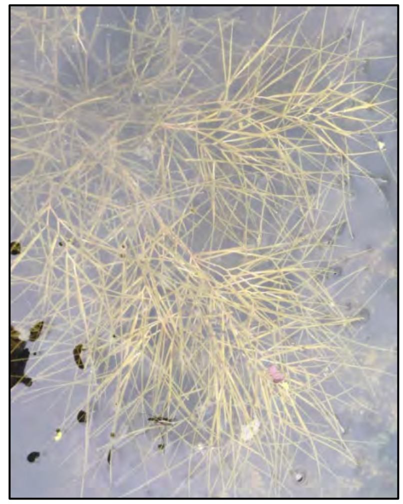


Figure 8.1.2-7. Littoral frequency of occurrence of sago pondweed in Round Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 8.1.2-4. Sago pondweed (*Stuckenia pectinata*). Photo credit Onterra.

Clasping-leaf pondweed (*Potamogeton richardsonii*) is another relatively common species in Round Lake (Photograph 8.1.2-5). As its name indicates, the submersed leaves of clasping-leaf pondweed clasp, or partially wrap, around the stem. Clasping-leaf pondweed is often found growing over harder substrates and is tolerant of low-light conditions; often one of the more abundant plants in lakes with stained water in northern Wisconsin. Clasping-leaf pondweed superficially resembles the non-native curly-leaf pondweed and is often misidentified as such. However, the leaf margins of curly-leaf pondweed are serrated, where the leaves of clasping-leaf pondweed lack serration. Like other native aquatic plants, clasping-leaf pondweed provides important structural habitat, stabilizes bottom sediments, and its fruits and rhizomes are important sources of food for wildlife. The clasping-leaf pondweed population in Round Lake has fluctuated from survey to survey, with 2020 marking the second lowest LFOO, and 2021 marking the third highest LFOO across all surveys (Figure 8.1.2-8).

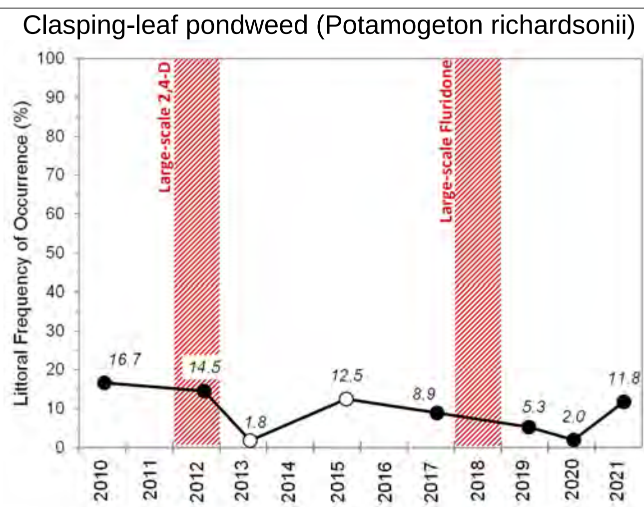
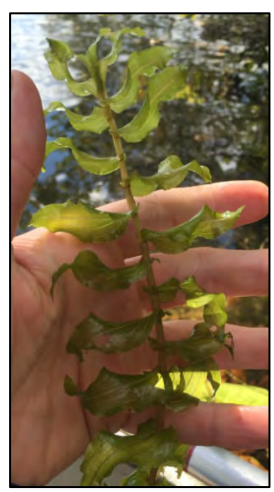


Figure 8.1.2-8. Littoral frequency of occurrence of clasping-leaf pondweed in Round Lake.



Photograph 8.1.2-5. Clasping-leaf pondweed (*Potamogeton richardsonii*).

The littoral frequencies of occurrence for some of the not as common species in Round Lake are displayed in Figure 8.1.2-9. Most of the LFOO charts below show relatively stable populations, aside from spatterdock which had a significant decrease between the 2010 and 2012 surveys and has not rebounded to 2010 levels. Spatterdock is a dicot which has shown to be sensitive to some herbicide treatments.

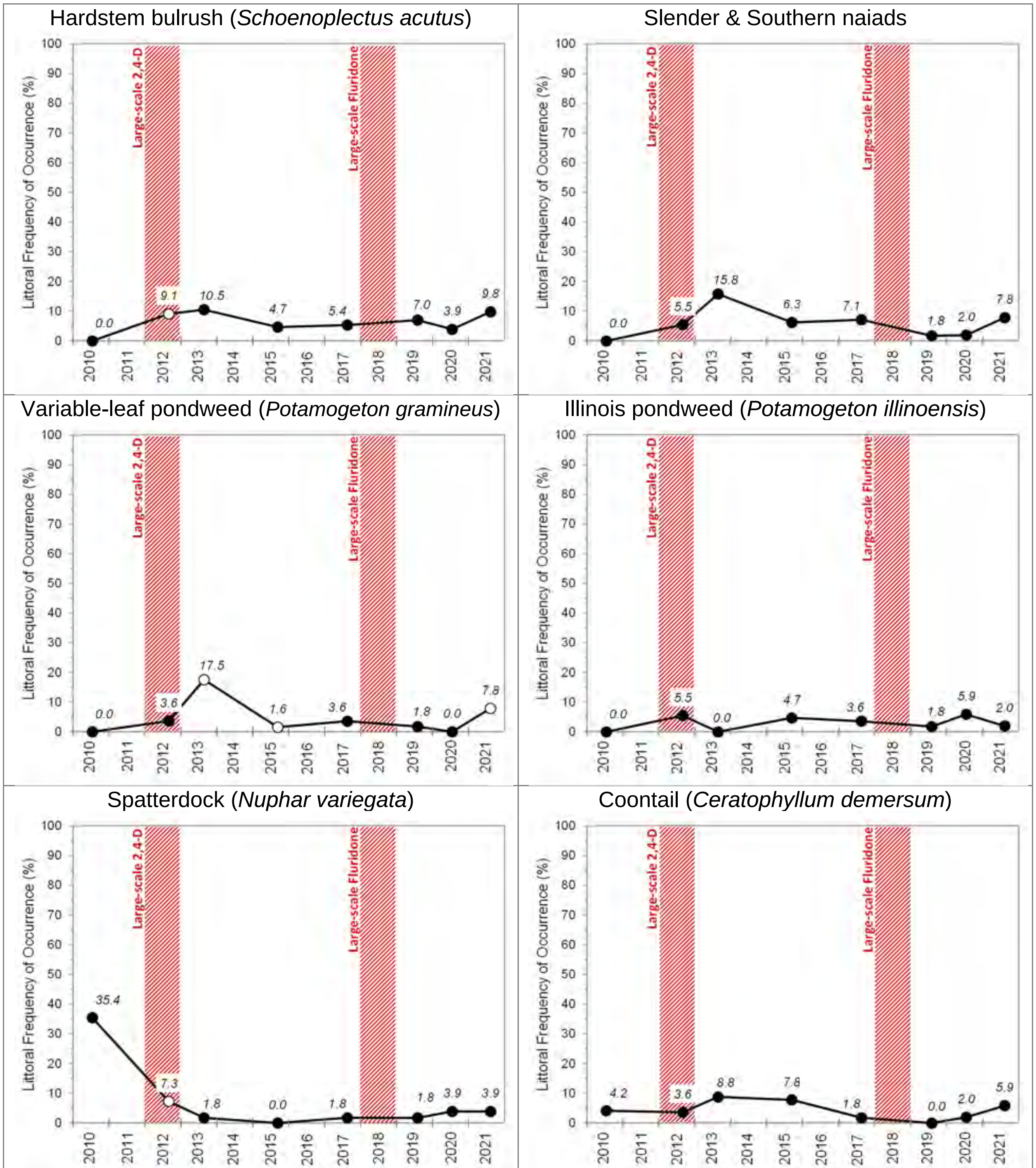


Figure 8.1.2-9. Littoral frequency of occurrence of select aquatic plant species in Round Lake from 2010-2021. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red areas indicate a large-scale herbicide treatment occurred during that year.

Because of the relatively high number of native species of plants (species richness) found in Round Lake, one may assume that the lake would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influences diversity. The diversity index for Round Lake's plant community in 2021 (0.85) lies just above the North Central Hardwood Forests ecoregion median value (0.84), and just below the state median (0.86), indicating that the lake holds relatively average diversity (Figure 8.1.2-10).

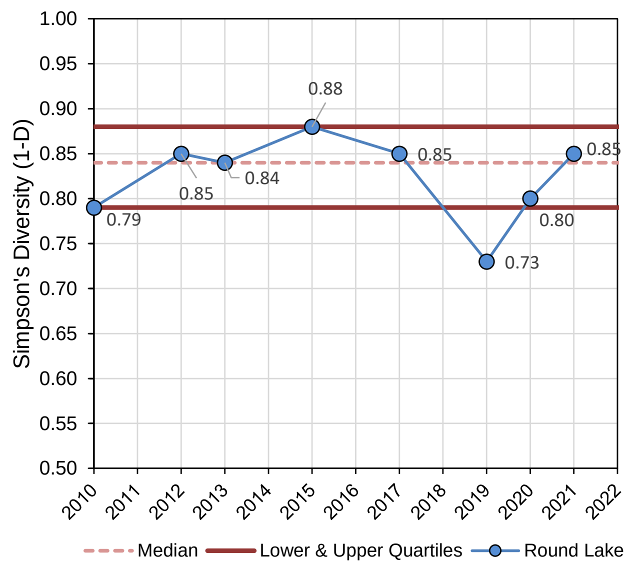


Figure 8.1.2-10. Simpson's diversity for Round Lake.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while muskgrasses were found at approximately 75% of the littoral sampling locations in 2021, its relative frequency of occurrence was 33.6%. Explained another way, if 100 plants were randomly sampled from Round Lake, 34 of them would be muskgrasses. This distribution can be observed in Figure 8.1.2-11 where together, 4 species accounted for about 58% of the population of plants within Round Lake in 2021, and the other 23 species account for the remaining 42%.

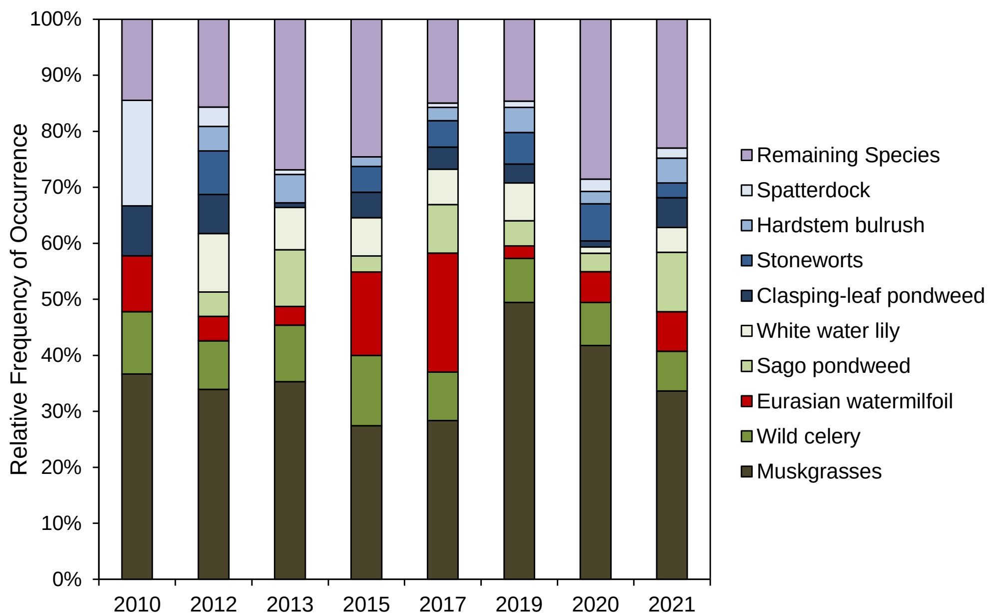


Figure 8.1.2-11. Round Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2020 point-intercept survey.

Round Lake's average conservatism value in 2021 (5.7) was slightly lower than both the state (6.3) and ecoregion (5.8) medians. This indicates that the aquatic plant community in Round Lake is not particularly sensitive to environmental degradation. Round Lake's species richness value exceeded the ecoregion and state medians in 2015, 2017, 2020, and 2021. Combining Round Lake's 2021 species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 25.5 which is in between the median values for the ecoregion and state (Figure 8.1.2-12).

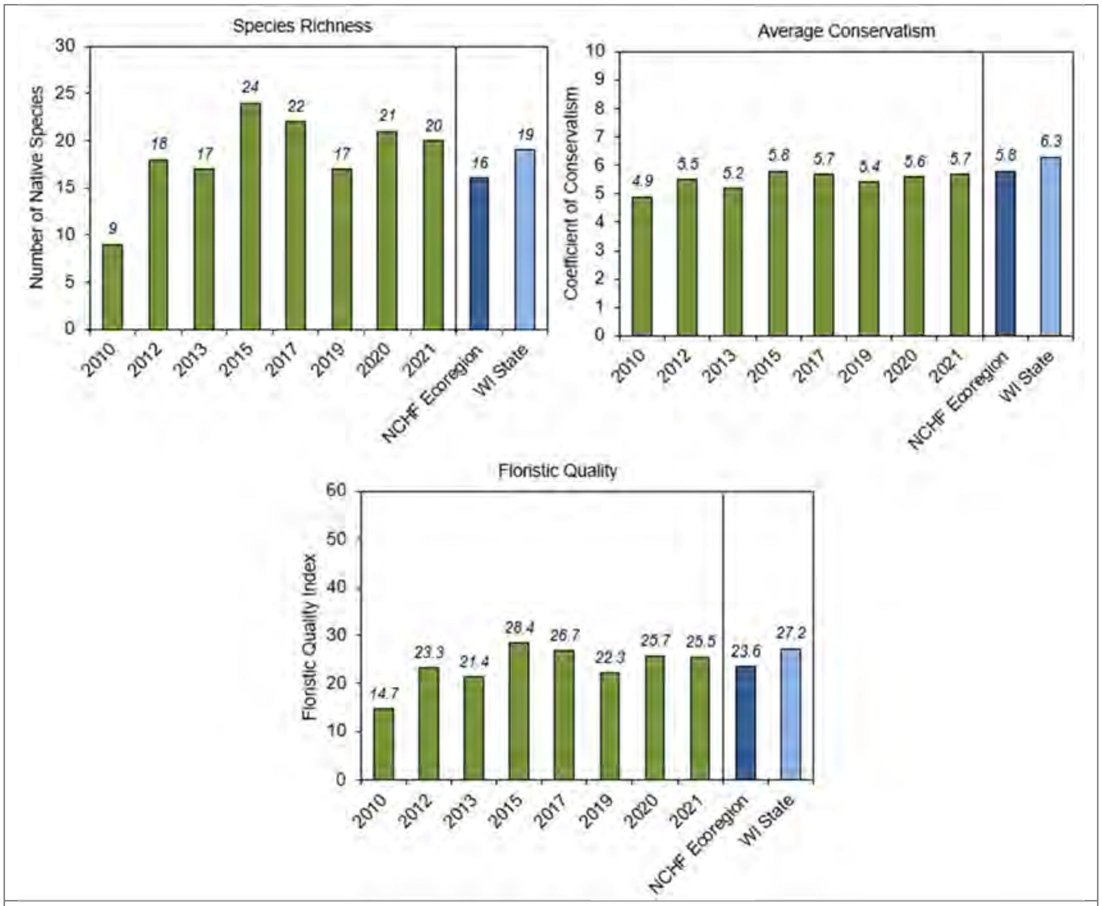


Figure 8.1.2-12. Round Lake Floristic Quality Analysis. Created using data from point-intercept surveys.

The 2020 community map indicates that approximately 4.8 acres of Round Lake contain emergent and floating-leaf plant communities (Map 2, Table 8.1.2-2). These valuable communities occur around the majority of the perimeter of Round Lake. Fourteen native floating-leaf and emergent species were located in and around Round Lake during the 2020 surveys (Table 8.1.2-1). These species provide valuable wildlife habitat and help protect the shoreline from erosion.

Table 8.1.2-2. Round Lake acres of emergent and floating-leaf plant communities from the community mapping survey.

Plant Community	Acres
Emergent	0.1
Floating-leaf	1.6
Mixed Emergent & Floating-leaf	3.1
Total	**4.8**

8.2.0 Grass Lake Introduction

An Introduction to Grass Lake

Grass Lake, Shawano County, is a deep, headwater mesotrophic drainage lake with a maximum depth of 52 feet, a mean depth of 13 feet, and a surface area of approximately 92 acres. Its direct surficial watershed encompasses approximately 611 acres comprised mainly of forests, wetlands and row crop agriculture. Water enters Grass Lake from Round Lake and flows out into Pine Lake and eventually into Matteson Creek which flows into the Embarrass River. In 2020, 25 native aquatic plant species were located within the lake, of which wild celery (*Vallisneria americana*) were the most common. During the 2020 survey, five invasive plants were found in Grass Lake: Eurasian watermilfoil, curly-leaf pondweed, pale-yellow iris, purple loosestrife, and giant reed.

Lake at a Glance - Grass Lake

Morphometry	
Lake Type	Deep Headwater Drainage Lake
Surface Area (Acres)	92
Max Depth (feet)	52
Mean Depth (feet)	13
Perimeter (Miles)	2.3
Shoreline Complexity	2.9
Watershed Area (Acres)	611
Watershed to Lake Area Ratio	7:1

Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	16
Avg Summer Chl-α (µg/L)	6
Avg Summer Secchi Depth (ft)	9.1
Summer pH	8.7
Alkalinity (mg/L as $CaCO_3$)	159

Vegetation	
Number of Native Species	25
NHI-Listed Species	
Exotic Species	Eurasian watermilfoil; Curly-leaf pondweed, Pale-yellow iris, Purple loosestrife, Giant reed
Average Conservatism	5.7
Floristic Quality	26.2
Simpson's Diversity (1-D)	0.88

Descriptions of these parameters can be found within the chain-wide portion of the management plan

8.2.1 Grass Lake Water Quality

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, and whether its health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, the status of a lake's water quality can be made by comparison.

Near-surface total phosphorus data for Grass Lake are available from 1981-82, 1995-2000, and 2002-2020 (Figure 8.2.1-1). With exception of 2002 and 2004, all historical near-surface total phosphorus concentrations and the data collected as part of the lake management planning project in 2020 fall within the *excellent* category for deep, headwater drainage lakes in Wisconsin. The weighted average of summer near-surface total phosphorus concentrations using all data that are available is 15.9 µg/L, and falls slightly below the median concentration for other deep, headwater drainage lakes in Wisconsin (17.0 µg/L) and considerably below the median concentration for all lake types within the North Central Hardwood Forests (NCHF) ecoregion (52.0 µg/L). Phosphorus concentrations have generally been stable during the period 1995-2020 and an increasing trend was not observed. Phosphorus concentrations in Grass Lake are slightly higher than the long-term average in Round and Pine lakes but still in the excellent category.

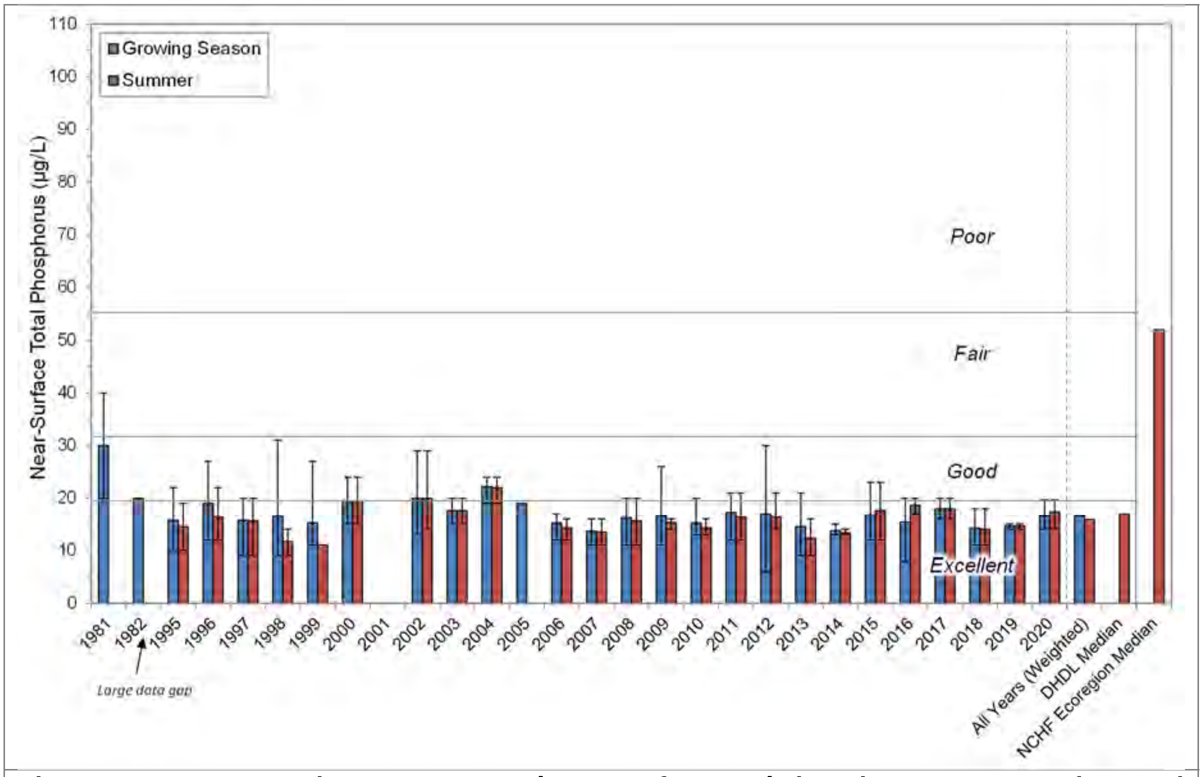


Figure 8.2.1-1. Grass Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake during stratification. In lakes which experience high levels of internal nutrient loading, the near-bottom phosphorus concentrations are significantly higher than those measured near the surface.

Near-bottom total phosphorus concentrations were collected in 1980, 1981, 1982, 1995, 1996, and on three occasions in 2020 from Grass Lake (Figure 8.2.1-2). In all of the years except 1980, near-bottom concentrations were considerable higher than the near-surface concentrations at least part of the year. It is likely when the concentrations were similar the lake was mixed. The elevated concentrations in the bottom waters indicate that some internal loading is occurring. Many of the near-bottom concentrations are higher in Grass Lake than in either Round or Pine lakes. This may explain why the long-term average phosphorus concentrations are highest in Grass Lake of the Cloverleaf Lakes. Even though some sediment release of phosphorus is occurring in Grass Lake, the amount of internal loading is not yet alarming since surface phosphorus concentrations are in the excellent range. However, the suggestion of some internal loading is a sign that internal loading could become more of a problem in the future.

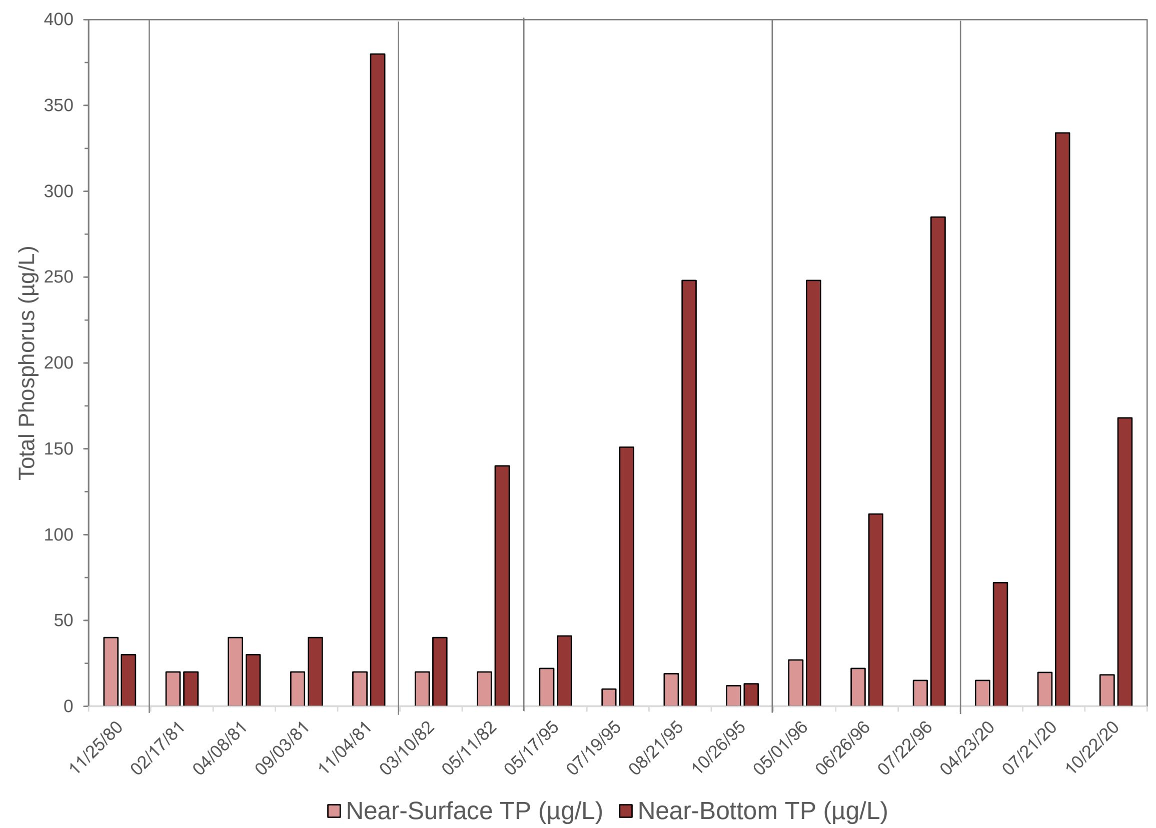


Figure 8.2.1-2. Grass Lake near-bottom and corresponding near-surface total phosphorus concentrations.

As with phosphorus, there is a longer record of chlorophyll-*a* data in Grass Lake than in Round Lake. Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Grass Lake from 1981-82, 1995-2000, and 2002-2020 (Figure 8.2.1-3). Chlorophyll-*a* concentrations are either in the excellent or good range with the long-term average being in the *good* range. The long-term average of 5.9 µg/L is slightly higher than the median value for other deep, headwater drainage lakes in Wisconsin (5.0 µg/L) and Tab Table much less than the median concentration for all lake types within the NCHF ecoregion (15.2 µg/L). Unlike chlorophyll-*a* concentrations in Round Lake which are higher the last two years, this trend is not evident in Grass Lake.

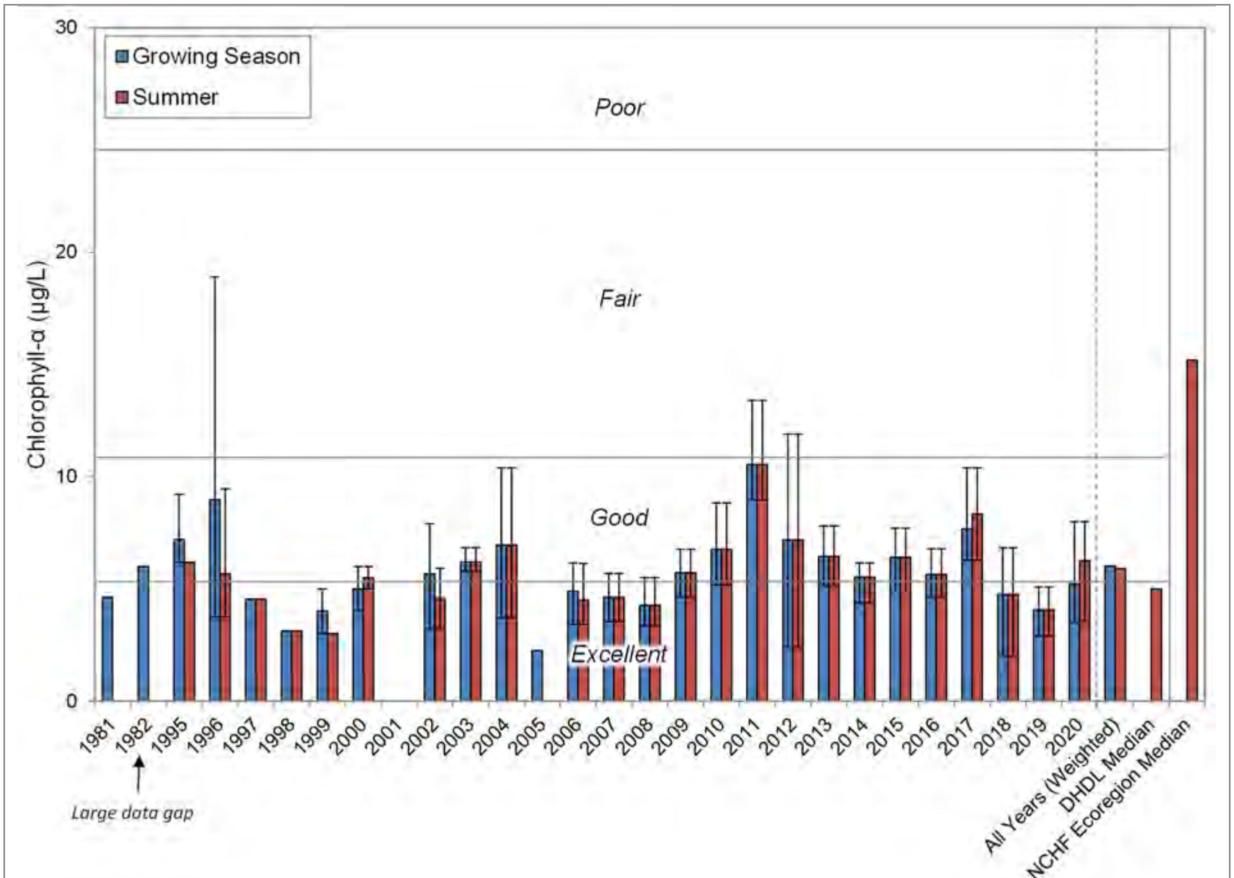


Figure 8.2.1-3. Grass Lake average annual near-surface chlorophyll-*a* concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

There is a slightly longer record of Secchi disk transparency from Grass Lake compared with phosphorus or chlorophyll *a*. A continuous record from 1987 to 2020 is available (Figure 8.2.1-4). For the period 1987-2006, the mean summer Secchi disk transparency (9.8 feet) fell within the *excellent* category for deep, headwater drainage lakes. However, for the period 2008-2020 the summer water clarity was not as good with a mean summer Secchi disk transparency of 7.2 feet. This places the lake in the *good* category. This mean transparency is less than the median depth (10.8 feet) for deep headwater drainage lakes in Wisconsin but is much better than the median value (5.3 feet) for all lake types in the NCHF ecoregion. Although water clarity has degraded on average in the last 15 years, phosphorus and chlorophyll-*a* have only increased a small amount. The summer average phosphorus concentrations increased from 15.4 to 16.4 µg/L and chlorophyll *a* levels from 5.3 to 6.1 µg/L between the two periods. Although the change has not been great the trend is not the direction the water quality should be taking.

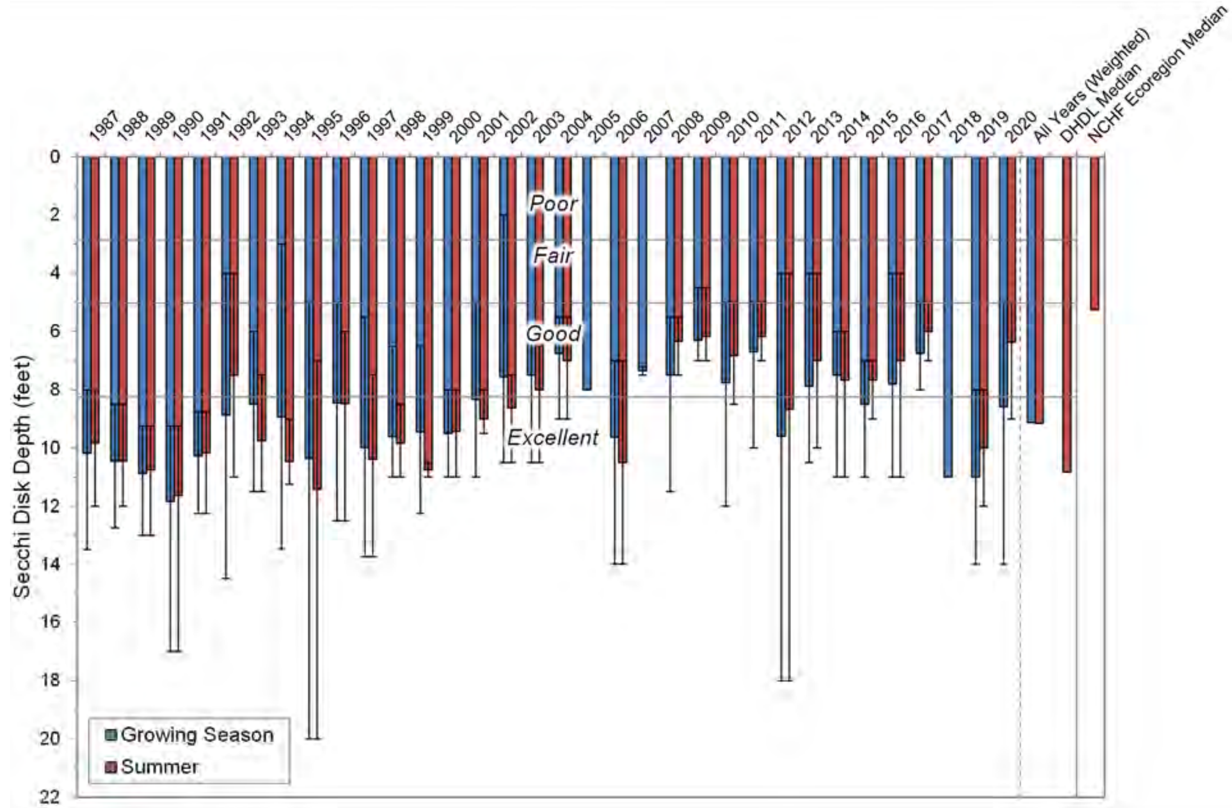


Figure 8.2.1-4. Grass Lake average annual Secchi disk transparency and median Secchi disk transparencies for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Grass Lake Trophic State

The Trophic State Index (TSI) values for Grass Lake were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figure 8.2.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae. Historical data indicate that Grass Lake was in a mesotrophic state, but with the increase in phosphorus and chlorophyll-*a* in recent years, the lake is currently in a lower eutrophic state.

Using the overall weighed TSI value, it can be said that Grass Lake is a mesotrophic system. Grass Lake's productivity level is comparable to other deep headwater drainage lakes in the state and less than other lakes in the Northern Lakes and Forests Ecoregion.

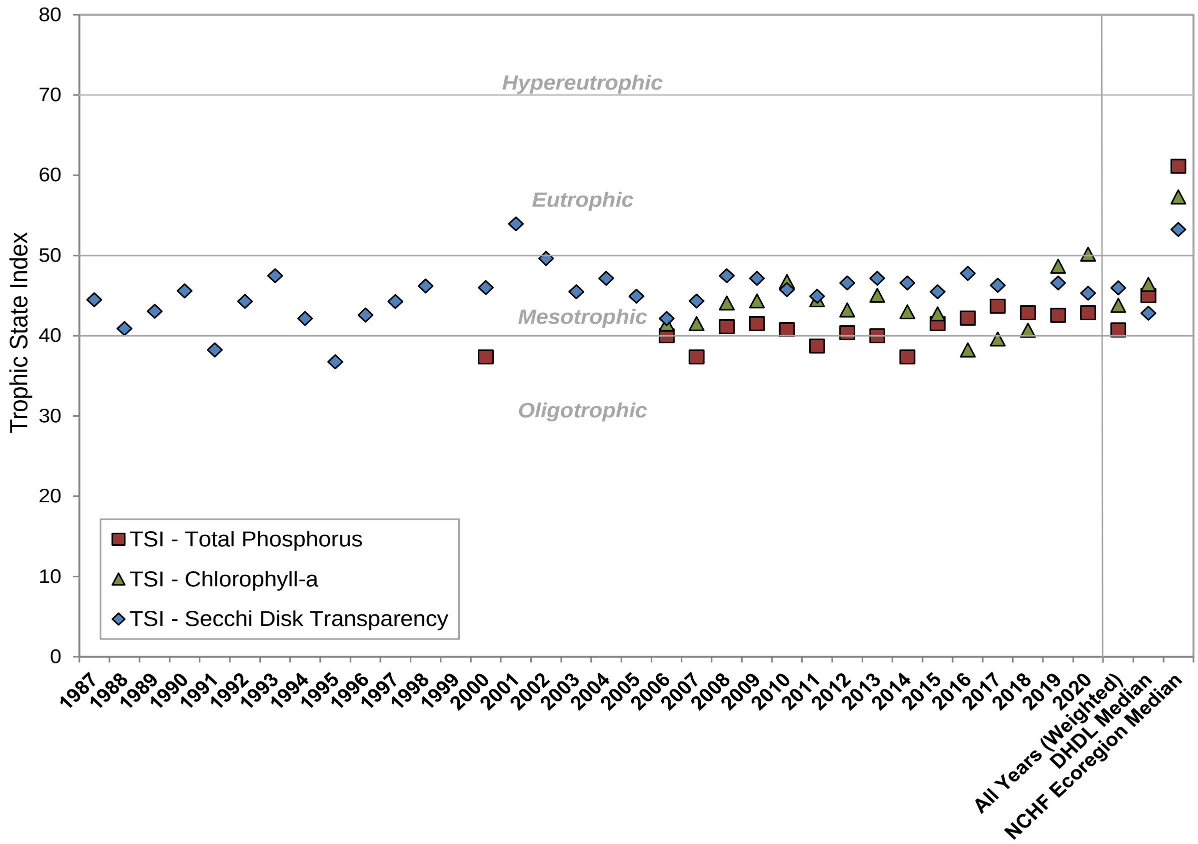


Figure 8.2.1-5. Grass Lake, state-wide deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Grass Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Grass Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.2.1-6. Grass Lake is *dimictic* meaning the lake remains stratified during the summer (and winter). Most dimictic lakes turnover in the spring and fall but this was not the case in Grass Lake in the spring 2020. The lake was stratified on April 23 and the bottom waters were devoid of oxygen. This suggests the lake never fully mixed and is supported by the high phosphorus concentration in the near-bottom waters (8.2.1-2). With stratification, wind and water movement are not sufficient to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen. The lake was still stratified on October 22 but likely mixed prior to the onset of ice cover.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. In February 2021, Grass Lake was found to support sufficient levels of dissolved oxygen under the ice throughout most of the water column. This indicates that winter fish kills are not a concern in the lake.

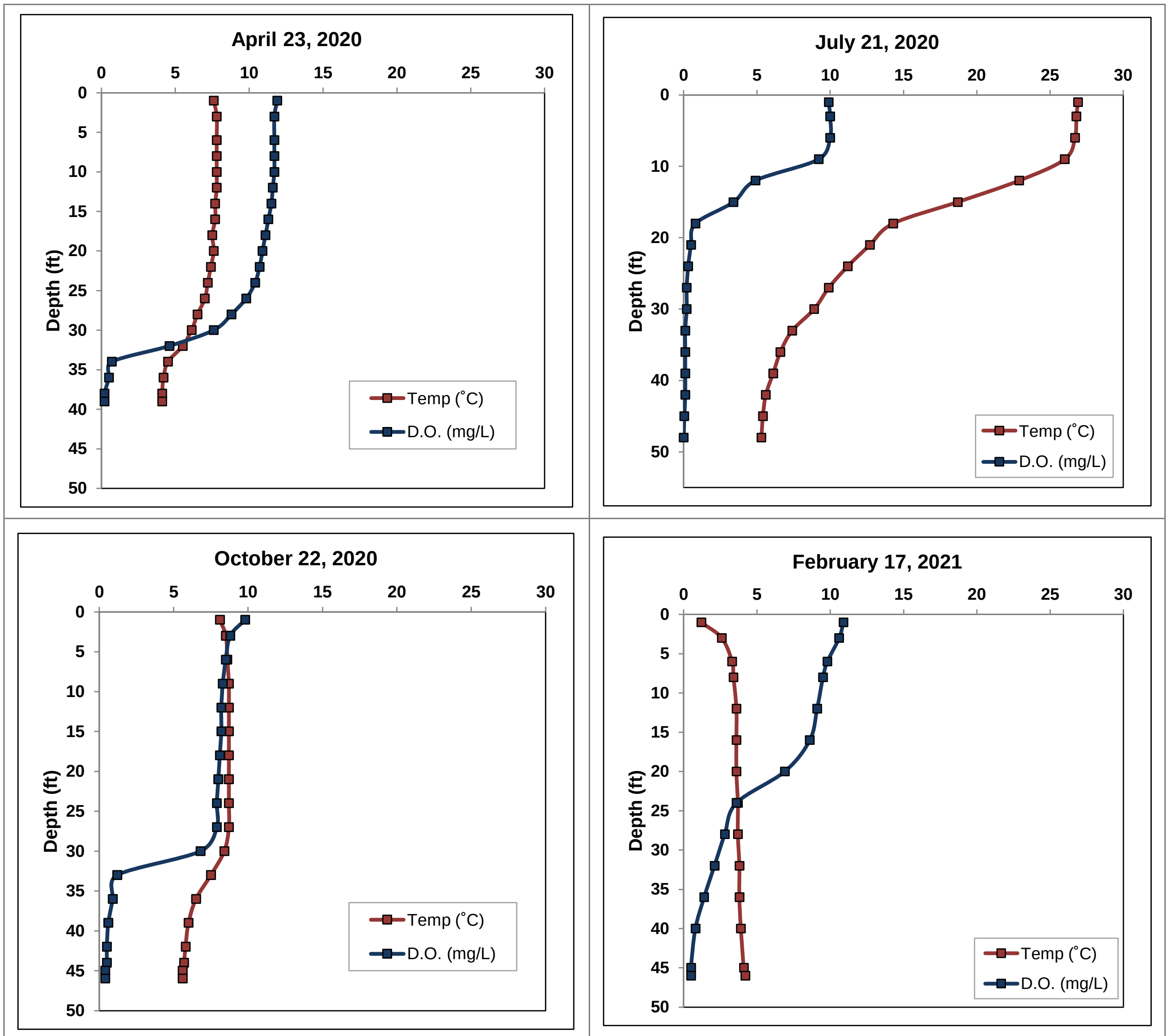


Figure 8.2.1-6. Grass Lake 2020/21 dissolved oxygen and temperature profiles.

8.2.2 Grass Lake Aquatic Vegetation

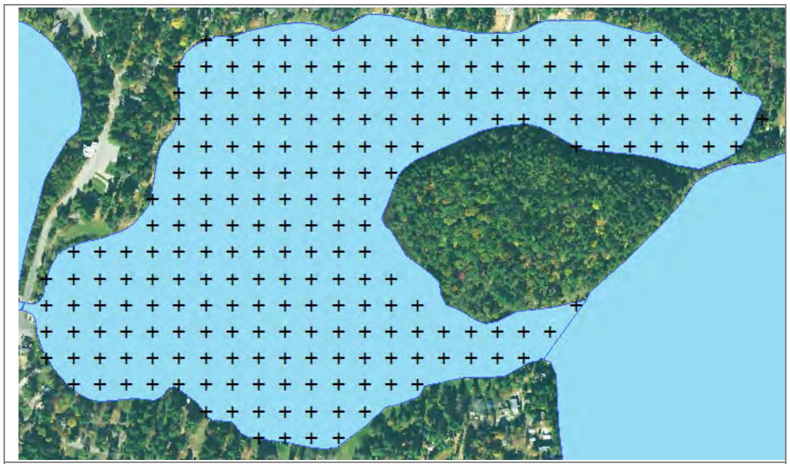


Figure 8.2.2-1. Grass Lake whole-lake aquatic point-intercept survey sampling locations.

The 2021 aquatic plant point-intercept survey was conducted on Grass Lake in August by Onterra (Figure 8.2.2-1). The floating-leaf and emergent plant community mapping survey was completed during the summer of 2020 to create the emergent and floating-leaf aquatic plant community map. Point intercept surveys had been previously completed on Grass Lake in 2010, 2012-2013, 2015, and 2017-2020. Taking all survey years into account total of 45 native aquatic plants species have been located in and around Grass Lake (Table 8.2.2-1). Only the species which were sampled directly on the rake during the point-intercept survey are used in the analyses that follow – incidentally located species are not included. In addition, five non-native species were located on Grass Lake: Eurasian watermilfoil (EWM), curly-leaf pondweed (CLP), pale-yellow iris, purple loosestrife, and giant reed. These non-native species were previously discussed at the end of section 3.4 in a subsection titled *Non-native Aquatic Plants in the Cloverleaf Lakes*.

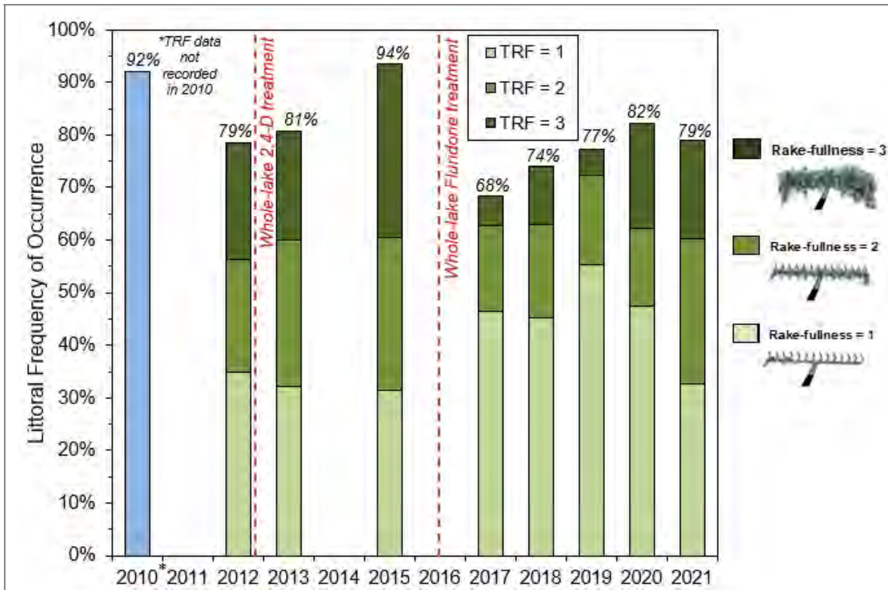


Figure 8.2.2-2. Total rake fullness ratings on Grass Lake. Created using data from point-intercept surveys.

During the 2021 PI survey, aquatic plants were found growing to a depth of 17 feet in Grass Lake. Of the 233 points on the sampling grid, (Figure 8.2.2-1) 138 were considered to be littoral (within depths at which plants can grow). Of the point-intercept locations sampled within the littoral zone in 2021, approximately 79% contained aquatic vegetation. Aquatic plant rake fullness data (density of plants pulled up on the rake) indicates that in 2021, about 33% of the littoral sampling sites contained TRF=1, 27% contained TRF=2, and 19% contained the highest density rating of TRF=3 (Figure 8.2.2-2). The percentage of sampling sites with vegetation in Grass Lake has fluctuated over the years, ranging from 68% (2017) to 94% (2015), with the most recent survey years falling somewhere in between.

Table 8.2.2-1. Aquatic plant species located in Grass Lake during the aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2012	2013	2015	2017	2018	2019	2020	2021
Emergent	*Carex aquatilis*	Long-bracted tussock sedge	Native	7								I	
	Decodon verticillatus	Water-willow	Native	7								I	
	Eleocharis palustris	Creeping spikerush	Native	6		X							
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A								I	
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A								I	
	Phragmites australis subsp. australis	Giant reed	Non-Native - Invasive	N/A								I	
	Pontederia cordata	Pickerelweed	Native	9		X	X					I	
	Sagittaria latifolia	Common arrowhead	Native	3	X	X	X						
	Schoenoplectus acutus	Hardstem bulrush	Native	5		X	X	X	X	X		X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	X					X		I	
	Typha spp.	Cattail spp.	N/A	N/A	X	X	X					I	
FL	*Brasenia schreberi*	Watershield	Native	7	X	X	X	X	X	X	X	X	X
	Nuphar variegata	Spatterdock	Native	6	X	X	X	X	X	X	X	X	X
	Nymphaea odorata	White water lily	Native	6	X	X	X	X	X	X	X	X	X
Submergent	*Bidens beckii*	Water marigold	Native	8			X						
	Ceratophyllum demersum	Coontail	Native	3	X	X	X	X	X	X	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	Native	10	X				X		X		
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3	X	X	X	X	X	X	X	X	X
	Heteranthera dubia	Water stargrass	Native	6			X		I				X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7				X			X		
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X		X	X	I	X	X	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X								
	Najas flexilis	Slender naiad	Native	6	X	X	X	X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7	X		X	X	X	X	X	X	X
	Nitella spp.	Stoneworts	Native	7		X			X				X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X		X			X	X	X	X
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X				X			I	X
	Potamogeton foliosus	Leafy pondweed	Native	6	X				X				
	Potamogeton friesii	Fries' pondweed	Native	8									X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7			X	X	X	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6		X	X	X	X	X		X	X
	Potamogeton natans	Floating-leaf pondweed	Native	5	X	X	X	X	X	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	Native	8				X	X	X			
	Potamogeton pusillus	Small pondweed	Native	7					X	X	X	X	
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X	X	X	X	X	X	X
	Potamogeton strictifolius	Stiff pondweed	Native	8			X			X			X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X	X	X	X	X	X	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8									X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A		X		X	X	X	X		X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X	X	X	X	X	X	X
	Utricularia gibba	Creeping bladderwort	Native	9			X			X			X
	Utricularia vulgaris	Common bladderwort	Native	7			X	X	X	X	X	X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X	X	X
	Zannichellia palustris	Horned pondweed	Native	7	X								
S/E	*Sagittaria graminea*	Grass-leaved arrowhead	Native	9		X							
FF	*Lemna minor*	Lesser duckweed	Native	5					X	X			
	Lemna trisulca	Forked duckweed	Native	6								X	
	Lemna turionifera	Turion duckweed	Native	2		X							X
	Spirodela polyrhiza	Greater duckweed	Native	5		X	X	X	X	X	X	X	X
	Wolffia spp.	Watermeal spp.	Native	N/A		X	X				X		

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
FL =Floating-leaf; S/E = Submergent/Emergent; FF = Free-floating

Please note Ceratophyllum echinatum has not been vouchered from this system as of the writing of this report.

Figure 8.2.2-3 shows that wild celery, muskgrasses, slender and southern naiads, clasping-leaf pondweed, and spatterdock are typically some of the most frequently encountered native plants in Grass Lake.

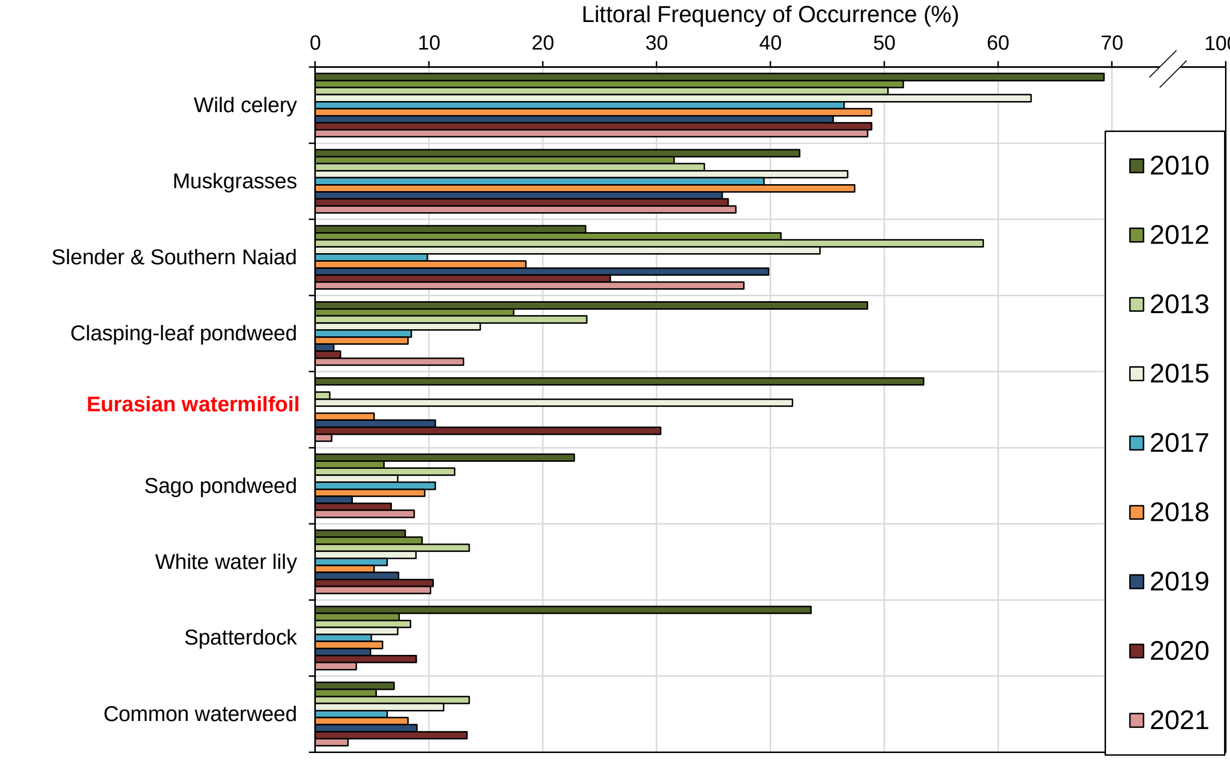


Figure 8.2.2-3. Grass Lake aquatic plant littoral frequency of occurrence analysis. Chart includes the top most frequently encountered species only. Created using data from the point-intercept surveys.

Wild celery (*Vallisneria americana*) had been the most frequent species in Grass Lake during all of the point-intercept surveys with the exception of 2013 (Figure 8.2.2-3, Photograph 8.2.2-1). Wild celery produces long, grass-like leaves which extend in a circular fashion from a basal rosette. To keep the leaves standing in the water column, lacunar cells in the leaves contain gas, making them buoyant. Towards the late-summer when wild celery is at its peak growth stage, it is easily uprooted by wind and wave activity. It can then pile up on shorelines depending on the predominant wind direction. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Cloverleaf Lakes ecosystem. The wild celery population in Grass Lake saw two statistically valid declines during the years following the large-scale herbicide treatments, but appears to have remained stable from 2017-2021 (Figure 8.2.2-4).

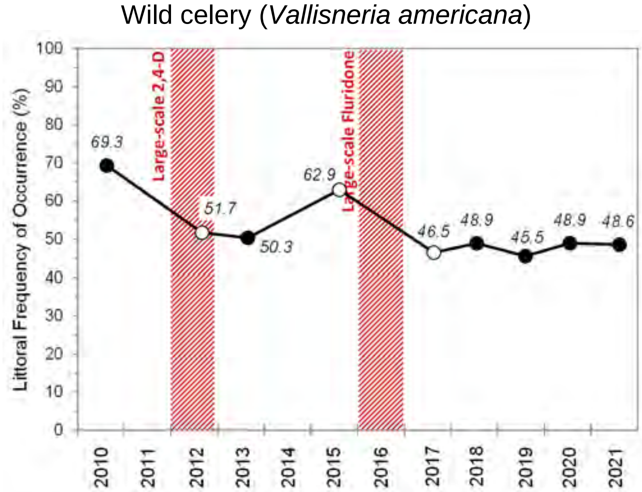


Figure 8.2.2-4. Littoral frequency of occurrence of wild celery in Grass Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.2.2-1. Wild celery (*Vallisneria americana*). Photo credit Onterra.

Muskgrasses (*Chara* spp.) are a genus of macroalgae, of which there are ten documented species that occur in Wisconsin (Photograph 8.2.2-2). Although the frequency of muskgrasses within Grass Lake has been of a different value each survey, their population has remained relatively stable overall (Figure 8.2.2-5). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes and these macroalgae have been found to be more competitive against vascular plants (e.g., pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel & Kufel, 2002); (Wetzel, 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate encrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops, 2002). Muskgrasses can often be easily identified by their strong skunk-like odor. As well as providing a food source for waterfowl, muskgrasses serve as a sanctuary for small fish and other aquatic organisms.

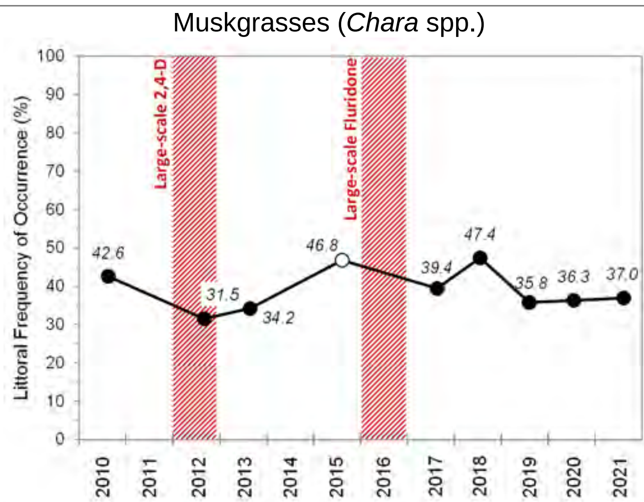


Figure 8.2.2-5. Littoral frequency of occurrence of muskgrasses in Grass Lake.

Photograph 8.2.2-2. Muskgrasses (Chara spp.). Photo credit Onterra.

Slender naiad (*Najas flexilis*) and southern naiad (*Najas guadalupensis*) occurrences within Grass Lake have been combined together due to these species' very similar morphological characteristics which can make them difficult to differentiate in the field (Photograph 8.2.2-3). Slender naiad produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman, Korth, & Temte, 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Southern naiad is a perennial that although native to North America, has been observed exhibiting aggressive growth in some northern Wisconsin lakes in recent years. It can uproot and form mats, often on taller vegetation, that can interfere with navigation and recreation. This level of growth however has not been observed in the Cloverleaf Lakes. As can be seen in Figure 8.2.2-6, the naiad population in Grass Lake has been highly dynamic, with statistically significant changes during every one of the point-intercept surveys. Onterra's experience is that slender naiad is particularly susceptible to whole-lake 2,4-D treatments, while southern naiad has shown to be more tolerant. The herbicide treatments in Grass Lake are likely a factor of the fluctuating naiad populations.

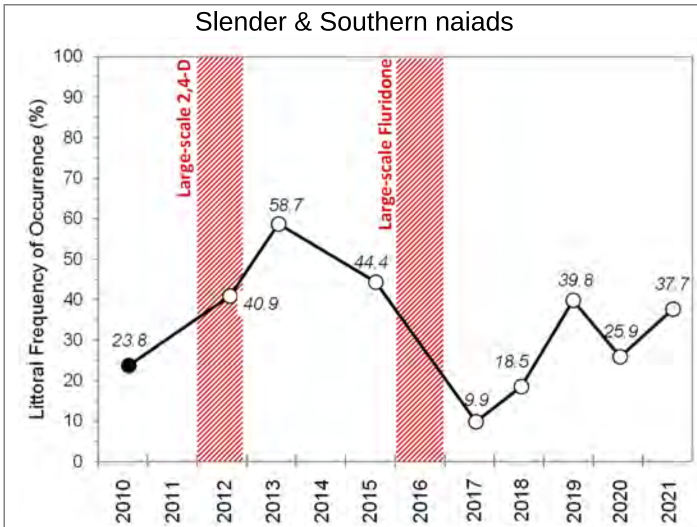


Figure 8.2.2-6. Littoral frequency of occurrence of slender and southern naiads in Grass Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.2.2-3. Slender (left) and Southern (right) naiads (*Najas flexilis* and *N. guadalupensis*). Photo credit Onterra.

Clasping-leaf pondweed (*Potamogeton richardsonii*) is another common species in Grass Lake (Photograph 8.2.2-4). As its name indicates, the submersed leaves of clasping-leaf pondweed clasp, or partially wrap, around the stem. Clasping-leaf pondweed is often found growing over harder substrates and is tolerant of low-light conditions; often one of the more abundant plants in lakes with stained water in northern Wisconsin. Clasping-leaf pondweed superficially resembles the non-native curly-leaf pondweed and is often misidentified as such. However, the leaf margins of curly-leaf pondweed are serrated, where the leaves of clasping-leaf pondweed lack serration. Like other native aquatic plants, clasping-leaf pondweed provides important structural habitat, stabilizes bottom sediments, and its fruits and rhizomes are important sources of food for wildlife. The clasping-leaf pondweed population in Grass Lake appears to be slowly declining over time between 2010-2019, with 2020 marking the second-lowest occurrence across all surveys, and then seeing a statistically valid increase in 2021 (Figure 8.2.2-7).

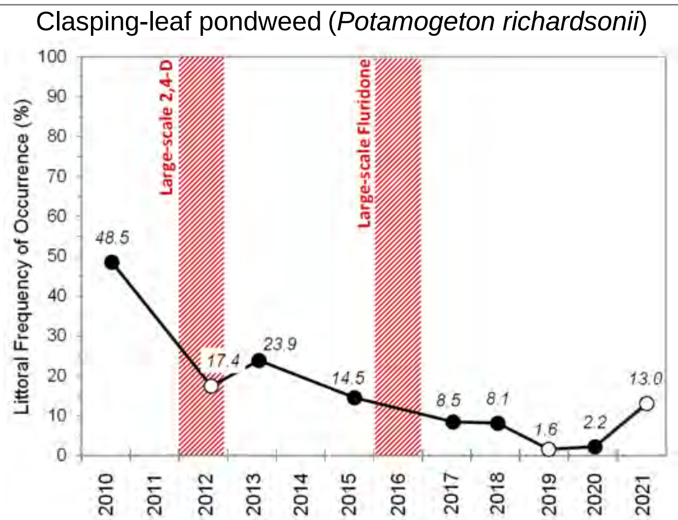
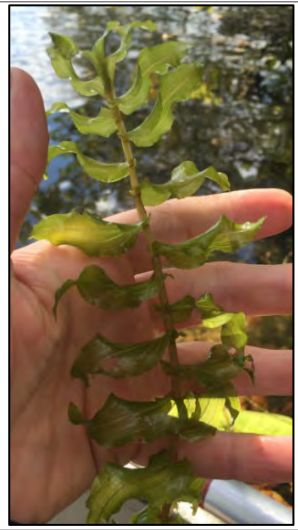


Figure 8.2.2-7. Littoral frequency of occurrence of clasping-leaf pondweed in Grass Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 8.2.2-4. Clasping-leaf pondweed (*Potamogeton richardsonii*). Photo credit Onterra.

Spatterdock (*Nuphar variegata*) is a rooted, floating-leaved plant with heart-shaped leaves and a bright yellow roundish flower in the summer months (Photograph 8.2.2-5). This plant provides shade, cover from predators, and a source of food for several species of mammals such as waterfowl, muskrat, beaver, and deer. The spatterdock population saw a statistically valid decline in Grass Lake from 2010-2012, but has since then remained relatively stable (Figure 8.2.2-8). Floating-leaved plants like spatterdock are known to be influenced by water levels, particularly lack of fluctuations.

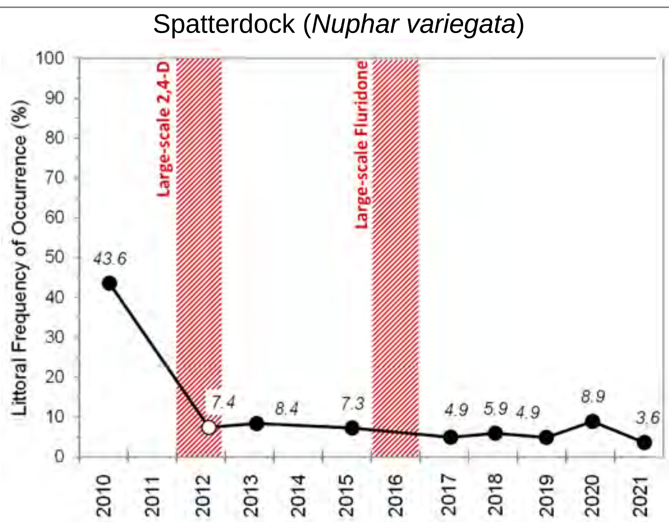
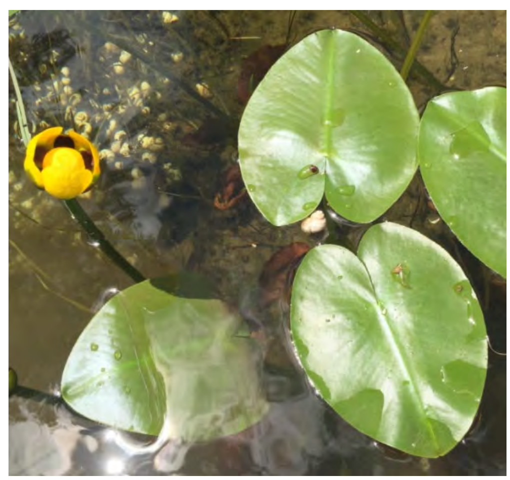


Figure 8.2.2-8. Littoral frequency of occurrence of spatterdock in Grass Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 8.2.2-5. Spatterdock (*Nuphar variegata*). Photo credit Onterra.

The littoral frequencies of occurrence for some of the not as common species in Grass Lake are displayed in Figures 8.2.2-9 and 8.2.2-10. Most of the LFOO charts in these figures below show relatively stable populations. Sago pondweed and Illinois pondweed both saw two statistically significant declines within the decade of available data. Common waterweed was the only native species to have a statistically valid decrease in 2021. Of the species displayed, Illinois pondweed and arrowheads saw a statistically valid increase in 2021.

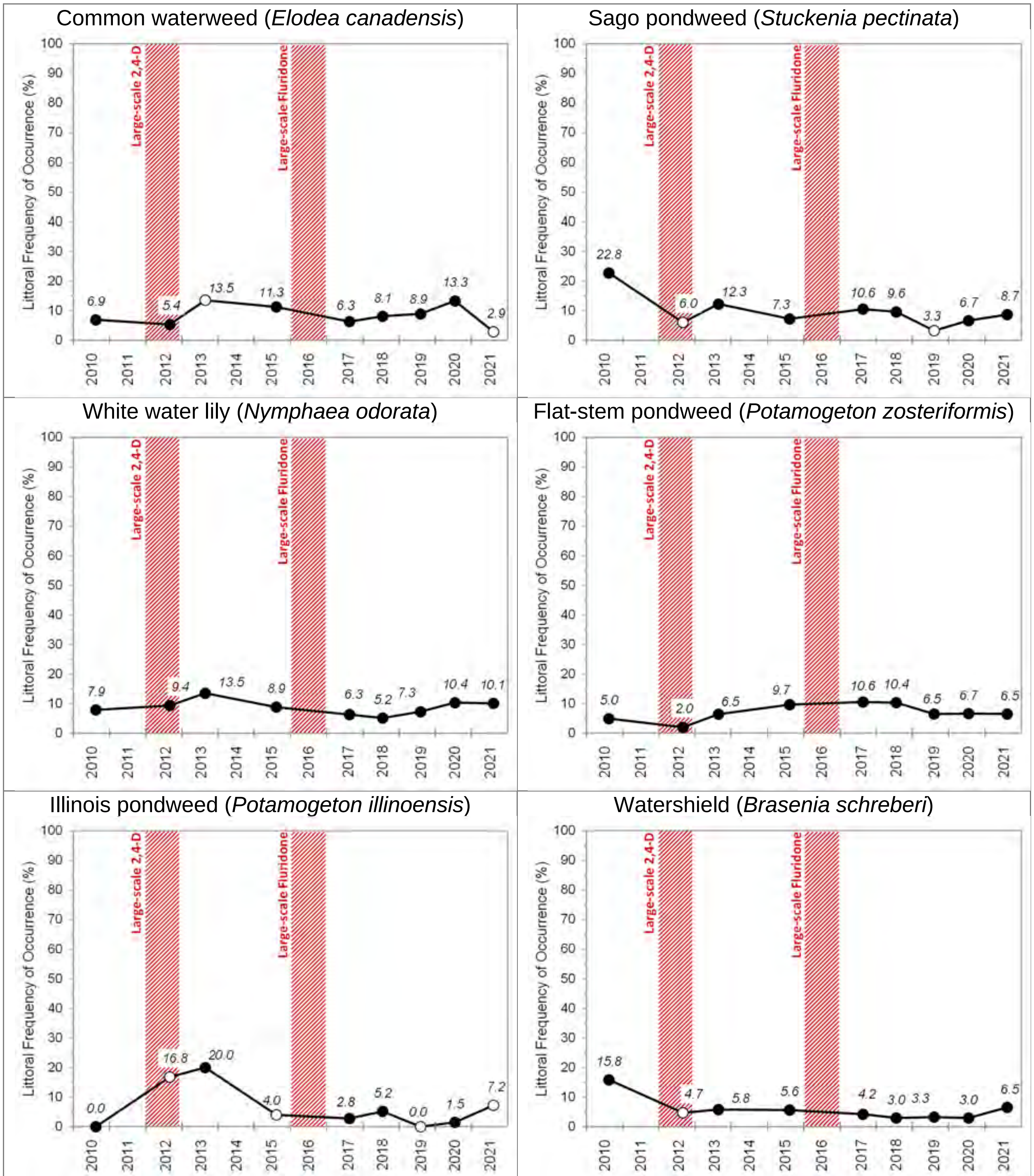


Figure 8.2.2-9. Littoral frequency of occurrence of select aquatic plant species in Grass Lake from 2010-2021. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red areas indicate a large-scale herbicide treatment occurred during that year.

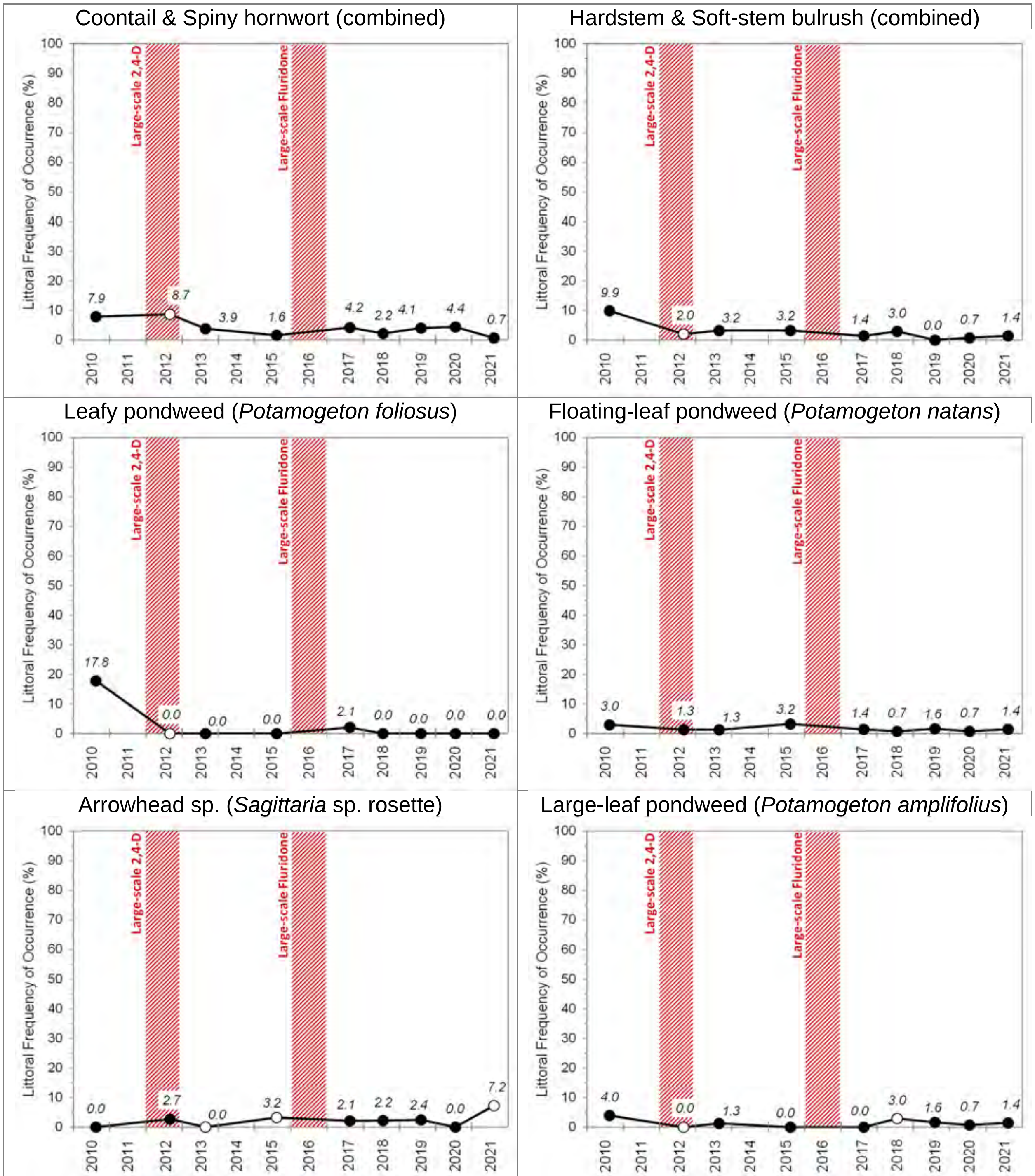


Figure 8.2.2-10. Littoral frequency of occurrence of select aquatic plant species in Grass Lake from 2010-2021. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red areas indicate a large-scale herbicide treatment occurred during that year.

Because of the relatively high number of native species of plants (species richness) found in Grass Lake, one may assume that the lake would also have a high diversity. As discussed earlier, how evenly the species are distributed throughout the system also influence diversity. The diversity index for Grass Lake's plant community in 2021 (0.89) lies above the North Central Hardwood

Forests ecoregion median value (0.84), as well as the state median (0.86), indicating the lake holds excellent diversity (Figure 8.2.2-11).

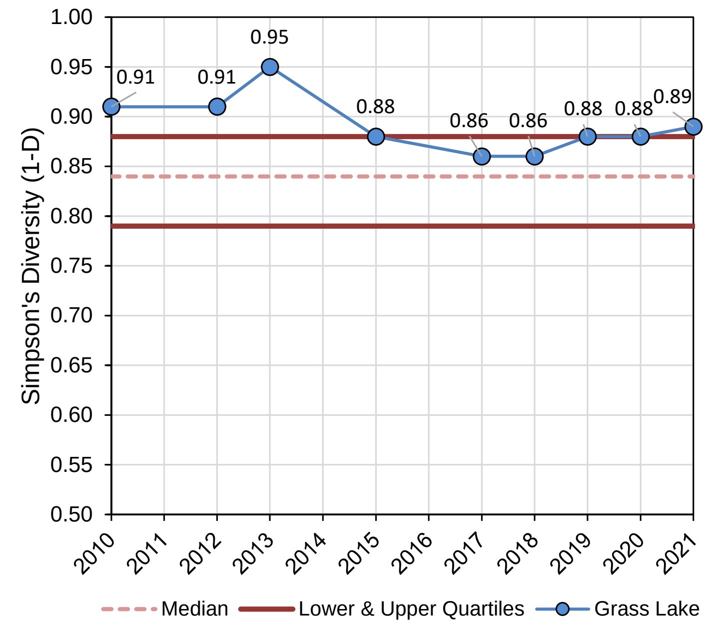


Figure 8.2.2-11. Simpson's diversity for Grass Lake.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while wild celery was found at approximately 49% of the littoral sampling locations in 2021, its relative frequency of occurrence is 22%. Explained another way, if 100 plants were randomly sampled from Grass Lake, 22 of them would be wild celery. This distribution can be observed in Figure 8.2.2-12 where in 2021, 4 species together accounted for 56% of the population of plants within Grass Lake, and the other 25 species accounted for the remaining 44%. As a reminder, the incidentally located species are not included in this analysis.

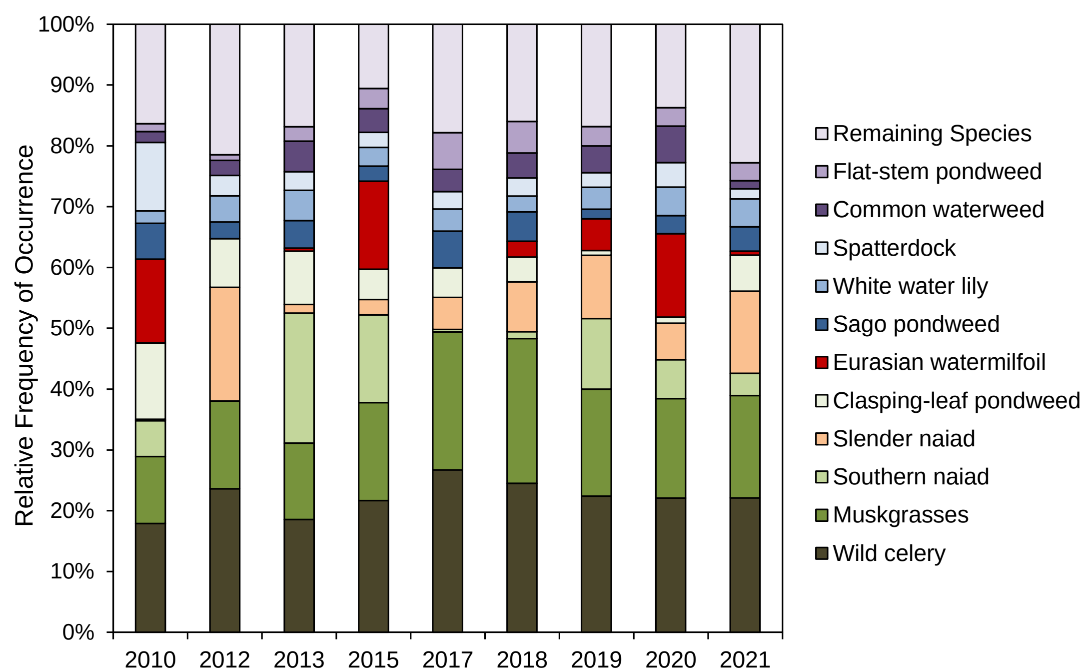


Figure 8.2.2-12. Grass Lake aquatic plant relative frequency of occurrence analysis. Created using data from point-intercept surveys.

Grass Lake's average conservatism value in 2021 (6.0) fell in between the state (6.3) and ecoregion (5.8) medians. This indicates that the aquatic plant community in Grass Lake is not particularly sensitive to environmental degradation. Grass Lake's species richness value however exceeded the ecoregion and state medians in each of the survey years. Combining Grass Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 31.2 in 2021 which is above both the ecoregion and state medians (Figure 8.2.2-13).

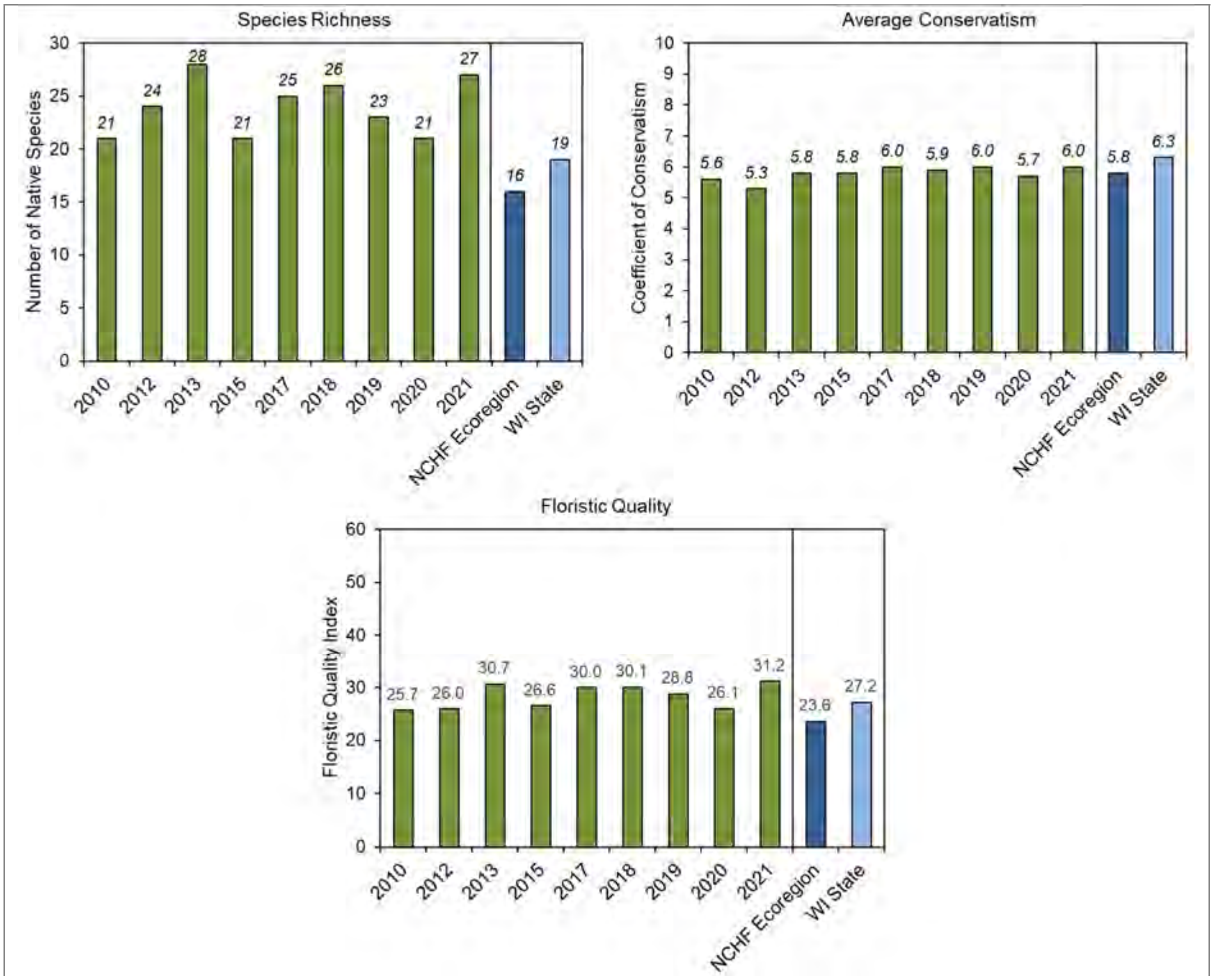


Figure 8.2.2-13. Grass Lake Floristic Quality Analysis. Created using data from point-intercept surveys.

The quality of Grass Lake is also indicated by the high incidence of emergent and floating-leaf plant communities that occur around much of the lake. The 2020 community map indicates that approximately 19.6 acres of the lake contains these types of plant communities (Map 3, Table 8.2.2-2). Nine native floating-leaf and emergent species were located in and around Grass Lake in 2020 (Table 8.2.2-1), providing valuable wildlife habitat.

Table 8.2.2-2. Grass Lake acres of emergent and floating-leaf plant communities from the 2020 community mapping survey.

Plant Community	Acres
Emergent	0.3
Floating-leaf	10.0
Mixed Emergent & Floating-leaf	9.3
Total	**19.6**

Some Cloverleaf Lakes stakeholders have expressed concerns about water levels and the reduction of emergent plants on the southern "wetland island" in Grass Lake where the loons nest. Figure 8.2.2-14 depicts the available aerial photographs of this area during six different years between 1938-2020.

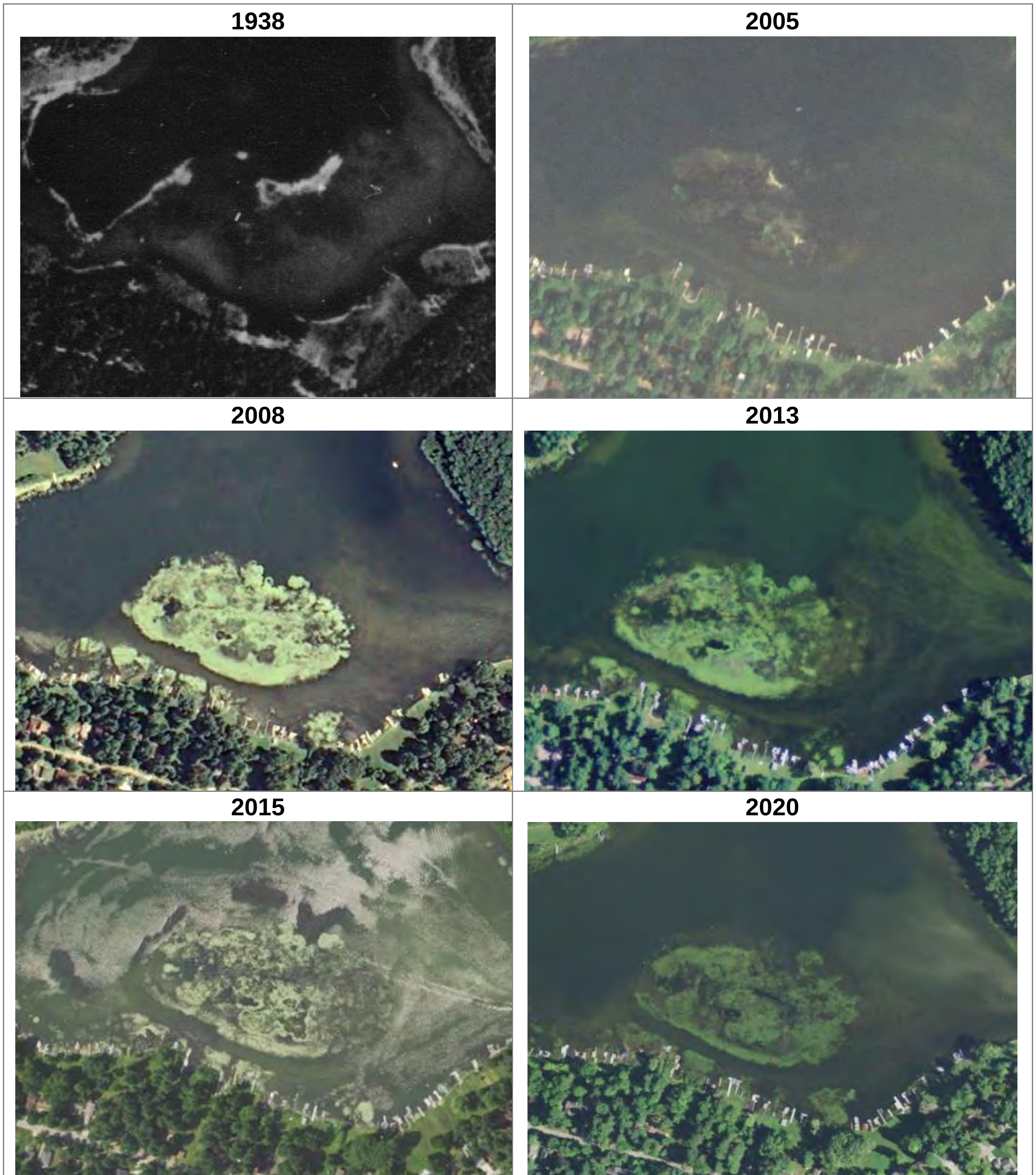


Figure 8.2.2-14. Historical photographs of Grass Lake's southern emergent island. 1938 aerial photograph from Wisconsin State Cartographer's Office Historical Aerial Image Finder (WHAIFinder). 2005, 2008, 2013, 2015, and 2020 aerial photograph from the National Agriculture Imagery Program (NAIP).

Since 2020 marked the first time a community mapping survey had been conducted to capture emergent and floating-leaf vegetation populations around the lakes. From the images, for the more recent time period of 2005-2020, the overall size of this wetland area does not appear to be decreasing. The density of vegetation may appear to change between years, although this is expected due to factors like weather and environment, natural population fluctuations, and could also be dependent on what month the photos may have been taken.

Numerous studies of lakes in North America and Europe have shown that the decline of emergent aquatic plant communities is often attributed to human activity. Emergent aquatic plant communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shoreland areas when compared to undeveloped shoreland areas in Minnesota lakes. Studies completed on Wisconsin lakes have also shown that aquatic plants are susceptible to direct impacts from watercraft such as cutting from the prop and uprooting of plants through scouring of the bottom (Asplund & Cook, 1997).

In addition to shoreland development and direct impacts from watercraft, emergent aquatic plant communities have also been shown to decline following alterations to natural hydrologic regimes such as the stabilization and/or heightening of water levels (Coops et al. 2003, Leira and Cantonati 2008, and Zhang, et al. 2014). Emergent plant communities can be completely dependent on slight water level fluctuations for germination and/or flooding seedlings (Coops et al. 2003). However, the response of aquatic vegetation following the alteration of natural water levels can be slow, and the loss of these communities may appear gradually over several decades following water level manipulation (Leira & Cantonati, 2008).

8.3.0 Pine Lake Introduction

An Introduction to Pine Lake

Pine Lake, Shawano County, is a deep, headwater mesotrophic drainage lake with a maximum depth of 35 feet, a mean depth of 15 feet, and a surface area of approximately 219 acres. Its direct surficial watershed encompasses approximately 475 acres comprised mainly of forests, wetlands and row crop agriculture. Water enters Pine Lake from Grass Lake and flows out into Matteson Creek which flows into the Embarrass River. In 2020, 19 native aquatic plant species were located within the lake, of which muskgrasses (*Chara* spp.) were the most common. During the 2020 survey, three invasive plants were found in Pine Lake: Eurasian watermilfoil, curly-leaf pondweed, and pale-yellow iris.

Lake at a Glance - Pine Lake

Morphometry	
Lake Type	Deep Headwater Drainage Lake
Surface Area (Acres)	219
Max Depth (feet)	35
Mean Depth (feet)	15
Perimeter (Miles)	2.2
Shoreline Complexity	1.1
Watershed Area (Acres)	475
Watershed to Lake Area Ratio	2:1

Water Quality	
Trophic State	Mesotrophic
Limiting Nutrient	Phosphorus
Avg Summer P (µg/L)	13
Avg Summer Chl-α (µg/L)	3
Avg Summer Secchi Depth (ft)	10.8
Summer pH	8.7
Alkalinity (mg/L as $CaCO_3$)	144

Vegetation	
Number of Native Species	19
NHI-Listed Species	
Exotic Species	Eurasian watermilfoil; Curly-leaf pondweed, Pale-yellow iris
Average Conservatism	5.9
Floristic Quality	22.7
Simpson's Diversity (1-D)	0.85

Descriptions of these parameters can be found within the chain-wide portion of the management plan

8.3.1 Pine Lake Water Quality

It is often difficult to determine the status of a lake's water quality purely through observation. Anecdotal accounts of a lake "getting better" or "getting worse" can be difficult to judge because a) a lake's water quality may fluctuate from year to year based upon environmental conditions such as precipitation, and b) differences in observation and perception of water quality can differ greatly from person to person. It is best to analyze the water quality of a lake through scientific data as this gives a concrete indication as to the health of the lake, and whether its health has deteriorated or improved. Further, by looking at data for similar lakes regionally and statewide, the status of a lake's water quality can be made by comparison.

Near-surface total phosphorus data for Pine Lake are available from 1981 and 1990-2020 (Figure 8.3.1-1). With exception of 1997, all historical near-surface total phosphorus concentrations and the data collected as part of the lake management planning project in 2020 fall within the *excellent* category for deep, headwater drainage lakes in Wisconsin. The weighted average of summer near-surface total phosphorus concentrations using all data that are available is 13.0 µg/L, and falls well below the median concentration for other deep, headwater drainage lakes in Wisconsin (17.0 µg/L) and considerably below the median concentration for all lake types within the North Central Hardwood Forests (NCHF) ecoregion (52.0 µg/L). Phosphorus concentrations have generally been stable during the period 1990-2020 and an increasing trend was not observed. Phosphorus concentrations in Pine Lake are slightly lower than the long-term average in Grass Lake but similar to the concentration in Round Lake.

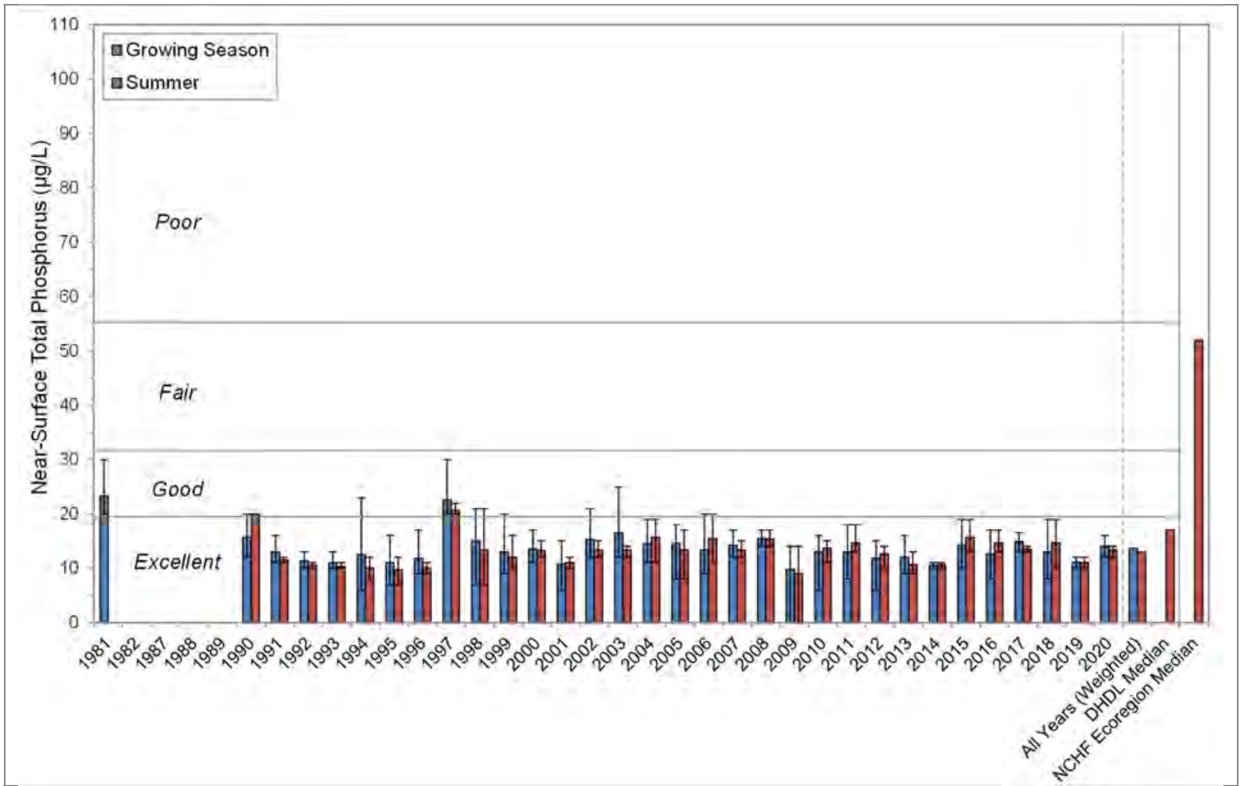


Figure 8.3.1-1. Pine Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

To determine if internal nutrient loading of phosphorus is occurring in a stratified lake, phosphorus concentrations are measured near the bottom in the deepest part of the lake during stratification. In lakes which experience high levels of internal nutrient loading, the near-bottom phosphorus concentrations are significantly higher than those measured near the surface.

Near-bottom total phosphorus concentrations were collected in 1981, 1982, 1991-1996, and on three occasions in 2020 from Pine Lake (Figure 8.3.1-2). In all of the years except 1981 and 1982 and 2020, near-bottom concentrations were higher than the near-surface concentrations at least part of the year but the concentrations were low enough that internal loading is not a concern in Pine Lake. In 2020 near-bottom concentrations were similar to surface concentrations. This is in contrast to Round and especially Grass Lake, where near-bottom concentrations in 2020 were significantly higher than the surface values. As will be discussed, Grass and Round lakes did not fully de-stratify in 2020 whereas Pine Lake did.

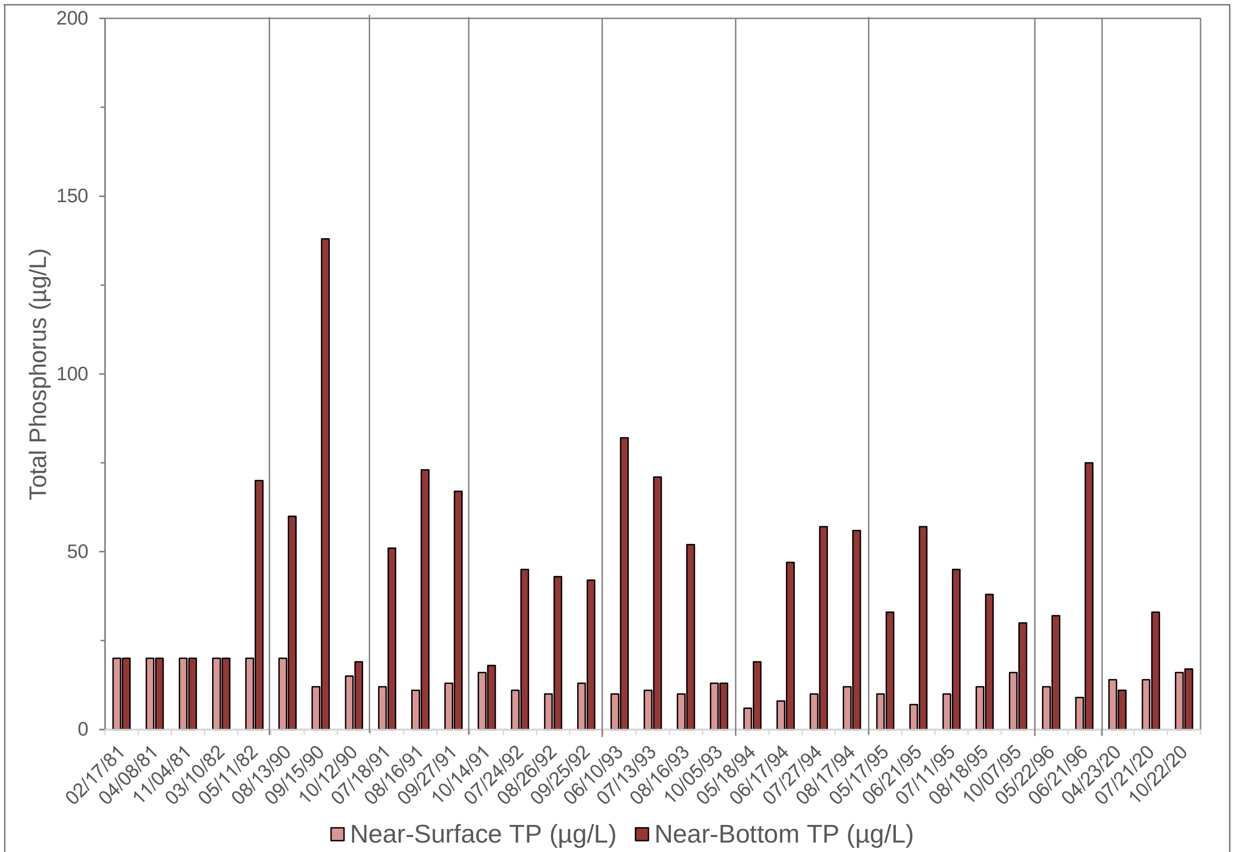


Figure 8.3.1-2. Pine Lake near-bottom and corresponding near-surface total phosphorus concentrations.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available for Pine Lake from 198-82 and 1993-2020, nearly as complete a record as for total phosphorus (Figure 8.3.1-3). All historical near-surface summer chlorophyll-*a* concentrations and the data collected as part of the lake management planning project in 2020 fall within the *excellent* category for deep, headwater drainage lakes in Wisconsin. The long-term average of 3.4 µg/L is lower than the median value for other deep, headwater drainage lakes in Wisconsin (5.0 µg/L) and much less than the median concentration for all lake types within the NCHF ecoregion (15.2 µg/L). Chlorophyll-*a* concentrations in Pine Lake do not exhibit a trend up or down over the period of record.

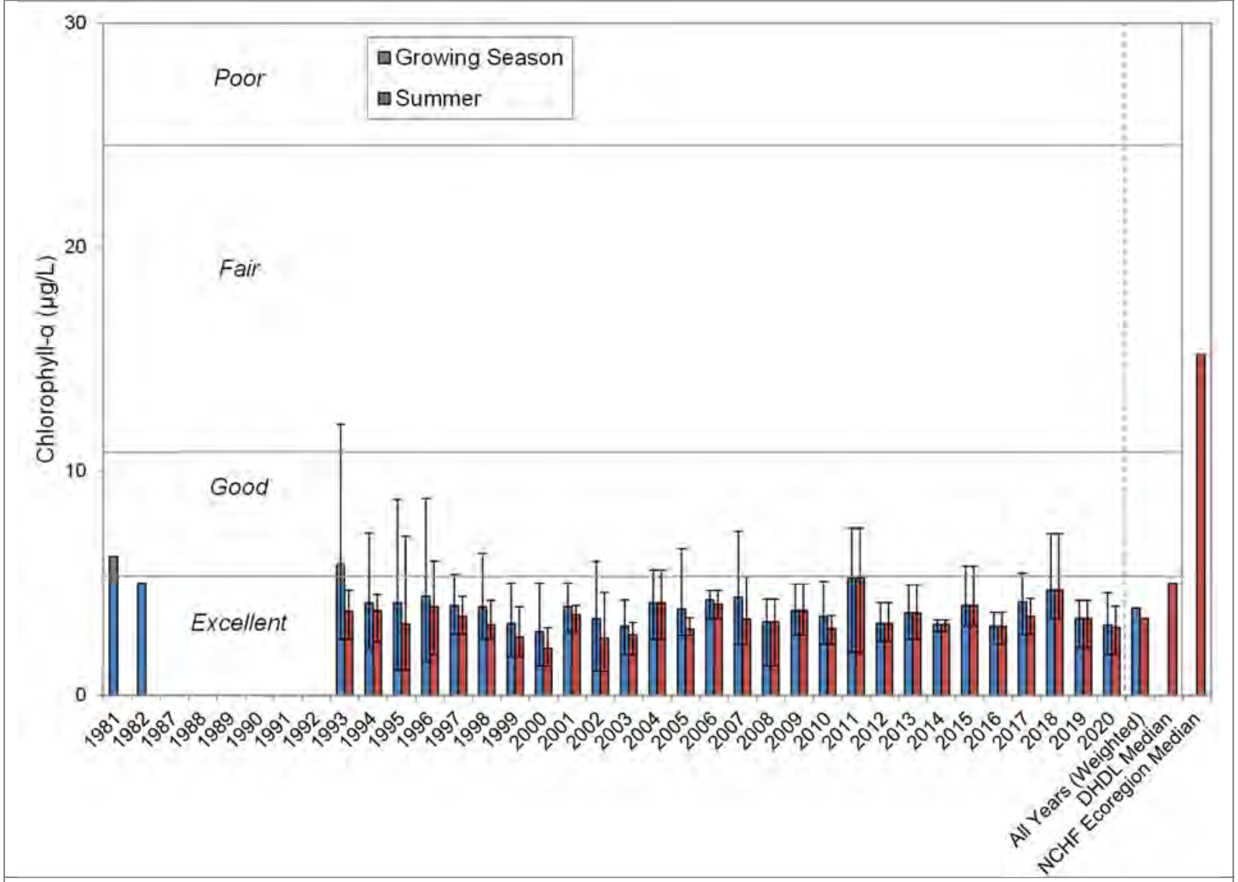


Figure 8.3.1-3. Pine Lake average annual near-surface chlorophyll-*a* concentrations and median near-surface total phosphorus concentrations for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

There is a slightly longer record of Secchi disk transparency from Pine Lake compared with phosphorus or chlorophyll *a*. A continuous record from 1987 to 2020, with the exception of 2007 is available (Figure 8.3.1-4). For the period 1987-1998, the mean summer Secchi disk transparency (11.9 feet) fell within the *excellent* category for deep, headwater drainage lakes. However, for the period 1999-2020 the summer water clarity was not as good with a mean summer Secchi disk transparency of 9.2 feet. During the latter period the water clarity was not always in the excellent category but some years was in the g*ood* category. This mean transparency is less than the median depth (10.8 feet) for deep headwater drainage lakes in Wisconsin but is much better than the median value (5.3 feet) for all lake types in the NCHF ecoregion. Although water clarity has degraded on average in the last 22 years, phosphorus and chlorophyll-*a* have only increased a small amount. The summer average phosphorus concentrations increased from 12.4 to 13.2 µg/L and chlorophyll *a* levels remained the nearly the same being 3.5 for the early period and 3.4 for the later period. Although the change has not been great the trend is not the direction the water quality should be taking. Overall, the mean water transparency is 10.8 feet which places the lake in the *excellent* category.

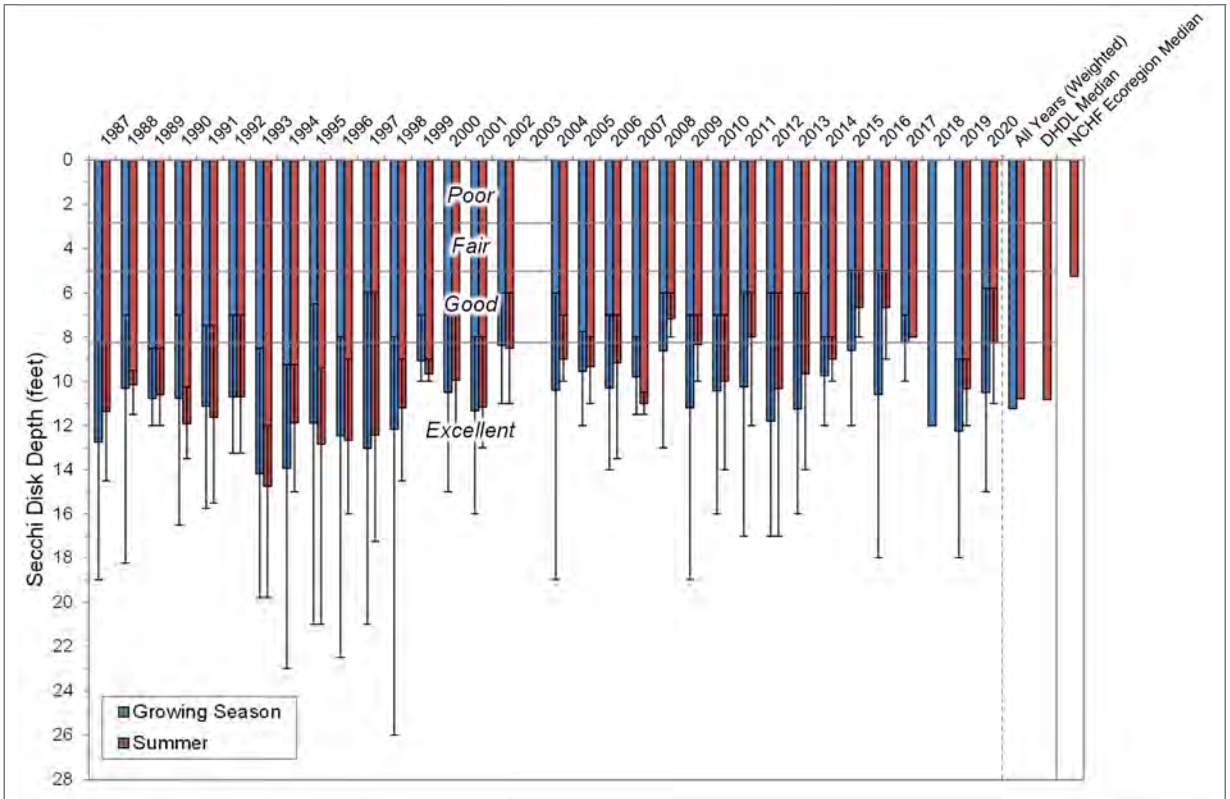


Figure 8.3.1-4. Pine Lake average annual Secchi disk transparency and median Secchi disk transparencies for state-wide deep, headwater drainage lakes (DHDL) and North Central Hardwood Forests (NCHF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913.

Pine Lake Trophic State

The Trophic State Index (TSI) values for Pine Lake were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figure 8.3.1-5). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors other than algae. Historical data indicate that Pine Lake was in a mesotrophic state, but with the increase in phosphorus and chlorophyll-*a* in recent years, the lake is currently in a lower eutrophic state.

Using the overall weighed TSI value, it can be said that Pine Lake is a *mesotrophic* system. Pine Lake's productivity level is slightly less than other deep headwater drainage lakes in the state and less than other lakes in the Northern Lakes and Forests Ecoregion.

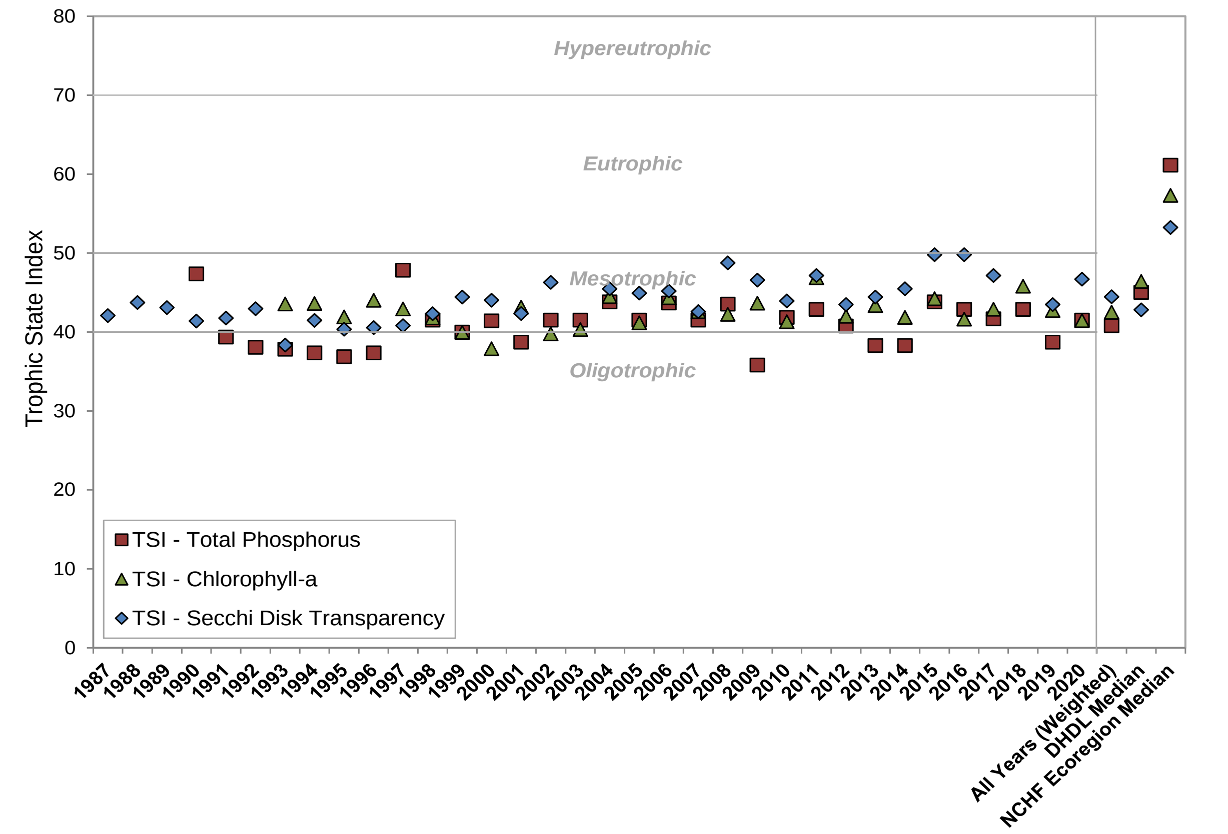


Figure 8.3.1-5. Pine Lake, state-wide deep headwater drainage lakes, and regional Trophic State Index values. Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Pine Lake

Dissolved oxygen and temperature were measured during water quality sampling visits to Pine Lake by Onterra staff. Profiles depicting these data are displayed in Figure 8.3.1-6. Pine Lake is *dimictic* meaning the lake remains stratified during the summer (and winter). Unlike Round and Grass lakes, Pine Lake experienced spring turnover in April 2020. Temperature and dissolved oxygen levels were the same top to bottom. With stratification, wind and water movement are not sufficient to mix these layers together, only the warmer upper layer will mix. As a result, the bottom layer of water no longer receives atmospheric diffusion of oxygen and decomposition of organic matter within this layer depletes available oxygen as exhibited in the July 2020 profile. The lake was still stratified on October 22 but likely mixed prior to the onset of ice cover.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39 °F, while oxygen gradually declines once again towards the bottom of the lake. In February 2021, Pine Lake was found to support sufficient levels of dissolved oxygen under the ice throughout most of the water column. This indicates that winter fish kills are not a concern in the lake.

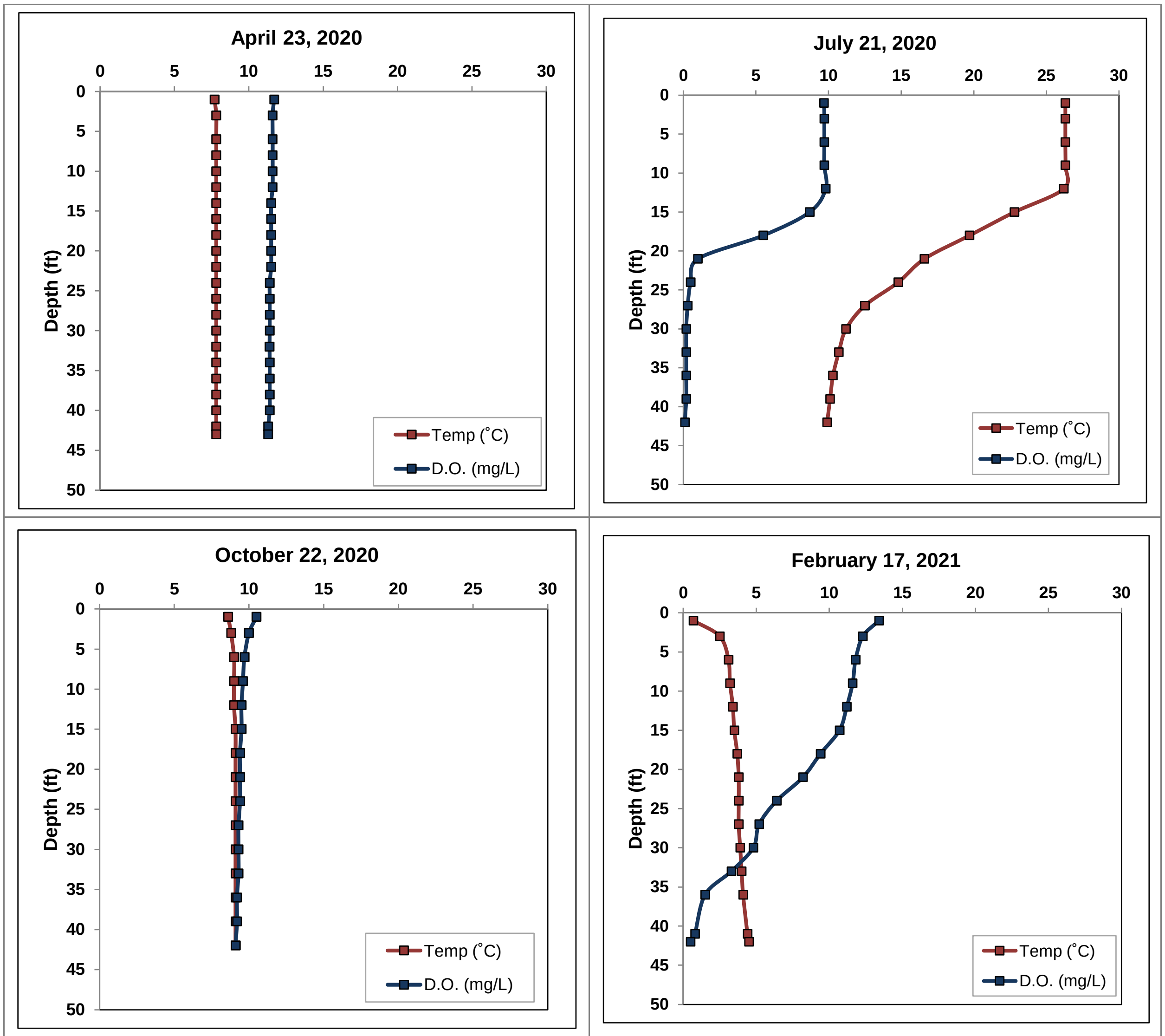


Figure 8.3.1-6. Pine Lake 2020/21 dissolved oxygen and temperature profiles.

8.3.2 Pine Lake Aquatic Vegetation

The 2021 aquatic plant point-intercept survey was conducted on Pine Lake in August by Onterra (Figure 8.3.2-1). The floating-leaf and emergent plant community mapping survey was completed during the summer of 2020 to create the emergent and floating-leaf aquatic plant community map. Point-intercept surveys have been previously completed on Pine Lake in 2010, 2013, 2015, and 2017-2020 also. Taking all survey years into account, a total of 28 native aquatic plants species were located in and around Pine Lake (Table 8.3.2-1). Only the species which were sampled directly on the rake during the point-intercept survey are used in the analyses that follow – incidentally located species are not included. In addition, four non-native species were located in Pine Lake: Eurasian watermilfoil (EWM), curly-leaf pondweed (CLP), starry stonewort, and pale-yellow iris. These non-native species were previously discussed at the end of section 3.4 in a subsection titled *Non-native Aquatic Plants in the Cloverleaf Lakes*.

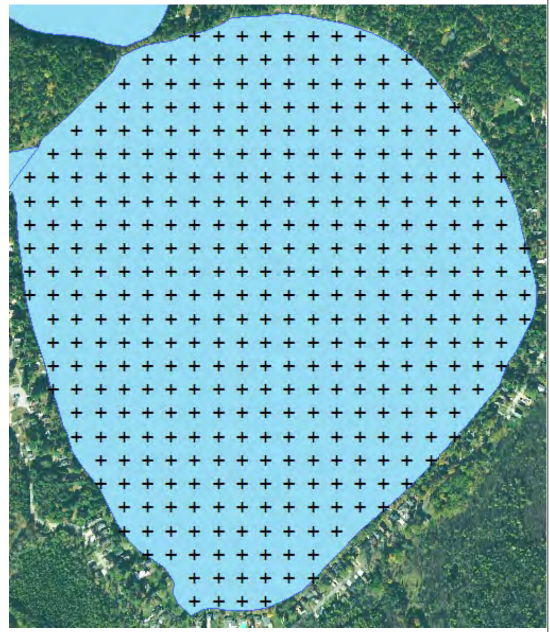


Figure 8.3.2-1. Pine Lake whole-lake aquatic point-intercept survey sampling locations.

During the 2021 PI survey, aquatic plants were found growing to a depth of 18 feet in Pine Lake. Of the 398 points on the sampling grid (Figure 8.3.2-1), 234 were considered to be littoral (within depths at which plants can grow). Of the point-intercept locations sampled within the littoral zone in 2021, approximately 68% contained aquatic vegetation. Aquatic plant rake fullness data (density of plants pulled up on the rake) indicates that in 2021, about 29% contained the highest density rating of TRF=3, 21% of the littoral sampling sites contained the lowest density rating of TRF=1, and the remaining 18% contained TRF=2 (Figure 8.3.2-2).

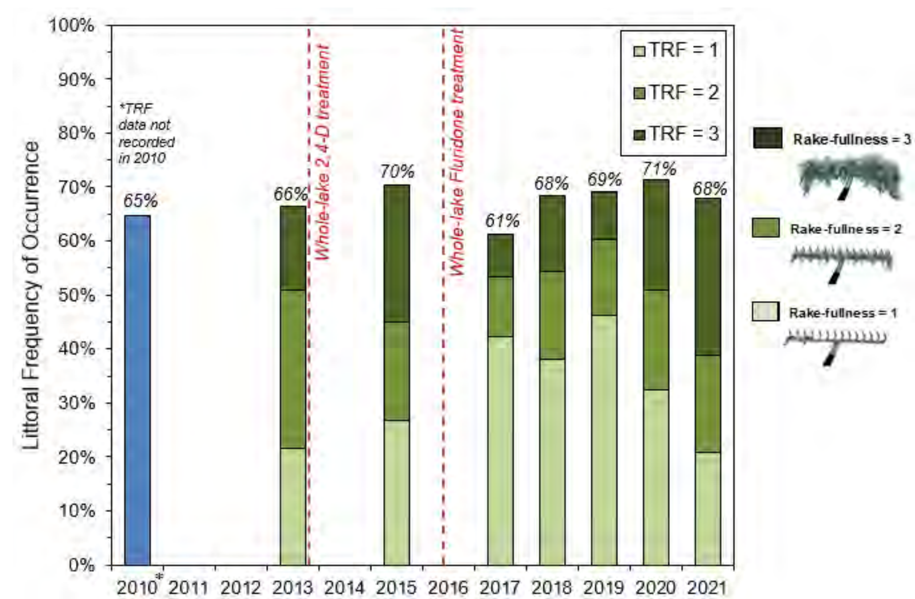


Figure 8.3.2-2. Total rake fullness ratings on Pine Lake. Created using data from 2020 point-intercept survey.

Table 8.3.2-1. Aquatic plant species located in Pine Lake during the aquatic plant surveys.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2010	2013	2015	2017	2018	2019	2020	2021
E	*Iris pseudacorus*	Pale-yellow iris	Non-Native - Invasive	N/A							I	
	Schoenoplectus acutus	Hardstem bulrush	Native	5							I	
FL	*Brasenia schreberi*	Watershield	Native	7							I	
	Nuphar variegata	Spatterdock	Native	6	X						I	
	Nymphaea odorata	White water lily	Native	6	X			X			I	
Submergent	*Ceratophyllum demersum*	Coontail	Native	3		X	X	X	X	X	X	X
	Ceratophyllum echinatum	Spiny hornwort	Native	10						X		
	Chara spp.	Muskgrasses	Native	7	X	X	X	X	X	X	X	X
	Elodea canadensis	Common waterweed	Native	3		X	X	X	X	X	X	X
	Heteranthera dubia	Water stargrass	Native	6						X		X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7							X	X
	Myriophyllum spicatum	Eurasian watermilfoil	Non-Native - Invasive	N/A	X	X	X		X	X	X	X
	Najas flexilis	Slender naiad	Native	6		X	X	X	X	X	X	X
	Najas guadalupensis	Southern naiad	Native	7		X	X	X		X	X	X
	Nitella spp.	Stoneworts	Native	7		X	X	X	X	X	X	X
	Nitellopsis obtusa	Starry stonewort	Non-Native - Invasive	N/A								X
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X					X		
	Potamogeton crispus	Curly-leaf pondweed	Non-Native - Invasive	N/A	X				X		X	X
	Potamogeton foliosus	Leafy pondweed	Native	6		X		X	X			X
	Potamogeton friesii	Fries' pondweed	Native	8					X		X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7		X	X	X	X	X	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6		X	X	X	X	X	X	X
	Potamogeton praelongus	White-stem pondweed	Native	8				X				X
	Potamogeton pusillus	Small pondweed	Native	7			X					X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X	X	X	X	X	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8		X						
	Potamogeton strictifolius	Stiff pondweed	Native	8					X	X		X
	Potamogeton X scoliophyllus	Large-leaf X Illinois pondweed	Native	N/A		X						
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6		X	X	X	X	X	X	X
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A								X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X	X	X	X	X	X	X
	Utricularia vulgaris	Common bladderwort	Native	7					X		X	X
	Vallisneria americana	Wild celery	Native	6	X	X	X	X	X	X	X	X

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
E = Emergent; FL = Floating-leaf

Figure 8.3.2-3 shows that muskgrasses, wild celery, slender and southern naiads, clasping-leaf pondweed, and sago pondweed are typically the most frequently encountered native plants in Pine Lake.

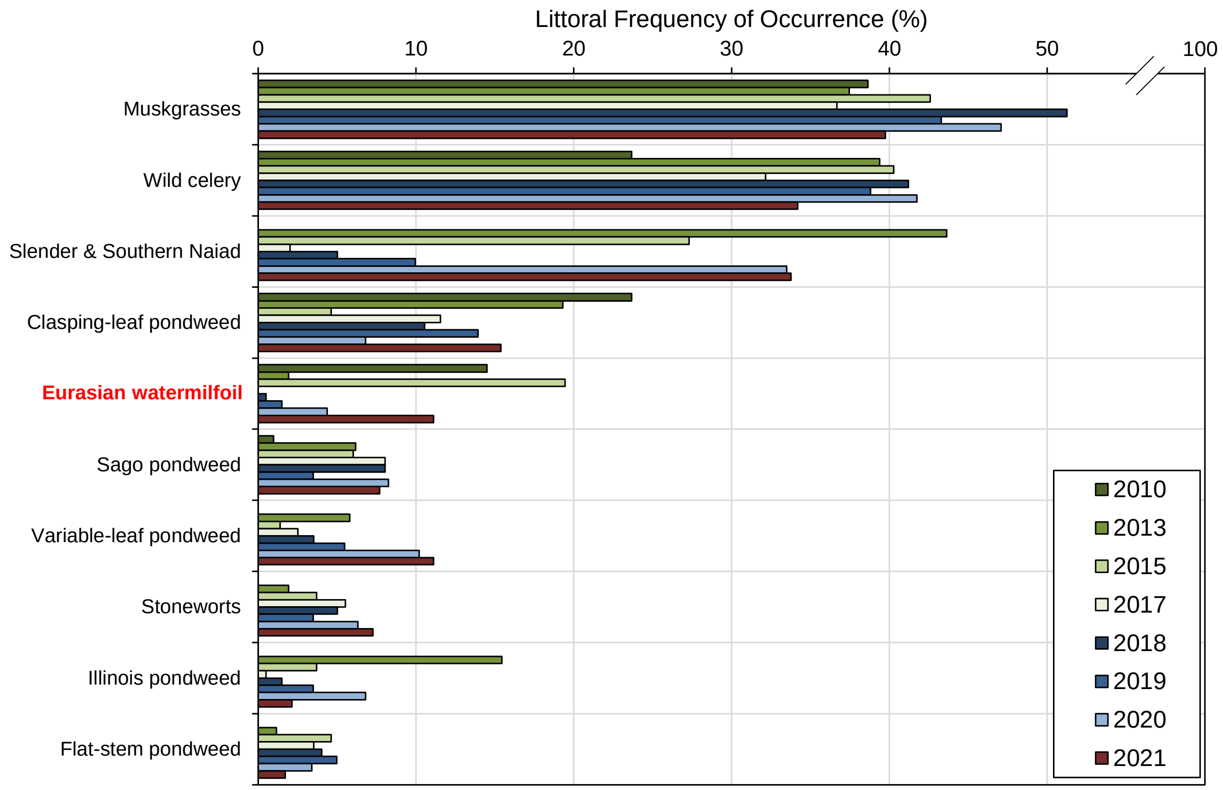


Figure 8.3.2-3. Pine Lake aquatic plant littoral frequency of occurrence analysis. Chart includes the top most frequently encountered species only. Created using data from the point-intercept surveys.

Muskgrasses (*Chara* spp.) are a genus of macroalgae, of which there are ten documented species that occur in Wisconsin (Photograph 8.3.2-1). Although the frequency of muskgrasses within Pine Lake has been of a different value each survey, their population has remained relatively stable overall as the most frequent plant during all of the surveys but one (Figure 8.3.2-4). Dominance of the aquatic plant community by muskgrasses is common in hardwater lakes and these macroalgae have been found to be more competitive against vascular plants (e.g., pondweeds, milfoils, etc.) in lakes with higher concentrations of calcium carbonate in the sediment (Kufel & Kufel, 2002); (Wetzel, 2001). Muskgrasses require lakes with good water clarity, and their large beds stabilize bottom sediments. Studies have also shown that muskgrasses sequester phosphorus in the calcium carbonate encrustations which form on these plants, aiding in improving water quality by making the phosphorus unavailable to phytoplankton (Coops, 2002). Muskgrasses can often be easily identified by their strong skunk-like odor. As well as providing a food source for waterfowl, muskgrasses serve as a sanctuary for small fish and other aquatic organisms.

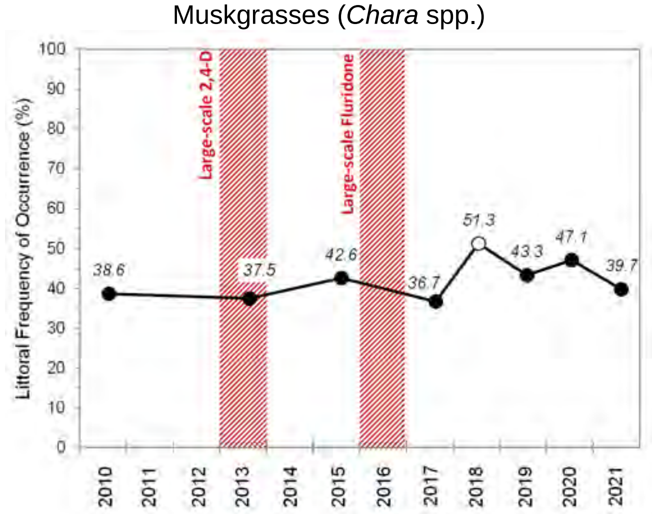


Figure 8.3.2-4. Littoral frequency of occurrence of muskgrasses in Pine Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.3.2-1. Muskgrasses (*Chara* spp.). Photo credit Onterra.

Wild celery (*Vallisneria americana*) was the second most frequent species in Pine Lake during the 2021 point-intercept survey, not far behind muskgrasses. Wild celery produces long, grass-like leaves which extend in a circular fashion from a basal rosette (Photograph 8.3.2-2). To keep the leaves standing in the water column, lacunar cells in the leaves contain gas, making them buoyant. Towards the late-summer when wild celery is at its peak growth stage, it is easily uprooted by wind and wave activity. It can then pile up on shorelines depending on the predominant wind direction. The leaves, fruits, and winter buds of wild celery are food sources for numerous species of waterfowl and other wildlife and are an important component of the Cloverleaf Lakes ecosystem. The wild celery population in Pine Lake saw one statistically valid increase between 2010-2013, but has remained relatively stable since then (Figure 8.3.2-5).

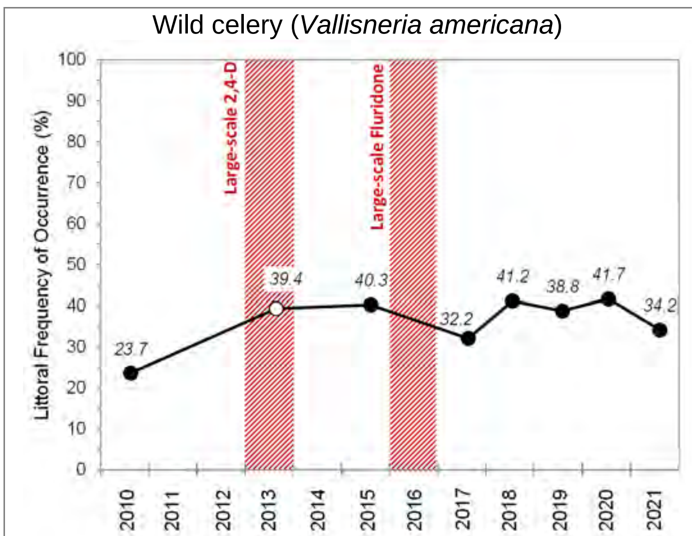


Figure 8.3.2-5. Littoral frequency of occurrence of wild celery in Pine Lake.

Photograph 8.3.2-2. Wild celery (*Vallisneria americana*). Photo credit Onterra.

Slender naiad (*Najas flexilis*) and southern naiad (*Najas guadalupensis*) occurrences within Pine Lake have been combined together due to these species' very similar morphological characteristics which can make them difficult to differentiate in the field (Photograph 8.3.2-3). Slender naiad produces numerous seeds on an annual basis and is considered to be one of the most important food sources for a number of migratory waterfowl species (Borman, Korth, & Temte, 1997). In addition, slender naiad's small, condensed network of leaves provide excellent habitat for aquatic invertebrates. Southern naiad, although native to North America, has been observed exhibiting aggressive growth in some northern Wisconsin lakes in recent years. It can uproot and form mats, often on taller vegetation, that can interfere with navigation and recreation. This level of growth however has not been observed in the Cloverleaf Lakes. As can be seen in Figure 8.3.2-6, the naiad population in Pine Lake has been highly dynamic, with statistically significant changes during five of the point-intercept surveys. Onterra's experience is that slender naiad is particularly susceptible to whole-lake 2,4-D treatments, while southern naiad has shown to be more tolerant. The herbicide treatments in Pine Lake are likely a factor of the fluctuating naiad populations.

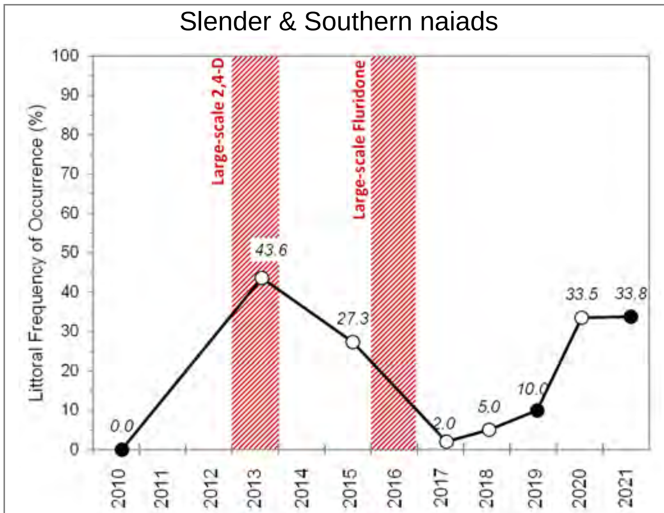


Figure 8.3.2-6. Littoral frequency of occurrence of slender and southern naiads in Pine Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.3.2-3. Slender (left) and Southern (right) naiads (*Najas flexilis and N. guadalupensis).* Photo credit Onterra.

Clasping-leaf pondweed (*Potamogeton richardsonii*) is another common species in Pine Lake (Photograph 8.3.2-4). As its name indicates, the submersed leaves of clasping-leaf pondweed clasp, or partially wrap, around the stem. Clasping-leaf pondweed is often found growing over harder substrates and is tolerant of low-light conditions; often one of the more abundant plants in lakes with stained water in northern Wisconsin. Clasping-leaf pondweed superficially resembles the non-native curly-leaf pondweed and is often misidentified as such. However, the leaf margins of curly-leaf pondweed are serrated, where the leaves of clasping-leaf pondweed lack serration. Like other native aquatic plants, clasping-leaf pondweed provides important structural habitat, stabilizes bottom sediments, and its fruits and rhizomes are important sources of food for wildlife. The clasping-leaf pondweed population in Pine Lake saw its second-lowest frequency of occurrence during the 2020 survey, which was a statistically valid decrease from the previous survey in 2019 (Figure 8.3.2-7). In 2021, however, the population rebounded to its third-highest frequency of the eight survey years.

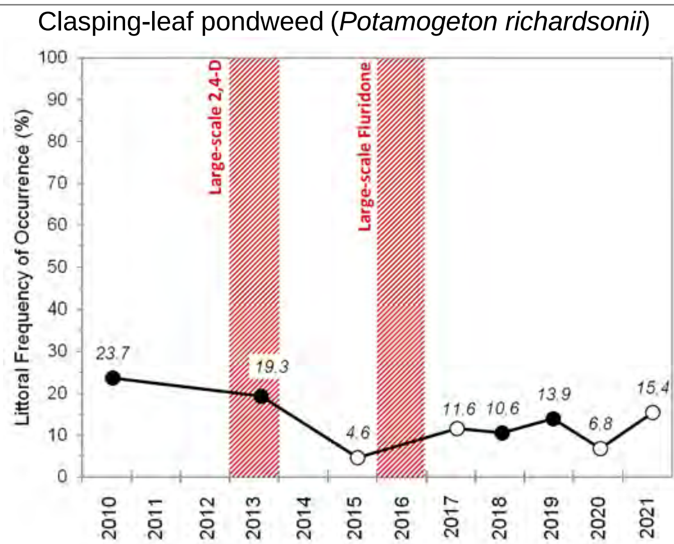


Figure 8.3.2-7. Littoral frequency of occurrence of clasping-leaf pondweed in Pine Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).

Photograph 8.3.2-4. Clasping-leaf pondweed (*Potamogeton richardsonii*). Photo credit Onterra.

Sago pondweed (*Stuckenia pectinata*) is another of the more common species in Pine Lake. It is a rooted plant that can be found in a variety of waterbodies throughout Wisconsin. It is highly tolerant of low-light conditions, and is often the last rooted plant able to survive in waterbodies with extremely turbid water (Borman, Korth, & Temte, 1997). To survive in these conditions, it produces numerous needle-like leaves that spread out near or at the water's surface in a fan-shape to gather light (Photograph 8.3.2-5). Sago pondweed has been found to be one of the most valuable food resources for waterfowl, producing numerous seeds and tubers. The sago pondweed population in Pine Lake in 2020 saw a statistically valid increase from the 2019 survey (Figure 8.3.2-8).

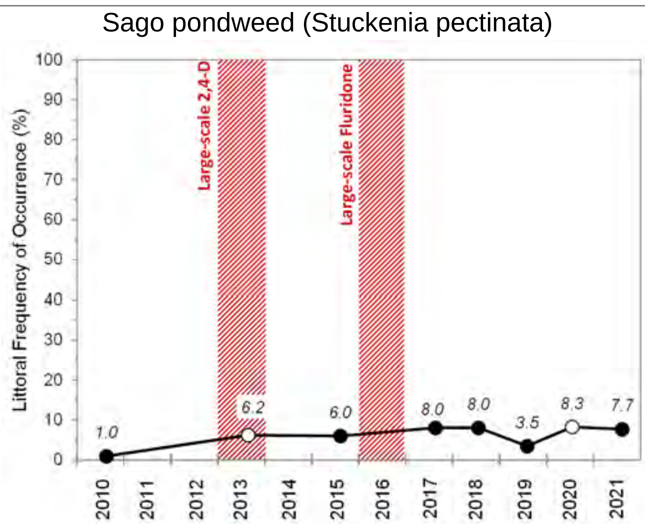
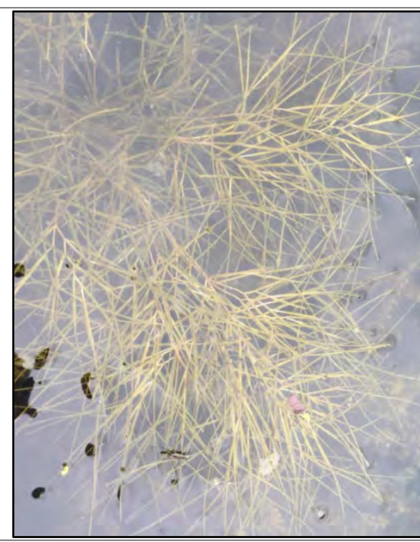


Figure 8.3.2-8. Littoral frequency of occurrence of sago pondweed in Pine Lake. Open circle indicates a statistically valid change in occurrence from the previous survey (Chi-Square α = 0.05).



Photograph 8.3.2-5. Sago pondweed (*Stuckenia pectinata*). Photo credit Onterra.

The littoral frequencies of occurrence for some of the not as common species in Pine Lake are displayed in Figure 8.3.2-9. These species' populations have remained relatively stable the past four years, with the exception of Illinois pondweed which saw a statistically valid decrease in 2021. Variable-leaf pondweed and nitella had their highest LFOO values during the 2021 survey.

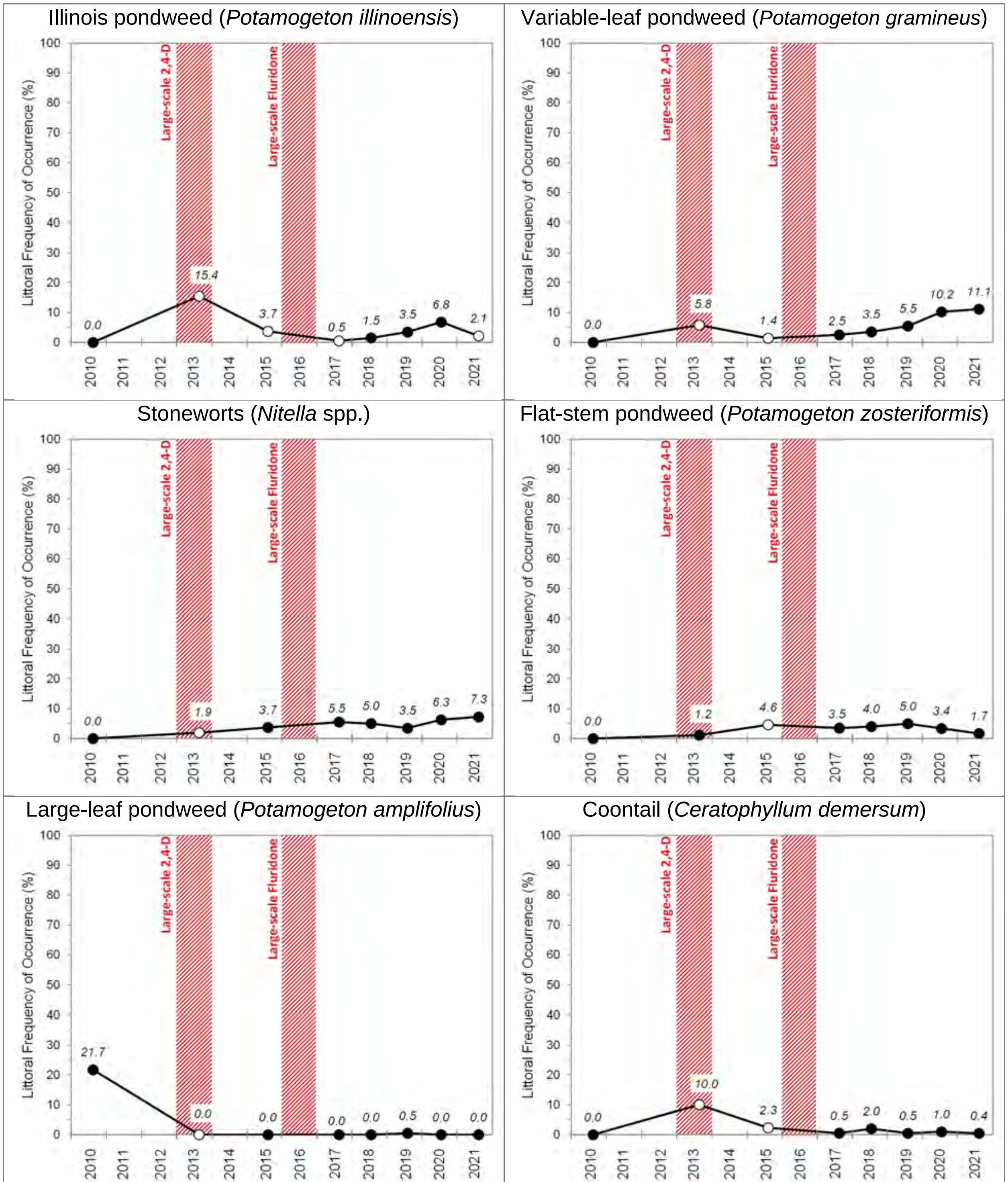


Figure 8.3.2-9. Littoral frequency of occurrence of select aquatic plant species in Pine Lake from 2010-2020. Open circles indicate occurrence is statistically different from previous survey (Chi-Square α = 0.05). Red areas indicate a large-scale herbicide treatment occurred during that year.

Because of the lower number of native plant species (species richness) found in Pine Lake, one may assume that the lake would have low diversity. As discussed earlier, how evenly the species are distributed throughout the system also influences diversity. The diversity index for Pine Lake's plant community in 2021 (0.87) lies slightly above both the North Central Hardwood Forests ecoregion median (0.84) and the state median (0.86), indicating that the lake holds fairly average diversity (Figure 8.3.2-10). 2013 had the highest diversity value across all surveys and was the only other year where the Simpson's diversity value exceeded both the ecoregion and state medians.

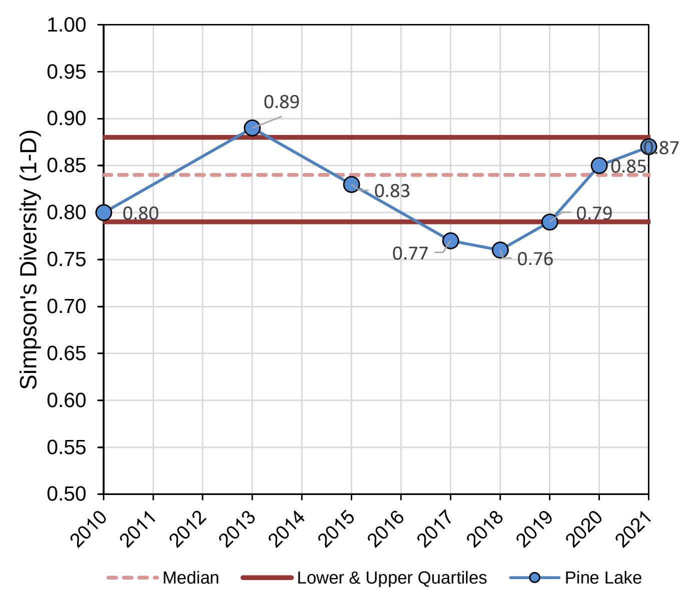


Figure 8.3.2-10. Simpson's diversity for Pine Lake.

As explained earlier in the Primer on Data Analysis and Data Interpretation Section, the littoral frequency of occurrence analysis allows for an understanding of how often each of the plants is located during the point-intercept survey. Because each sampling location may contain numerous plant species, relative frequency of occurrence is one tool to evaluate how often each plant species is found in relation to all other species found (composition of population). For instance, while muskgrasses were found at approximately 40% of the littoral sampling locations in 2021, its relative frequency of occurrence was 22%. Explained another way, if 100 plants were randomly sampled from Pine Lake, 22 of them would be a type of muskgrass. This distribution can be observed in Figure 8.3.2-11 where together 4 species accounted for about 62% of the population of plants within Pine Lake in 2021, and the other 20 species account for the remaining 38%.

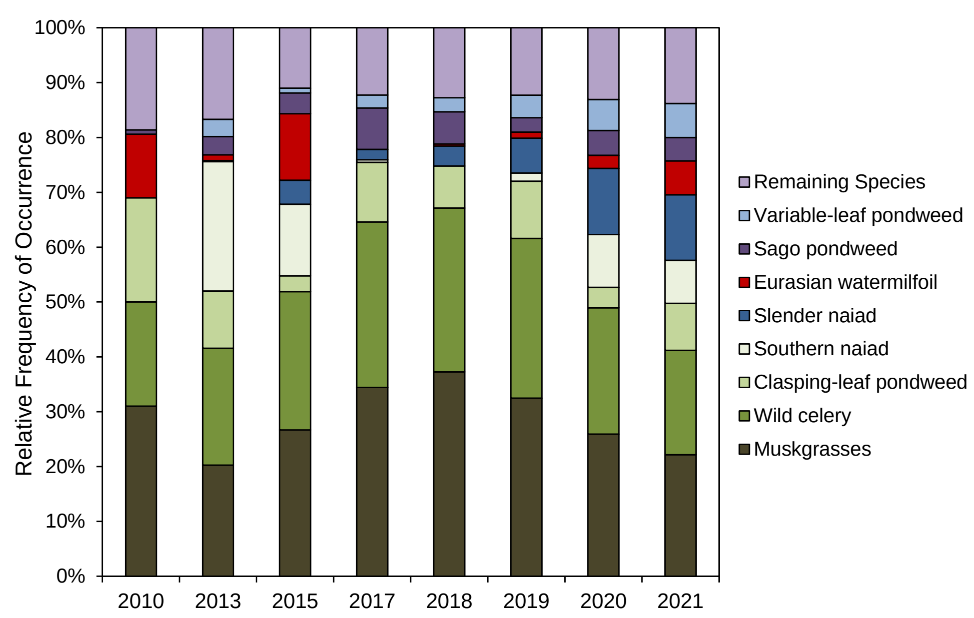


Figure 8.3.2-11. Pine Lake aquatic plant relative frequency of occurrence analysis. Created using data from 2020 point-intercept survey.

Pine Lake's average conservatism value in 2021 (6.2) was above the ecoregion median (5.8), but just below the state median (6.3). This indicates that the aquatic plant community in Pine Lake is of relatively average quality. Pine Lake's species richness value (21) in 2021 fell above both the ecoregion (16) and state median (19). Combining Pine Lake's species richness and average conservatism values to produce its Floristic Quality Index (FQI) results in a value of 28.4 for 2021 which is above the median values for the ecoregion and state (Figure 8.3.2-12).

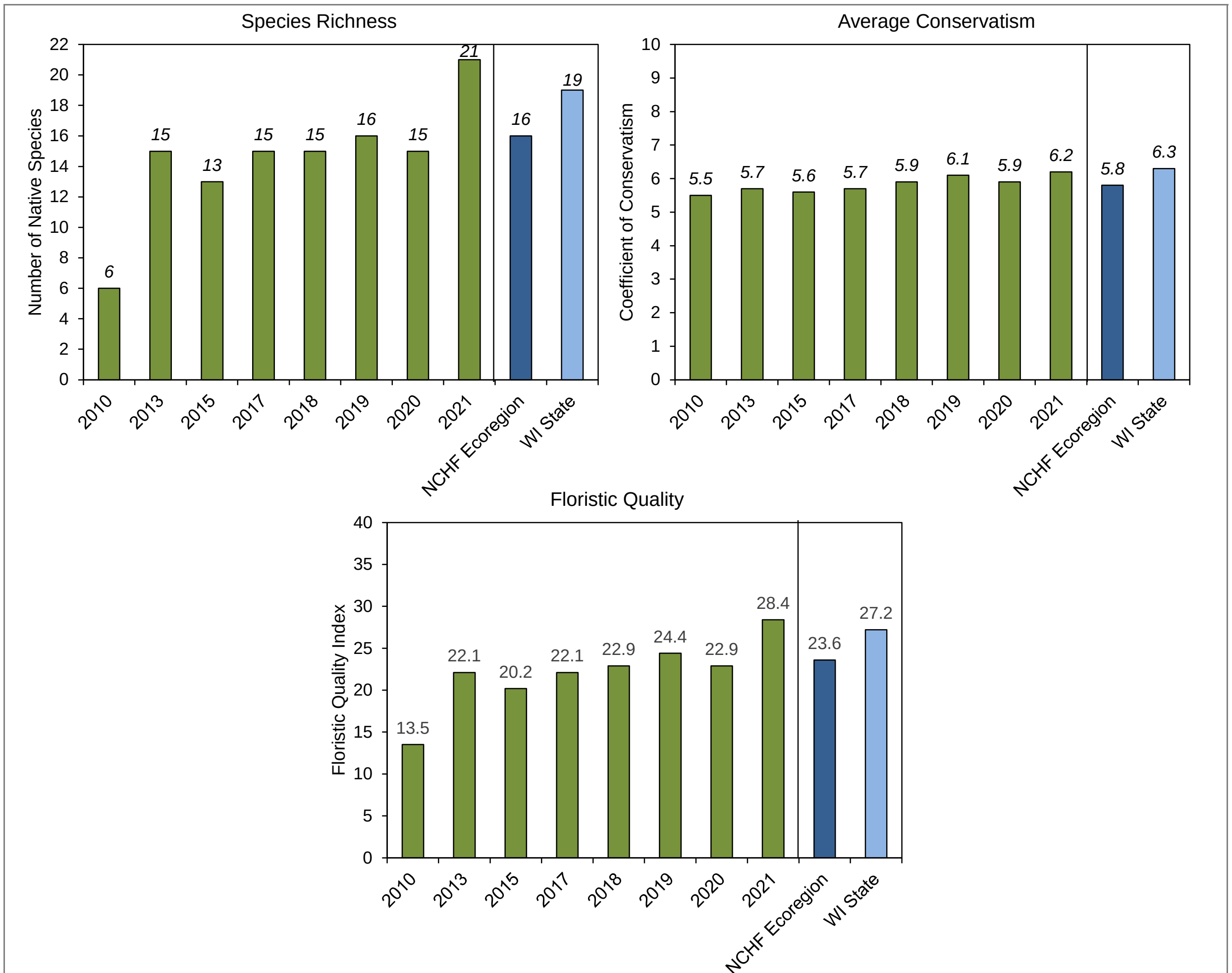
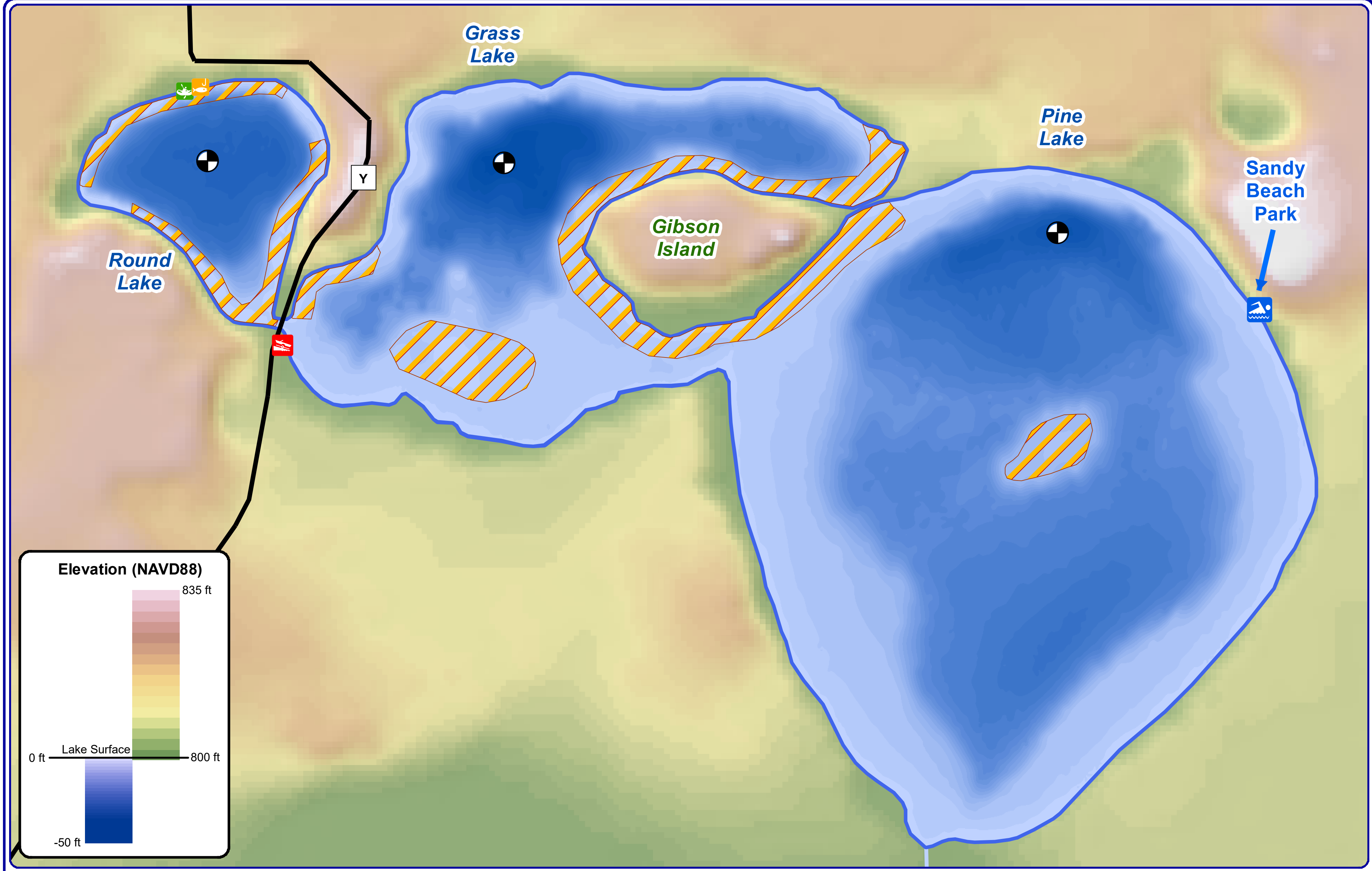


Figure 8.3.2-12. Pine Lake Floristic Quality Analysis. Created using data from point-intercept surveys.

The 2020 floating-leaf and emergent community map for Pine Lake indicates that approximately 1.4 acres of the lake contains these types of plant communities (Map 4, Table 8.3.2-2). Four native floating-leaf and emergent species were located in and around Pine Lake in 2020 (Table 8.3.2-1), which is a small number compared to Round and Grass lakes, as well as other lakes in the ecoregion. This is likely due in part to the uniformly round shape of Pine Lake which does not contain any protected bays, as well as the level of development that is present around much of the lake. The largest contiguous area of valuable floating-leaf communities was along the undeveloped shoreline of Gibson Island.

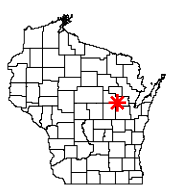
Table 8.3.2-2. Pine Lake acres of emergent and floating-leaf plant communities from the 2020 community mapping survey.

Plant Community	Acres
Emergent	0.0
Floating-leaf	1.4
Mixed Emergent & Floating-leaf	0.0
Total	**1.4**



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

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra, 2016
Map Date: November 25, 2019 - EJH



Project Location in Wisconsin

Legend

- Cloverleaf Lakes
- Sensitive Areas (WDNR, 2003)
- Water Quality Monitoring Location
- Boat Landing
- Beach
- Carry-In Access
- Fishing Pier

Map 1

Cloverleaf Lakes
Shawano County, Wisconsin

Project Location & Lake Boundaries

N
W E
S
350
Feet

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

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2020
Map date: December 2, 2020 AMS

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife
- Giant Reed
- Pale Yellow Iris

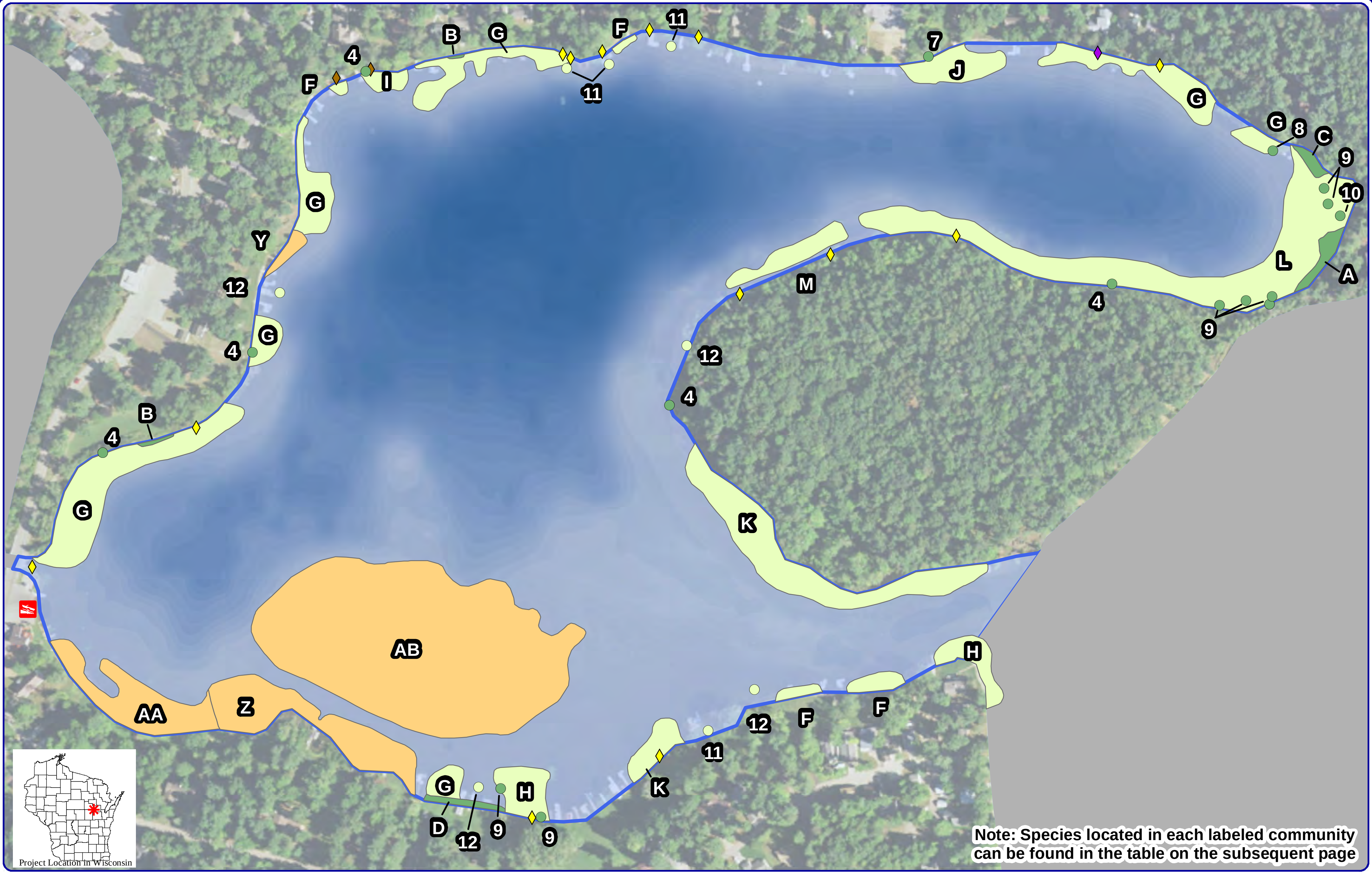
Large Plant Communities

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

Map 2

Round Lake
Shawano County, Wisconsin

Aquatic Plant Communities



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

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 2, 2020 AMS

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife
- Giant Reed
- Pale Yellow Iris

Large Plant Communities

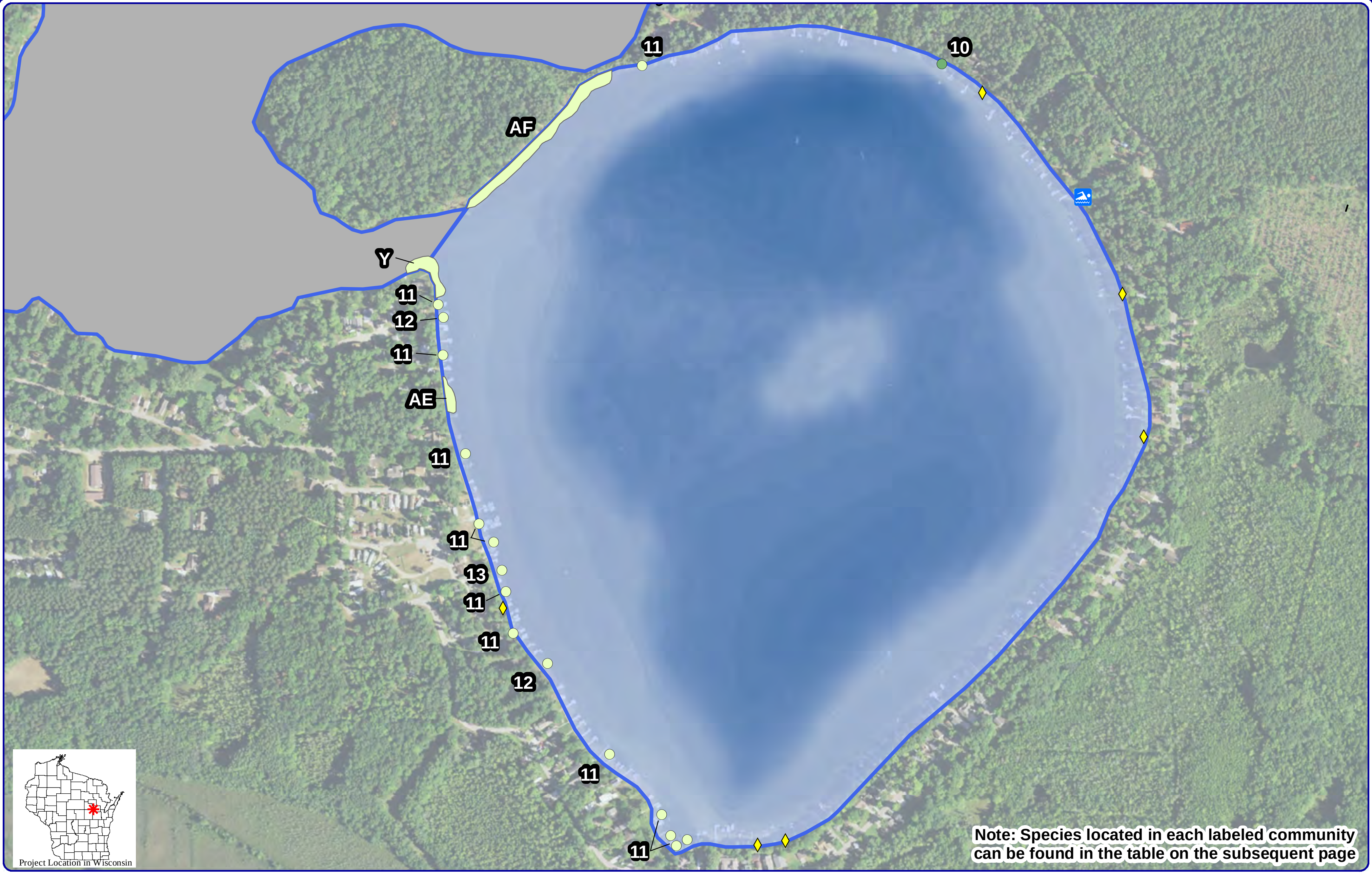
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Map 3

Grass Lake

Shawano County, Wisconsin

Aquatic Plant Communities



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Lake Management Planning
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De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources
Hydro: WDNR
Aquatic Plants: Onterra, 2020
Orthophotography: NAIP, 2018
Map date: December 2, 2020 AMS

Legend

Small Plant Communities

- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent
- Purple Loosestrife
- Giant Reed
- Pale Yellow Iris

Large Plant Communities

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

Map 4
Pine Lake
Shawano County, Wisconsin
Aquatic Plant Communities

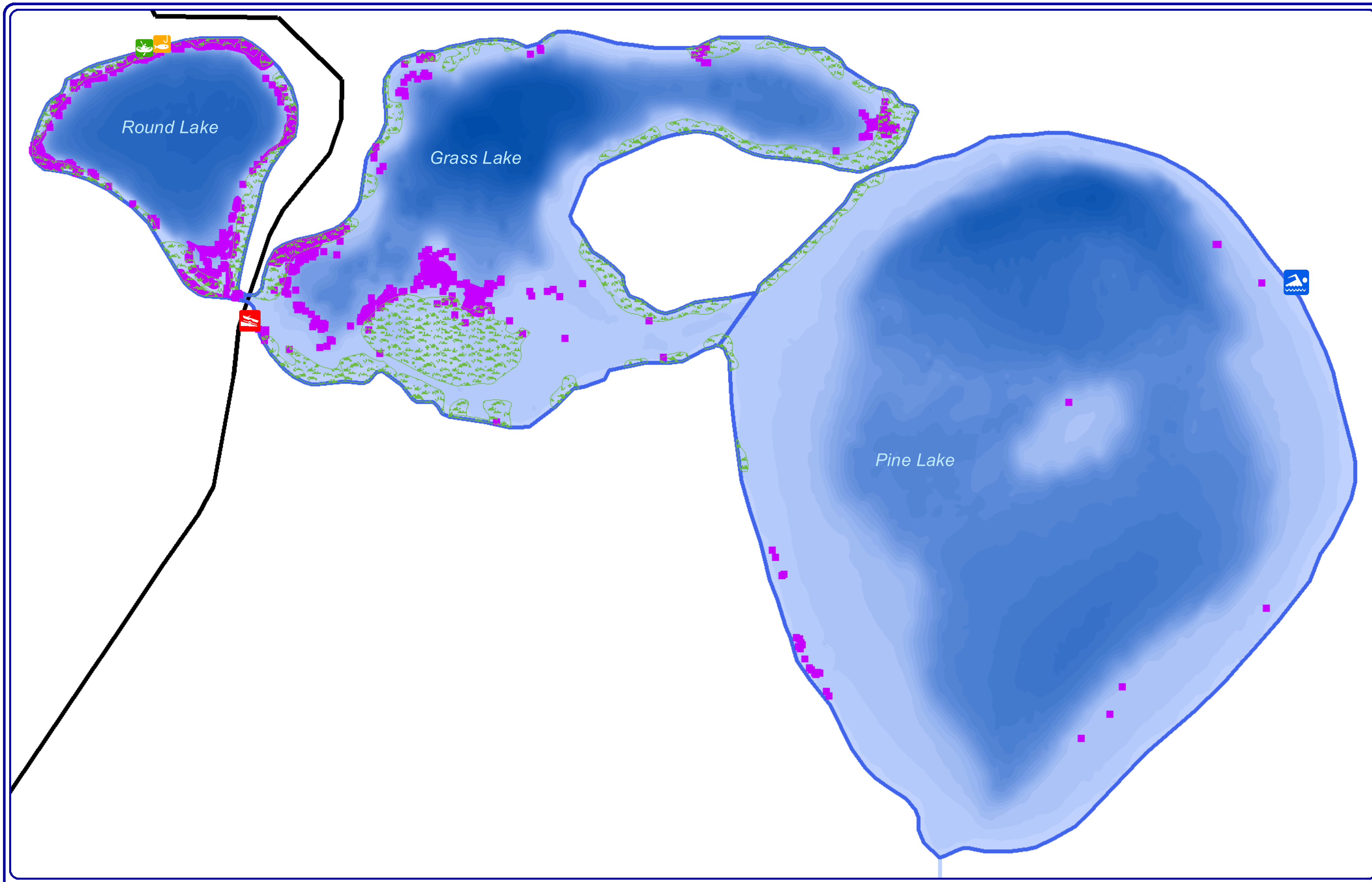
Cloverleaf Lakes 2020 Emergent & Floating-Leaf Plant Species

Corresponding Community Polygons and Points are displayed on Cloverleaf Maps 2-4

Large Plant Community (Polygons)									
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
A	Hardstem bulrush								0.08
B	Hardstem bulrush								0.14
C	Cattail sp.								0.02
D	Cattail sp.								0.01
E	Cattail sp.	Pickerelweed							0.07
F	Cattail sp.	Water sedge							0.08
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
G	White water lily	Spatterdock							0.78
H	White water lily								0.18
I	White water lily								0.20
J	White water lily	Spatterdock							0.38
K	Spatterdock	White water lily							0.11
L	White water lily	Spatterdock							1.30
M	White water lily	Spatterdock							0.21
N	White water lily	Spatterdock							0.41
O	White water lily								0.03
P	White water lily	Spatterdock	Watershield						0.13
Q	White water lily	Spatterdock							0.50
R	White water lily								0.03
S	Spatterdock	Watershield	White water lily						0.44
T	White water lily	Spatterdock	Watershield						0.60
U	White water lily	Spatterdock							0.12
V	Watershield	Spatterdock	White water lily						2.90
W	Spatterdock								0.37
X	White water lily	Spatterdock	Watershield						1.58
Y	Spatterdock	White water lily							0.32
Z	White water lily								0.15
AA	White water lily								0.08
AB	White water lily	Spatterdock	Watershield						0.28
AC	Spatterdock	White water lily							0.40
AD	White water lily	Spatterdock							0.17
AE	Spatterdock								0.14
AF	White water lily	Spatterdock	Watershield						0.99
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**	**Acres**
AG	Hardstem bulrush	White water lily							0.20
AH	Hardstem bulrush	White water lily							0.12
AI	Hardstem bulrush	White water lily							0.10
AJ	Hardstem bulrush	Spatterdock	Watershield	Pickerelweed	Cattail sp.				0.18
AK	Hardstem bulrush	White water lily	Cattail sp.	Pickerelweed	Common arrowhead				0.29
AL	Spatterdock	Sweetflag	Cattail sp.						0.14
AM	Spatterdock	Pickerelweed							0.02
AN	White water lily	Spatterdock	Common arrowhead						0.01
AO	White water lily	Spatterdock	Cattail sp.	Hardstem bulrush					0.19
AP	White water lily	Hardstem bulrush	Cattail sp.						0.14
AQ	White water lily	Cattail sp.							0.07
AR	White water lily	Hardstem bulrush	Cattail sp.						0.14
AS	Spatterdock	Hardstem bulrush	White water lily	Pickerelweed	Creeping spikerush	Common arrowhead			0.26
AT	Hardstem bulrush	White water lily	Sedge sp. (sterile)						1.22
AU	Spatterdock	Cattail sp.							0.10
AV	White water lily	Hardstem bulrush	Cattail sp.	Spatterdock	Water sedge				1.28
AW	Spattedock	White water lily	Cattail sp.						0.96
AX	White wtaer lily	Spatterdock	Hardstem bulrush	Pickerelweed	Water willow	Watershield			6.97

Small Plant Community (Points)								
Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
1	Purple loosestrife							
2	Creeping spikerush							
3	Phragmites							
4	Cattail sp.							
5	Phragmites	Cattail sp.						
6	Pale yellow iris							
7	Water willow							
8	Cattail sp.	Softstem bulrush						
9	Pickerelweed							
10	Hardstem bulrush							
Floating-leaf	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
11	White water lily							
12	Spatterdock							
13	White water lily	Spatterdock						
Floating-leaf & Emergent	**Species 1**	**Species 2**	**Species 3**	**Species 4**	**Species 5**	**Species 6**	**Species 7**	**Species 8**
14	Hardstem bulrush	White water lily						

Species are listed in order of dominance within the community; Scientifc names can be found in the species list in Table 3.4-3



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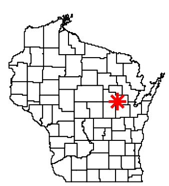
Project Location in Wisconsin

Legend

CLP Occurence From Any Year

Floating-leaf and/or Emergent Plant Colony

Map 2

Cloverleaf Lakes

Shawano County, Wisconsin

2011-2019 Curly-Leaf Pondweed Footprint

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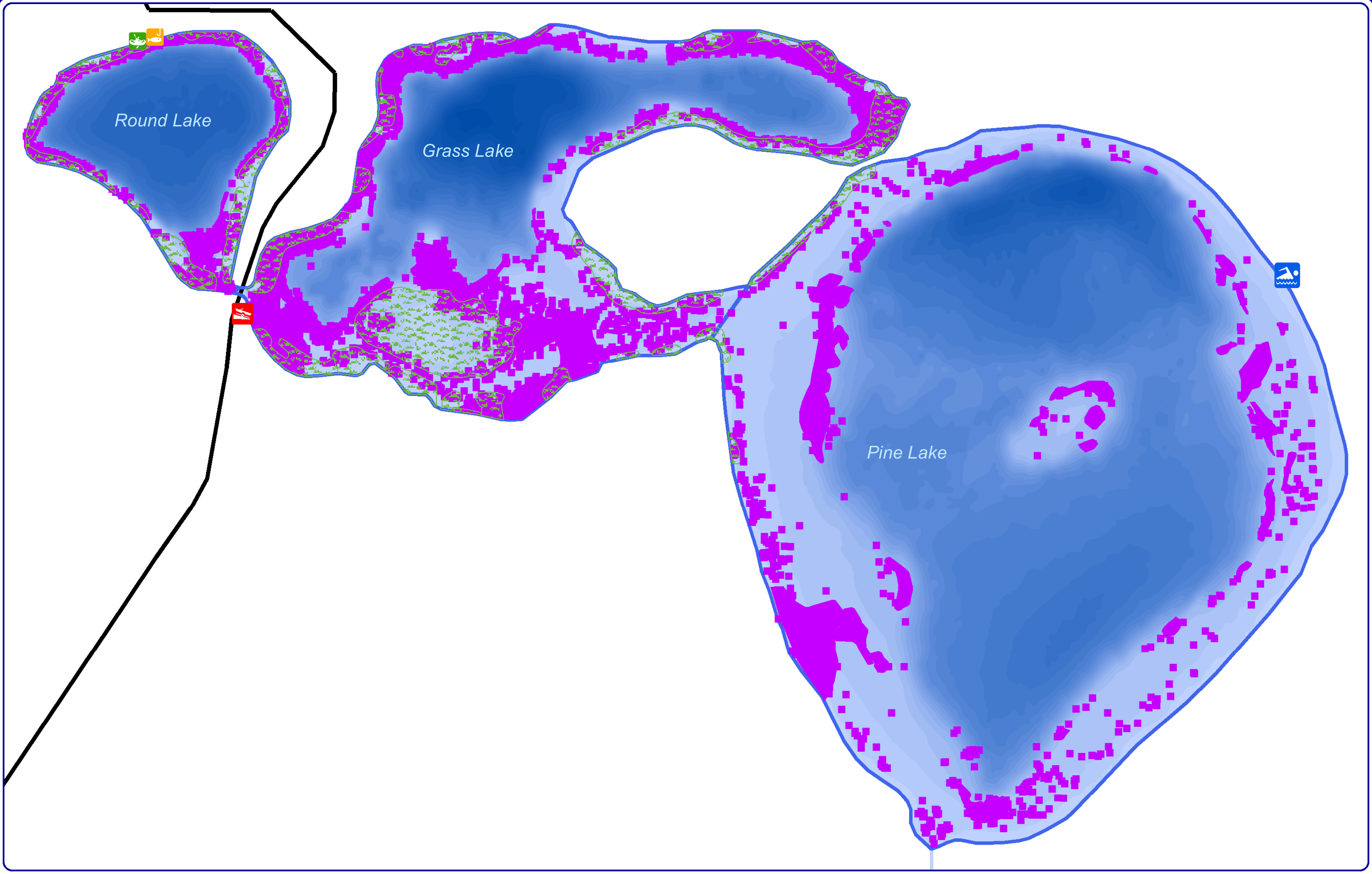
815 Prosper Road
De Pere, WI 54115
920.338.8860
www.onterra-eco.com

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2011-19

Map Date: May 24, 2020 - EJH
Filename:Cloverleaf_CLP_May19.mxd



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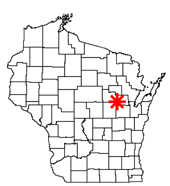


Project Location in Wisconsin

Legend

HWM Occurence From Any Year

Floating-leaf and/or Emergent Plant Colony

Map 6

Cloverleaf Lakes

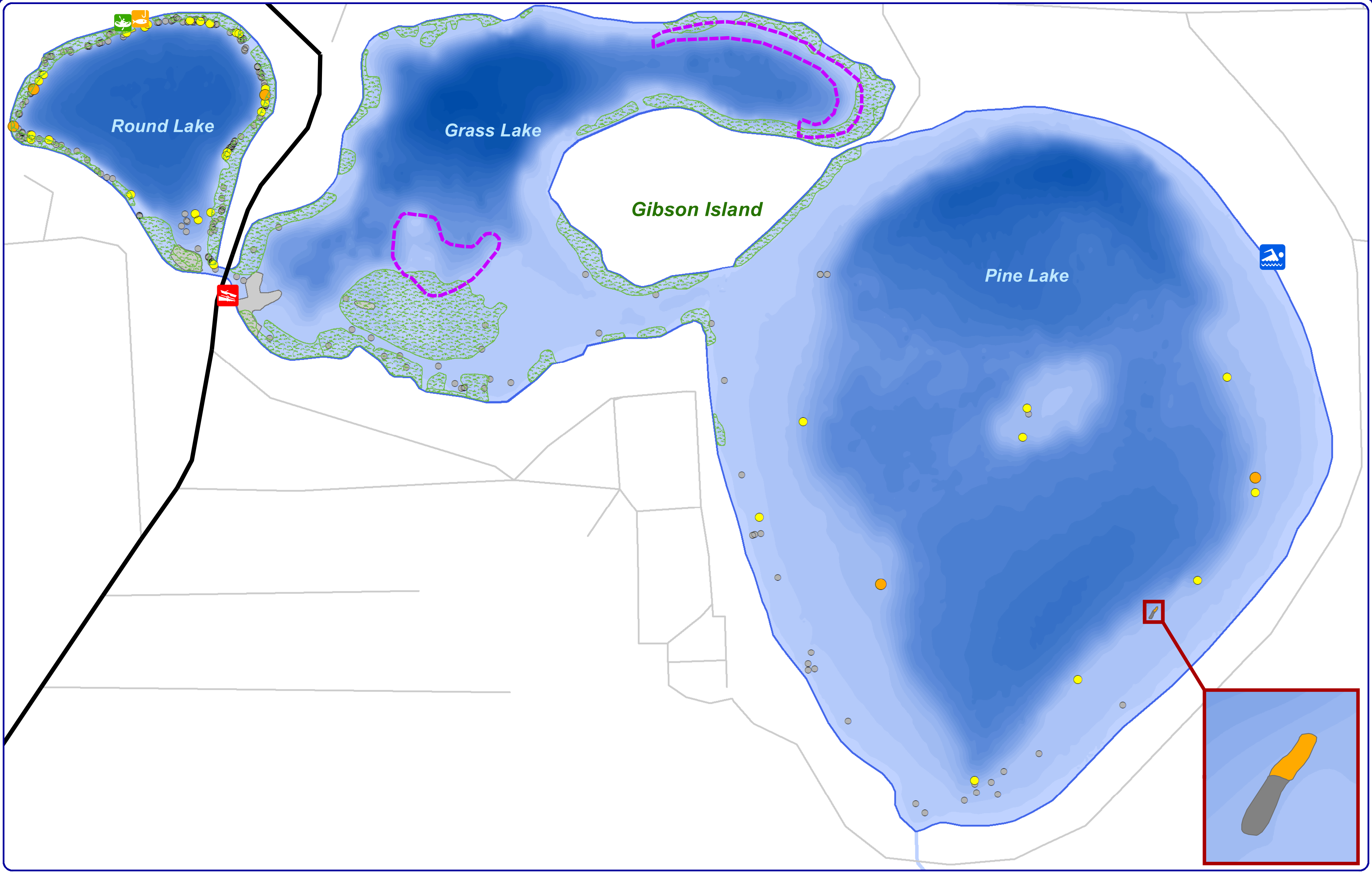
Shawano County, Wisconsin

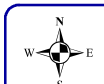
2011-2021
Hybrid Watermilfoil Footprint

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

Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2011-19

Map Date: May 24, 2020 - EJH
Filename: Cloverleaf_EWM_Footprint.mxd





720

Feet

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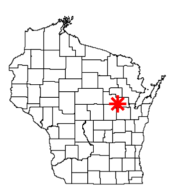
Sources:
Roads and Hydro: WDNR
Bathymetry: Onterra
Aquatic Plants: Onterra, 2021
Map Date: September 22, 2021 AMS



Project Location in Wisconsin

Legend

EWM Survey Results (8-11-2021)

- Highly Scattered
- Scattered
- Dominant
- Highly Dominant
- Surface Matting
- Single or Few Plants
- Clumps of Plants
- Small Plant Colony
- Floating-leaf and/or Emergent Plant Colony
- 2021 ProcellaCOR Treatment Site

Map 7

Cloverleaf Lakes

Shawano County, Wisconsin

2021 Late-Season HWM Survey Results