Presque Isle Wilderness Waters Program

Aquatic Plant Management Plan – McCullough Lake

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This plan is a product of a WDNR Aquatic Invasive Species Control Grant (Subchapter II – Education, Prevention, and Planning Projects) awarded to:

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CHAPTER 1

Introduction

The ***Presque Isle Wilderness Waters Program*** results from the efforts of the Presque Isle Town Lakes Committee, an organization that has been active since 2005. The Lakes Committee views stewardship of lakes as an ongoing endeavor that is integrated, coordinated, and administered by the Lakes Committee. This broader perspective accommodates the appropriate range of geographic scales from which to approach lake stewardship: a discrete "lake specific" focus that goes hand-in-hand with waterscape-wide awareness.

This aquatic plant management plan (APMP) addresses McCullough Lake in Vilas County, Wisconsin. Despite this specificity, it maintains the waterscape perspective crucial to effective lake stewardship. This is especially important when it comes to preventing introduction and establishment of aquatic invasive species (AIS). The closely related ***Wilderness Waters Adaptive Management Plan*** (Stine et al., 2019) offers additional overarching waterscape level inspection that allows greater opportunity and efficiency in water resource management and education.

A 2018 systematic survey of aquatic plants using the Wisconsin Department of Natural Resources (WDNR) "point-intercept" method was an important underpinning of this aquatic plant management plan. An analysis of the plant data along with water quality and other lake information allowed the preparation of the plan.

Aquatic plants rarely get the respect they merit, although this is slowly changing. We still call an aquatic plant bed a "weed bed." Many aquatic plants have "weed" in their names (e.g., duckweed, pondweed, or musky weed). Likely this term was borrowed from "seaweed" and not intended as derogatory, but in today's use, "weed" connotes an unwanted, aggressively growing plant. Such is not the case for the vast majority of aquatic plants. In fact, aquatic plants are a vital part of a lake ecosystem, recycling nutrients, providing vertical and horizontal structure, and creating habitat for animal life. Invertebrates, including crustaceans and insects, live on or within this "aquatic forest." Fish find food and shelter within aquatic plant beds. Waterfowl eat parts of plants directly as well as feed on invertebrates associated with the plants. Muskrats eat aquatic plants and particularly love cattails and bulrushes. Otter and mink hunt invertebrates and small vertebrates within the shelter of submergent and emergent beds. In shallow water, great blue herons find fishes among the plants.

In lakes that receive an excess of nutrients (particularly from fertilizers or leaking septic tanks), plant growth can become too lush or dominated by only a few species. As these abundant plants die, their decomposition can depress dissolved oxygen levels and diminish suitability for fish. Algae can respond rapidly to nutrient influxes and create nuisance conditions. These phenomena can cause humans to view all aquatic plants in a negative light.

On another negative front, non-native plant species, transported on boats and trailers or dumped from home aquariums, private ponds and water gardens may proliferate in a water body negatively influence the community of native species. Eurasian water-milfoil (*Myriophyllum spicatum*) is one of the invasive plant species capable of this kind of population boom. Fortunately, this kind of rampant growth of aquatic invasive plants does not always occur. On occasion, even a native plant species can exhibit rampant growth and results in a population that is viewed by some as a recreational nuisance. The Southern Naiad (*Najas guadalupensis*) has exhibited this kind of behavior in some northern Wisconsin lakes.

For most lakes, native aquatic plants are an overwhelmingly positive attribute, greatly enhancing the aesthetics of the lake and providing good opportunities for fishing, boating, swimming, snorkeling, sight-seeing, and hunting. In some lakes even the presence of an aquatic invasive plant species is not a significantly negative phenomenon.

When it comes to aquatic plant management, it is useful to heed the mantra of the medical profession: "First, do no harm." It is both a social and scientific convention that aquatic plant management is more effective and beneficial when a lake is considered as an entire and integrated ecosystem. Actions taken to curtail specific plant population (for example, herbicide use to treat Eurasian water-milfoil) will invariably impact other desirable native species. Rare plants, important habitats, or culturally significant plants (such as wild rice) should always be given careful consideration and protection.

Anyone involved in aquatic plant management should be aware that a permit may be required to remove, add, or control aquatic plants. In addition, anyone using Wisconsin's lakes must comply with the "Boat Launch Law" that addresses transport of aquatic plants on boat trailers and other equipment. A good review of the laws, permits, and regulations that affect management and behavior surrounding aquatic plants can be found in the WDNR guidelines called ***Aquatic Plant Management in Wisconsin***.[1]

[1] *http://www4.uwsp.edu/cnr/uwexlakes/ecology/APM/APMguideFull2010.pdf*

In preparing this plan, we followed guidelines in ***Aquatic Plant Management in Wisconsin***. The resulting plan is an adaptive plan (Walters, 1986). Simply put, it will be modified as new information becomes available. The WDNR Guidance document outlines three objectives that may influence preparation of an aquatic plant management plan. Currently, the principle motivation for this plan lies in the first two objectives:

- ***Protection*** - preventing the introduction of nuisance or invasive species into waters where these plants are not currently present;
- ***Maintenance*** - continuing the patterns of recreational use that have developed historically on and around a lake; and
- ***Rehabilitation*** - controlling an imbalance in the aquatic plant community leading to the dominance of a few plant species, frequently associated with the introduction of invasive non-native species.

During projects with the WDNR Planning Grant Program and through past efforts, Town Lakes Committee has followed the seven-step plan outlined in the Guidance Document for developing an aquatic plant management plan:

1. Goal setting – Getting the effort organized, identifying problems to be addressed, and agreeing on the goals;
2. Inventory – Collecting baseline information to define the past and existing conditions;
3. Analysis – Synthesizing the information, quantifying and comparing the current conditions to desired conditions, researching opportunities and constraints, and setting directions to achieving the goals;
4. Alternatives – Listing possible management alternatives and evaluating their strengths, weaknesses and general feasibility;
5. Recommendations – Prioritizing and selecting preferred management options, setting objectives, drafting the plan;
6. Implementation – Formally adopting the plan, lining up funding, and scheduling activities for taking action to achieve the goals;
7. Monitor & Modify – Developing a mechanism for tracking activities and adjusting the plan as it evolves.

Including this introductory chapter, this APMP is organized in six Chapters. The study area is described in Chapter 2. Chapter 3 states the purpose and goals. Chapter 4 presents an inventory and analysis of information that pertain to the plan including the results of the plant survey. Chapter 5 provides recommendations that support the overall goals and establish the stewardship component of plan. Finally, Chapter 6 presents actions and objectives for implementing the plan. Five appendices complete this document.

CHAPTER 2

Study Area

Presque Isle Township is one of the northern-most townships in Vilas County, Wisconsin. Presque Isle Township's northern border is shared with the State of Michigan. In fact some of the Presque Township lakes lie on the state border. The location of the subject of this APM Plan (McCullough Lake) is shown in Exhibit 1 along with other lakes in Presque Isle Township that have had point-intercept aquatic plant surveys conducted. Exhibit 2 is an aerial view of McCullough Lake.

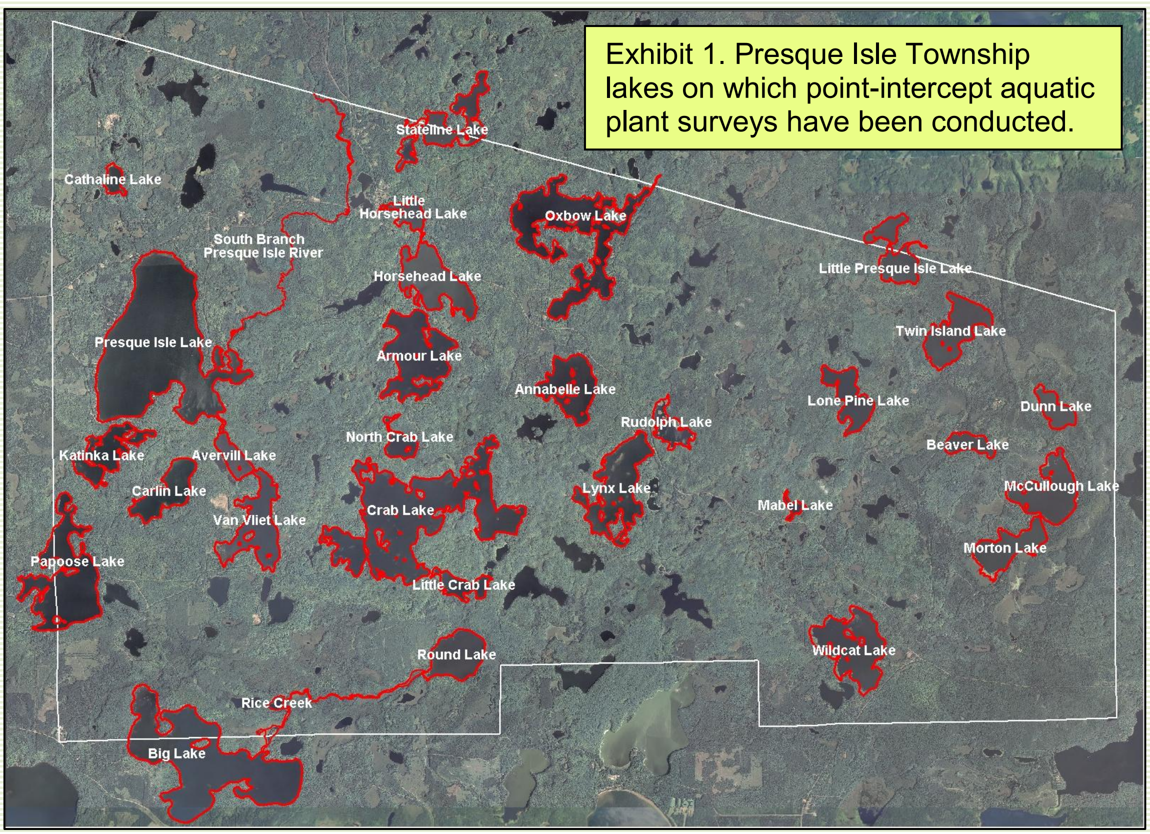


Exhibit 1. Presque Isle Township lakes on which point-intercept aquatic plant surveys have been conducted.

“Almost an island” is the literal translation of the French phrase “Presque Isle.” Early French missionaries, perhaps disoriented by the preponderance of water in this north central Wisconsin landscape applied the name, “Presque Isle” to describe an area where the water seemed to dominate the land. The French visitors and Native Americans certainly recognized this landscape as special. Modern ecologists and recreationist share this view. The region that includes the Township of Presque Isle, Wisconsin is an ecological landscape marvelously rich in surface waters. Aerial photography reveals a concentration of lakes and streams that is unique in North America. Presque Isle Township has eighty-four lakes. The Presque Isle area could as easily be termed a “waterscape” as a “landscape.”

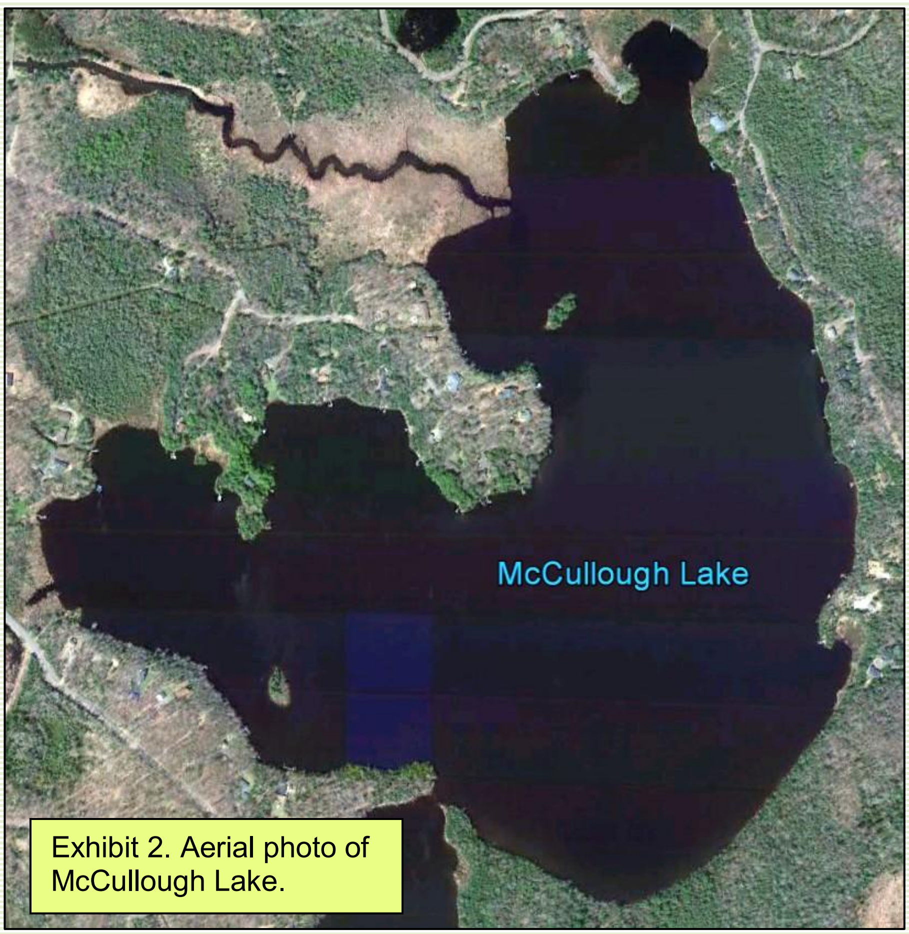


Exhibit 2. Aerial photo of McCullough Lake.

Descriptive parameters for McCullough Lake are in Exhibit 3. It is a drainage lake of about 221 acres and maximum depth of 27 feet. The shoreline development index (SDI) is a quantitative expression derived from the shape of the lake defined as the ratio of the shoreline length to the length of the circumference of a circle of the same area as the lake. A perfectly round lake has an index of 1. McCullough Lake has an SDI of 1.8. Increasing irregularity of a lake's shoreline in the form of bays and projections of the shore is results in SDIs greater than 1. For example, fjord lakes with extremely irregular shorelines sometimes have SDI's exceeding 5. A higher shoreline development index indicates that a lake has relatively more productive littoral zone habitat.

Exhibit 3. Water Body Parameters.	
Water Body Name	McCullough
County	Vilas
Township/Range/Section	T43N-R07E-S13,S14,S23,S24
Water Body Identification Code	2960400
Lake Type	Drainage
Surface Area (acres)	221
Maximum Depth (feet)	27
Maximum Length (miles)	0.9
Maximum Width (miles)	0.8
Shoreline Length (miles)	3.82
Shoreline Development Index	1.8
Total Number of Piers (2020 aerial)	37
Number of Piers / Mile of Shoreline	9.7
Total Number of Homes (2020 aerial)	43
Number of Homes / Mile of Shoreline	11.3

McCullough Lake has no access site for the general public, although it does have an improved access site for members of the Natural Lakes development. We observe a total of 37 piers on the shoreline of McCullough Lake from 2020 aerial photography or about 9.7 piers per mile of shoreline. The riparian area consists of both upland and wetland areas (Exhibit 4).

Exhibit 4. Topographic Map of McCullough Lake Area.

CHAPTER 3

Purpose and Goal Statements

This plan approaches aquatic plant management with a healthy dose of humility. We do not always understand the causes of environmental phenomena or the effects of our actions to manage the environment. With that thought in mind, we have crafted a statement of purpose and goals for this plan:

> ***Comprehensive aquatic plant surveys in 2011 and 2018 establish that McCullough Lake has a healthy and diverse aquatic plant community. This plant community is essential to, and part of, a high quality aquatic ecosystem that benefits the human community. The purpose of this aquatic plant management plan is to maintain a balanced, high quality, and diverse native aquatic plant community in McCullough Lake.***

Supporting this purpose, the goals of this aquatic plant management plan are:

> ***(1) Monitor and protect the native aquatic plant community;***
> ***(2) Monitor for AIS and prevent establishment of new non-native biota;***
> ***(3) Consider and evaluate the efficacy of active aquatic plant management; and***
> ***(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that can alter the plant community, minimizing physical removal of native riparian and littoral zone plants, and living with a lake whose natural healthy state includes aquatic plants.***

The purpose and goals are the foundation for the aquatic plant management plan presented in this document. They inform the objectives and actions outlined in Chapter 5 and are the principal motivation of McCullough Lake stewards.

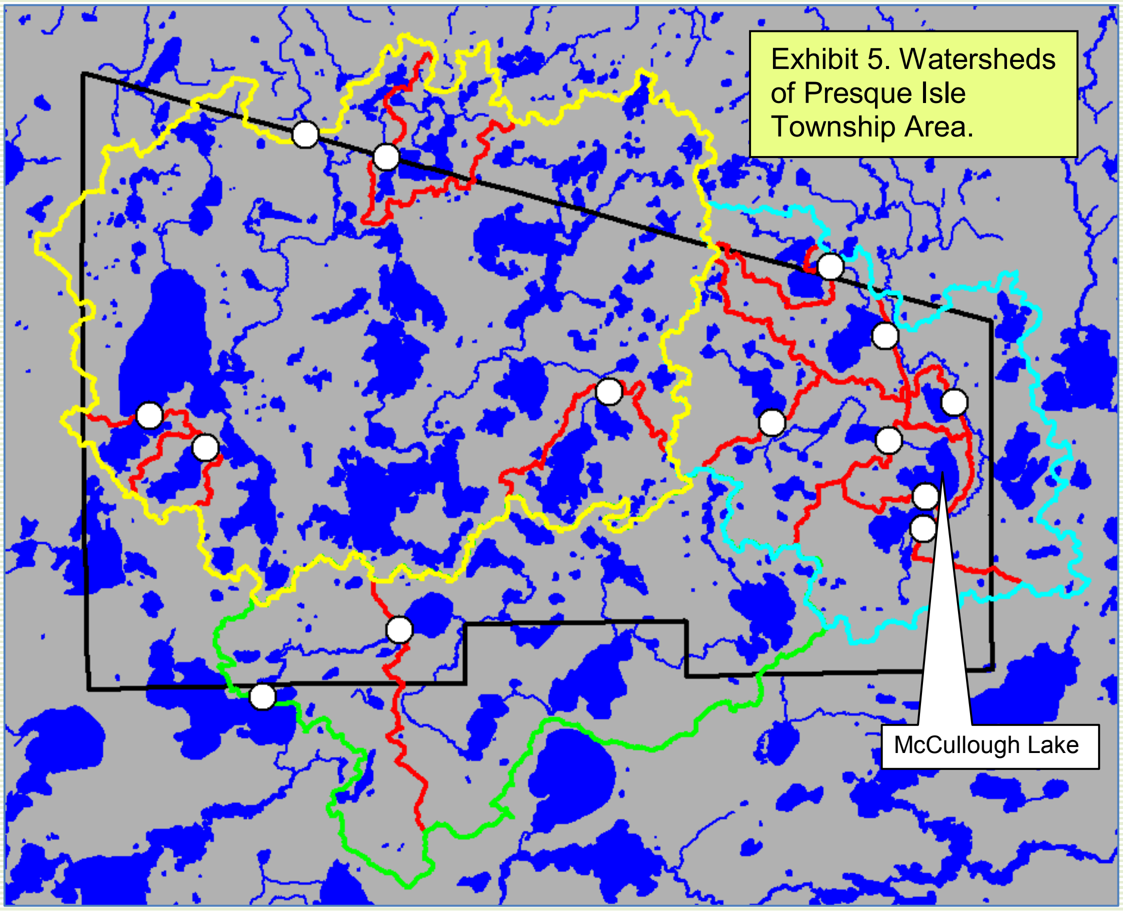
CHAPTER 4

Information and Analysis

Our efforts in the Wilderness Waters Program have compiled information about historical and current conditions of the McCullough Lake ecosystem and its surrounding watershed. Of particular importance to this aquatic plant management plan is the aquatic plant survey that was conducted using the ***WDNR Protocol for Aquatic Plant Survey, Collecting, Mapping, Preserving, and Data Entry*** (Hauxwell et al., 2010). The results of this comprehensive "point-intercept" survey along with relevant components of other information are presented in this chapter under nine respective subheadings: watershed, aquatic plant management history, aquatic plant community description, fish community, water quality and trophic status, water use, riparian area, wildlife, and stakeholders.

Part 1. Watershed

The Presque Isle Township waterscape sits on a large-scale watershed divide. Some of the water drains north through the Presque Isle River system and eventually enters Lake Superior. Some of the water drains into the Wisconsin River system to the Mississippi River and to the Gulf of Mexico. In fact there are two federal hydrologic sub-basins (designated by 8-digit HUC codes) that include Presque Isle Township. The Black-Presque Isle Rivers sub-basin (HUC#04020101) drains north to Lake Superior and the Flambeau River sub-basin (HUC#0705002) drains southwesterly to the Mississippi River. The Black-Presque Isle Rivers sub-basin contains two federal hydrologic sub-watersheds within Presque Isle Township: the South Branch Presque Isle River sub-watershed (HUC#040201010303) and the Pomeroy Creek-East Branch Presque Isle River sub-watershed (HUC#040201010301). The Flambeau River sub-basin contains one sub-watershed within Presque Isle Township: the Rice Creek sub-watershed (HUC#07050020103). Exhibit 5 illustrates these watersheds and the watersheds of the water bodies subject to the Wilderness Waters Program studies. McCullough Lake is contained within the Pomeroy Creek-East Branch Presque Isle River sub-watershed (Exhibit 5).



Description: Portions of 3 federal hydrologic sub-watersheds are illustrated: (1) S.Br. Presque Isle River (bounded by yellow), (2) Pomeroy Cr-E.Br. Presque Isle River (bounded by blue and yellow), and (3) Rice Cr. (bounded by green, yellow, and blue). Also shown are the smaller watersheds of individual water bodies subject to the Wilderness Waters studies (bounded by red). White dots show outlet points for the smaller watersheds.

The elevation in Presque Isle Township ranges from around 1,550 feet above sea level to 1,750 feet above sea level. A digital elevation model is provided as Exhibit 6 and shows the relative elevations for the area with orange areas of the landscape being the highest elevations and greens and blues being the lowest elevations.

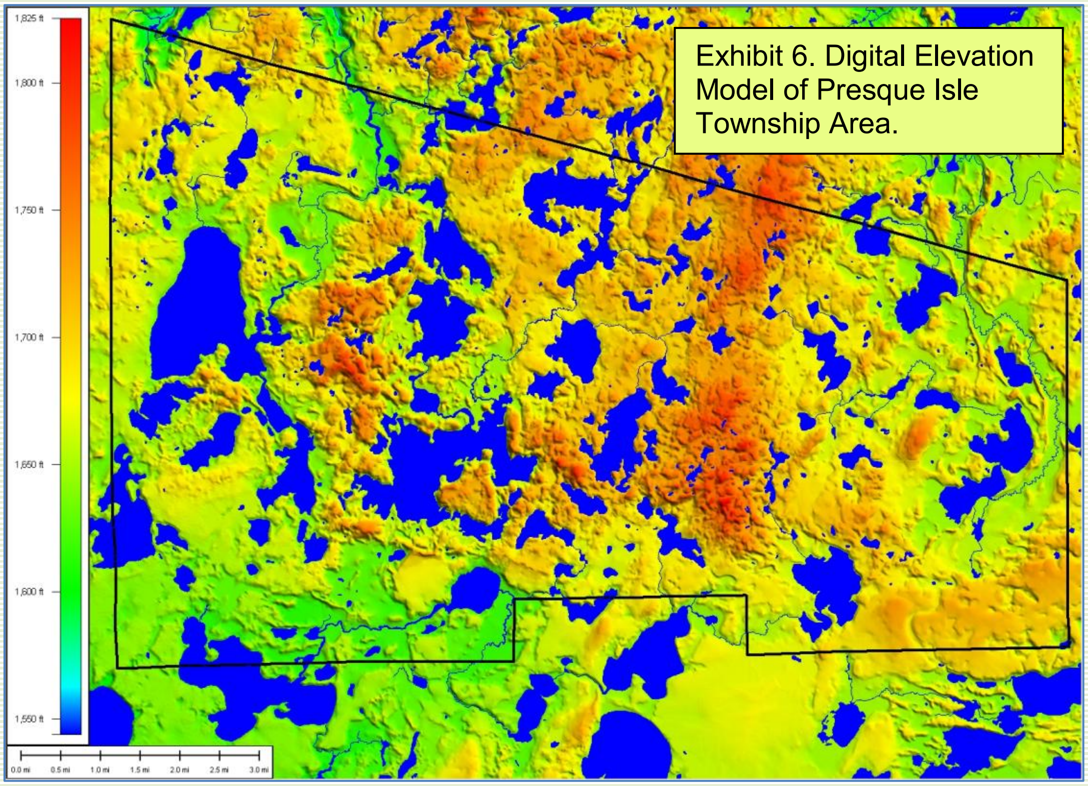


Exhibit 6. Digital Elevation Model of Presque Isle Township Area.

The watershed (drainage basin) is all of the land and water areas that drain toward a particular river or lake. A water body is greatly influenced by its watershed. Watershed size, topography, geology, land use, soil fertility and erodibility, and vegetation are all factors that influence water quality. The McCullough Lake watershed is about 4751 acres. It is identified in Exhibit 5 and bounded by the blue and yellow lines. The cover types in the watershed are presented in Exhibit 7. Forest and surface water comprise the largest components. All soil groups (A, B, C and D) are present. Soil group B makes up almost 60% of the watershed and group D makes up around 36%. Infiltration rates rank from highest to lowest, with A having the highest and D having the lowest. The watershed to lake area ratio is 22:1. Water quality often decreases with an increasing ratio of watershed area to lake area. As the watershed to lake area increases there are more sources and amounts of runoff. In larger watersheds, runoff water can leach more minerals and nutrients and carry them to the lake. The runoff to a lake (such as after a rainstorm or snowmelt) differs greatly among land uses. Forest cover is the most protective as it exports much less soil (through erosion) and nutrients (such as phosphorus and nitrogen) to the lake than agricultural or urban land use.

<table>
<tr><th colspan="4">Exhibit 7. Cover Types and Soil Groups of the McCullough Lake Watershed.</th></tr>
<tr><th colspan="2">Cover Type</th><th colspan="1">Acres</th><th>Percent</th></tr>
<tr><td colspan="2">Agriculture</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Commercial</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Forest</td><td>2504.4</td><td>52.7</td></tr>
<tr><td colspan="2">Grass/Pasture</td><td>6.3</td><td>0.1</td></tr>
<tr><td colspan="2">High-density Residential</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Low-density Residential</td><td>257</td><td>5.4</td></tr>
<tr><td colspan="2">Water</td><td>1983.2</td><td>41.7</td></tr>
<tr><td colspan="2">Total</td><td>4750.9</td><td>100.0</td></tr>
</table>

Soil Group	Acres	Percent	**Hydrologic Soil Groups** - Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups* based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. Where A has the smallest runoff potential and D the greatest.
A	271.3	5.7	**Group A** is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
B	2745.7	57.8	**Group B** is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
C	45.6	1.0	**Group C** soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	1688.3	35.5	**Group D** soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This soil has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

*(*USDA, Natural Resources Conservation Service, 1986*)

Part 2. Aquatic Plant Management History

As far as we can determine, no systematic or large-scale plant management activity has ever taken place in McCullough Lake. Over the years, no particular nuisance issues have warranted control action. It is our understanding that the plant survey conducted in 2011 was the first effort of its kind on the lake. A second plant survey was conducted in 2018 and results are presented and discussed in the next section (Part 3) and compared to findings from 2011.

Part 3. Aquatic Plant Community Description

Why do lakes need aquatic plants? In many ways, they are underwater forests. Aquatic plants provide vertical and horizontal structure in the lake just like the many forms and variety of trees do in a forest. Imagine how diminished a forest's biodiversity becomes in the advent of a clear-cut. Similarly, a lake's biodiversity in large part depends on a diversity of plants.

Aquatic plants are beneficial in many ways. Areas with plants produce more food for fish (insect larvae, snails, and other invertebrates). Aquatic vegetation offers fish shelter and spawning habitat. Many submerged plants provide food for waterfowl and habitat for insects on which some waterfowl feed. Aquatic plants further benefit lakes by producing oxygen and absorbing nutrients (phosphorus and nitrogen) from runoff. Aquatic plants also protect shorelines and lake bottoms by dampening wave action and stabilizing sediments.

The distribution of plants within a lake is generally limited by light availability, which is, in turn, controlled by water clarity. Aquatic biologists often estimate the depth to which rooted aquatic plants can exist as about two times the average Secchi clarity depth. For example, if the average Secchi depth is eight feet then it is fairly accurate to estimate that rooted plants might exist in water as deep as sixteen feet. At depths greater than that (in our hypothetical example), light is insufficient for rooted plants to grow. In addition to available light, the type of substrate influences the distribution of rooted aquatic plants. Plants are more likely to be found in muddy or soft sediments containing organic matter, and less likely to occur where the substrate is sand, gravel, or rock. Finally, water chemistry influences which plants are found in a body of water. Some species prefer alkaline lakes and some prefer more acidic lakes. The presence of nutrients like phosphorous and nitrogen also influence plant community composition.

As mentioned earlier, non-native invasive plant species can reach high densities and wide distribution within a lake. This diminishes the native plant community and the related habitat. At times, even a native plant species can reach nuisance levels with respect to certain kinds of human recreation. These cases may warrant some kind of plant management. It should be noted, however, herbicides, or other means are expensive (in time and/or money) and by no means permanent. Long-term outcomes of these manipulations are difficult to predict. In addition, permits are required in many cases of aquatic plant management.

Aquatic plant surveys were conducted on McCullough Lake in 2011 and 2018. In each year, the survey used the WDNR point-intercept protocol. This formal survey assessed the plant species composition on a grid of 511 points distributed evenly over the lake. Using latitude-longitude coordinates and a handheld GPS unit, we navigated to the points and used a rake to sample plants. Plants were identified, recorded, and all data were entered into a dedicated spreadsheet for storage and data analysis. These systematic surveys provided baseline data about the lake and allow analysis of change in the plant community.

An examination of changes in the aquatic plant community over nearly a decade is robust because the plant surveys were conducted using the same protocol. Future aquatic plant monitoring will allow additional analysis. Changes in a lake environment might manifest as loss of species, change in species abundance or distribution, difference in the relative composition of various plant life forms (emergent, floating leaf, or submergent plants), and/or appearance of an AIS or change in its population size. Monitoring can track changes and provide valuable insight on which to base management decisions. In the remainder of this section, we provide a report of the aquatic plant findings for McCullough Lake and compare the plant communities of 2011 and 2018. The supporting tables and figures for the aquatic plant survey are provided in Appendix B.

Species richness refers to the total number of species recorded. When considering plant species recorded at sampling points only, species richness in 2011 (33 species collected on the rake) was identical to that observed in 2018 (33 species collected on the rake)(see Table 1). During the surveys, additional plant species observed but not collected at the sampling points are also documented. In 2018, a total of 33 species of aquatic plants were recorded in McCullough Lake at the sample points but an additional 3 species were seen near shore on the boat survey, indicating a diverse plant community. Table 1 displays summary statistics for the 2018 survey. Table 2 provides a list of the species encountered, including common and scientific name along with summarizing statistics for the 2018 survey.[2] In 2018, the number of species encountered at any given sample point ranged from 0 to 8 and 136 sample points were found to have aquatic vegetation present. The average number of species encountered at these vegetated sites was 2.40. The actual number of species encountered at each of the vegetated sites is graphically displayed

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[2] *If you more are interested in learning about the plant species found in the lake, visit the University of Wisconsin Steven Point Freckmann Herbarium website at: http://wisplants.uwsp.edu/ or obtain a copy of "Through the Looking Glass (A Field Guide to the Aquatic Plants in Wisconsin)."*

on Figure 1. Plant density is estimated by a rake fullness metric (3 is highest possible density). These densities (considering all species) are displayed for each sampling site on Figure 2.

The maximum depth of plant colonization is 10.5 feet (Table 1 and Figure 3). Rooted vegetation was found at 136 of the 213 sample sites with depth ≤ the maximum depth of plant colonization (63.85% of sites). These sites are displayed as a black dot within a circle on Figure 4. This indicates that although availability of appropriate depth may limit the distribution of plants, it is not the only habitat factor involved. Substrate is another feature that influences plant distribution (e.g., soft substrate often harbors more plants than hard substrate). Figures 5 presents the substrates encountered during the aquatic plant survey (mud, sand, or rock).

Table 2 provides information about the frequency of occurrence of the plant species recorded in the lake in 2018. Several metrics are provided, including total number of sites in which each species was found and frequency of occurrence at sites ≤ the maximum depth of rooted vegetation. This frequency metric is standardized as a “relative frequency” (also shown in Table 2) by dividing the frequency of occurrence for a given species by the sum of frequency of occurrence for all plants and multiplying by 100 to form a percentage. The resulting relative frequencies for all species total 100%. The relative frequencies for the plant species collected with a rake in 2011 and 2018 are graphically displayed on Figure 6. This display shows that *Najas flexilis* (Slender naiad) had the highest relative frequency followed by *Potamogeton robbinsii* (Fern pondweed) in 2018. In 2011, *Potamogeton robbinsii* (Fern pondweed) had the highest followed by *Nitella sp*. These changes are natural fluctuations of the individual populations and no cause for concern. They simply indicate a dynamic plant community. Figure 7 displays sampling sites with emergent and floating aquatic plants. As examples of individual species distributions, we show the occurrences of a few of the most frequently and least frequently encountered plants in Figures 8-14.

“Species richness” is the term given to the total number of species in a given area. For example, the total number of plant species in a lake would be its plant species richness. Generally speaking, a high species richness means high biodiversity and this is considered a healthy and desirable condition in an ecosystem. But species richness doesn’t tell the whole story. As an example, consider the plant communities of two hypothetical ponds each with 1,000 individual plants representing ten plant species (in other words, richness is 10). In the first pond each of the ten species populations is comprised of 100 individuals. In the second pond, Species #1 has a population of 991 individuals and each of the other nine species is represented by one individual plant. Intuitively, we would say that first pond is more diverse because there is more "even" distribution of individual species. The "Simpson Diversity Index" takes into account both richness and evenness in estimating diversity. It is based on a plant's relative frequency in a lake. The closer the Simpson Diversity Index is to 1, the more diverse the plant community. The Simpson Diversity Index for McCullough Lake aquatic plants was 0.93 in 2018 (Table 1) which indicates a highly diverse aquatic plant community. This value was virtually unchanged from the 2011 value (Table 3).

Another measure of floristic diversity and quality is the *Floristic Quality Index* (FQI). Floristic quality is an assessment metric designed to evaluate the closeness that the flora of an area is to that of undisturbed conditions (Nichols, 1999). Among other applications, it forms a standardized metric that can be used to compare the quality of different lakes (or different locations within a single lake) and monitor long-term changes in a lake's plant community (an indicator of lake health). The FQI for a lake is determined by using the average *coefficient of conservatism* times the square root of the number of native plant species present in the lake. Knowledgeable botanists have assigned to each native aquatic plant a *coefficient of conservatism* representing the probability that a plant is likely to occur in pristine environments (relatively unaltered from presettlement conditions). The coefficients range from 0 to 10, with 10 being assigned to those species most sensitive to disturbance. As more environmental disturbance occurs, the less conservative species become more prevalent.

Nichols (1999) analyzed aquatic plant community data from 554 Wisconsin Lakes to ascertain geographic (ecoregional) characteristics of the FQI metric. This is useful for considering how the McCullough Lake FQI (39.9) compares to other lakes and regions. The statewide medians for number of species and FQI are 13 and 22.2, respectively. McCullough Lake values are quite high compared to these statewide values (see Table 3). Nichols (1999) determined that there are four ecoregional-lake types groups in Wisconsin: (1) Northern Lakes and Forests lakes, (2) Northern Lakes and Forests Flowages, (3) North Central Hardwoods and Southeastern Till Plain Lakes and Flowages, and (4) Driftless Area and Mississippi River Backwater Lakes. McCullough Lake is located in the Northern Lakes and Forests Lakes group. Nichols (1999) found species numbers for the Northern Lakes and Forests Lakes group had a median value of 13. McCullough Lake data is consistent with that find. Finally, the McCullough Lake FQI is higher than the median value for the Northern Lakes and Forests Lakes group (24.3). These findings support the contention that the McCullough Lake plant community is healthy and diverse.

We observed no aquatic plants in McCullough Lake exhibiting nuisance-level population. Our survey found no aquatic invasive plant species or state or federally listed species.

Part 4. Fish Community

It was beyond the scope of the current project to characterize the fish community and fish habitat of this water body. The WDNR Lake Pages website (http://dnr.wi.gov/lakes/lakepages/) indicates that the bottom is comprised of 65% sand, 15% gravel, 10% rock, and 10% muck and that fish species present include musky, panfish, largemouth bass, northern pike, and walleye. Knowledgeable lake users report that muskellunge is not present.

Part 5. Water Quality and Trophic Status

McCullough Lake is a 221 acre drainage lake with a maximum depth of 27 feet. Existing water quality information includes data collected in 1960 (Black); data from WDNR SWIMS (Surface Water Integrated Monitoring System) database (collected by Northern Lakes Monitoring in 1984, 1985, 1990, 1991, 1997, and 2001 to present); and data from Citizen Lake Monitoring Network (CLMN) volunteers, from 2002 to present. In August and September 1989, there were reports of a fish kill. In 2011 and 2018, White Water Associates Inc. sampled McCullough Lake. That water quality information is briefly summarized in this section, but more fully interpreted in Appendix C.

At times, temperature and dissolved oxygen showed stratification in McCullough Lake in the ice-free season. Water clarity was "fair," but user perception of McCullough Lake aesthetic quality was generally regarded as "high." Water color was low, and the appearance of the water was clear. The trophic state was "mesotrophic to mildly eutrophic." Water quality would be classified as "good" with respect to phosphorus concentrations. Chlorophyll *a* (a measure of the amount of algae) was good. Nitrogen, chloride, sulfate, hardness, conductivity, calcium (borderline with respect to suitable habitat for zebra mussels); magnesium, sodium, and potassium would all be considered low. Alkalinity was low (a measure of a lake's buffering capacity against acid rain). The pH of McCullough Lake was alkaline.

Part 6. Water Use

McCullough Lake has no public access site, but is used by riparian owners and their guests for a variety of recreational activities. Land bordering the southeast end of the lake, and the two islands in McCullough Lake are owned by the State of Wisconsin.

Part 7. Riparian Area

Part 1 (Watershed) describes the larger riparian area context of McCullough Lake. The near shore riparian area can be appreciated by viewing Exhibits 2 and 4. The lake is lightly developed with a fairly intact forested riparian zone that extends for hundreds of feet back from the lake. The forest is a mixture of coniferous and deciduous trees and shrubs. Our review of available aerial photography reveals 43 houses on the lake. This intact riparian area provides numerous important functions and values to the lake. It effectively filters runoff to the lake. It provides excellent habitat for birds and mammals. Trees that fall into the lake from the riparian zone contribute important habitat elements to the lake. Educating riparian owners as to the value of riparian areas is important to the maintenance of these critical areas.

The WDNR, in 2016, formulated a protocol called *Lake Shoreland and Shallows Habitat Monitoring* (WDNR, 2016). It provides a standard methodology for surveying, assessing, and mapping habitat in lakeshore areas, including the Riparian buffer, Bank, and Littoral Zones (WDNR, 2016). In 2018, a shoreland and shallow water assessment was conducted on McCullough Lake. This information will be useful to local and regional resource managers, community stakeholders, and others interested in protecting and enhancing Wisconsin's lakes and rivers (WDNR, 2016). Part of the shallow water habitat survey includes documenting woody habitat. A detailed report can be found in Appendix D.

Part 8. Wildlife

A study of wildlife was beyond the scope of the current study, but would be valuable for future iterations of the plan. This would be especially true of wetland and water oriented wildlife such as frogs, waterfowl, fish-eating birds, aquatic and semi-aquatic mammals, and invertebrate animals. In the future, it would be desirable to monitor indicator species of wildlife such as common loons, bald eagles, and osprey. Also of special importance would be monitoring for the presence of aquatic invasive wildlife species (for example, rusty crayfish, spiny water flea, or zebra mussel) and fish species (for example, rainbow smelt or common carp). In 2003, the WDNR reported that rusty crayfish (*Orconectes rusticus*) was found in McCullough Lake (although the 2018 AIS survey did not detect this species).

McCullough Lake is currently designated as an *area of special natural resource interest* (ASNRI) and a *priority navigable water* (PNW) (WDNR, 2012). A water body designated as an ASNRI can be any of the following: trout streams; Outstanding or Exceptional Resource Waters (ORW/ERW); waters or portions of waters inhabited by endangered, threatened, special concern species or unique ecological communities; wild rice waters; waters in ecologically significant coastal wetlands along Lake Michigan and Superior; or federal or state waters designated as wild or scenic rivers (WDNR, 2012). McCullough Lake is considered an ASNRI because it harbors rare plant and animal species. The Wisconsin Natural Heritage Inventory (NHI) lists several rare or sensitive plant and animal species and natural communities considered high-quality natural features that are found in the same town/range as McCullough Lake (NHI, 2013). PNWs meet any of these standards: navigable waterways, or portions thereof, that are considered OWR/EWR or trout streams; lakes less than 50 acres in size; tributaries and rivers connecting to inland lakes containing naturally-reproducing lake sturgeon populations; waters with self-sustaining walleye populations in ceded territories; waters with self-sustaining musky populations; or perennial tributaries to trout streams (WDNR, 2012). The WDNR considers McCullough Lake a PNW with a self-sustaining musky population. Nevertheless, lake users report musky are not present.

Exhibit 8. Rare Species and Communities located near McCullough Lake.

Common Name	*Scientific Name*	*State Status*[3]	*Group Name*
Bald eagle	*Haliaeetus leucocephalus*	SC/P	Bird
Boreal chickadee	*Poecile hudsonicus*	SC/M	Bird
Northern dry-mesic forest		NA	Community
Northern mesic forest		NA	Community
Spring pond		NA	Community
Stream—slow, soft, warm		NA	Community

Part 9. Stakeholders

At this juncture in the ongoing aquatic plant management planning process, the Town Lakes Committee has represented the McCullough Lake stakeholders. Additional stakeholders and interested citizens are invited to participate as the plan is refined and updated in order to broaden input, build consensus, and encourage participation in stewardship. No contentious direct plant management actions (for example, harvesting or use of herbicides) are a component of the current plan. The Town Lakes Committee has conducted a township wide lake users'

[3] **END**=Endangered; **THR**=Threatened; **SC**=Special Concern; **SC/P**=fully protected; **SC/N**=no laws regulating use, possession or harvesting; **SC/H**=take regulated by establishment of open/closed seasons; **SC/FL**=federally protected as endangered or threatened, but not so designated by DNR; **SC/M**=fully protected by federal and state laws under Migratory Bird Act.

survey that is presented in the overarching ***Wilderness Waters Adaptive Management Plan*** (Stine et al., 2019).

CHAPTER 5

Recommendations, Actions, and Objectives

In this chapter we provide recommendations for specific objectives and associated actions to support the APM Plan's goals stated in Chapter 3 and re-stated here for convenient reference:

(1) Monitor and protect the native aquatic plant community;
(2) Monitor for AIS and prevent establishment of new non-native biota;
(3) Consider and evaluate the efficacy of active aquatic plant management; and
(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that can alter the plant community, minimizing physical removal of native riparian and littoral zone plants, and living with a lake whose natural healthy state includes aquatic plants.

Since McCullough Lake is a healthy and diverse ecosystem, we could simply recommend an alternative of "no action." In other words, McCullough Lake continues without any effort or intervention on part of lake stewards. Nevertheless, we consider the "no action" alternative imprudent. Many forces threaten the quality of the lake and Wilderness Waters Program and Town Lakes Committee feels a great responsibility to minimize the threats. We therefore outline in this section a set of actions and related management objectives that will actively engage lake stewards in the process of management.

The actions are presented in tabular form. Each "action" consists of a set of four statements: (1) a declarative "action" statement that specifies the action (2) a statement of the "objective" that the action serves, (3) a "monitoring" statement that specifies the party responsible for carrying out the action and maintaining data, and (4) a "status" statement that suggests a timeline/calendar and indicates status (not yet started, ongoing, or completed).

At this time, we recommend no direct manipulation of plant populations in McCullough Lake. No aquatic invasive plant species are known to be present and no native plants exhibit nuisance population size or distribution.

Recommended Actions for the McCullough Lake APM Plan
Action #1: Formally adopt the Aquatic Plant Management Plan. ***Objective:*** To provide foundation for long-term native plant community conservation and stewardship and to be prepared for response to AIS introductions. ***Monitoring:*** The Lake Association and Town Lakes Committee oversee activity and maintains the plan. ***Status:*** Planned for 2020.
Action #2: Monitor water quality. ***Objective***: Continue with collection and analysis of water quality parameters to detect trends in parameters such as nutrients, chlorophyll *a*, and water clarity. ***Monitoring:*** The Lake Association or Town Lakes Committee oversees activity. ***Status:*** Ongoing.
Action #3: Monitor the lake for aquatic invasive plant species. ***Objective***: To understand the lake's biotic community, provide for early detection of AIS and continue monitoring any existing populations of AIS. ***Monitoring:*** The Lake Association or Town Lakes Committee oversees activity and maintains data. ***Status:*** Ongoing.
Action #4: Monitor the lake for aquatic invasive animal species. ***Objective***: To understand the lake's biotic community, provide for early detection of AIS and continue monitoring any existing populations of AIS. ***Monitoring:*** The Lake Association or Town Lakes Committee oversees activity and maintains data. ***Status:*** Ongoing.
Action #5: Monitor the population of rusty crayfish in McCullough Lake by simple trapping. ***Objective***: Determine potential effects of this aquatic invasive animal. ***Monitoring:*** The Lake Association or Town Lakes Committee oversees activity. ***Status:*** Ongoing.

Recommended Actions for the McCullough Lake APM Plan

Action #6: Form an Aquatic Invasive Species Rapid Response Team and interface with the Town Lakes Committee AIS Rapid Response Coordinator.

Objective: To be prepared for AIS discovery and efficient response.

Monitoring: The Lake Association and/or Town Lakes Committee coordinate activity.

Status: Ongoing.

Action #7: Conduct plant survey every five years using WDNR methodology.

Objective: To watch for changes in native species diversity, floristic quality, plant abundance, distribution and to check for occurrence of non-native, invasive plant species.

Monitoring: Town Lakes Committee (Wilderness Waters Program) oversees and maintains data; copies to WDNR.

Status: Anticipated in 2023.

Action #8: Update the APM plan approximately every five years or as needed to reflect new plant information from plant surveys and monitoring.

Objective: To have current information and management science included in the plan.

Monitoring: Lake Association and/or Town Lakes Committee (Wilderness Waters Program) oversees and maintains data; copies to WDNR.

Status: Ongoing.

Action #9: Develop a Citizen Lake Monitoring Network to monitor for invasive species and develop strategies including education and monitoring activities (see http://www.uwsp.edu/cnr/uwexlakes/clmn for additional ideas).

Objective: To create a trained volunteer corps to monitor aquatic invasive species and to educate recreational users regarding AIS.

Monitoring: The Lake Association oversees activity and reports instances of possible introductions of AIS.

Status: Anticipated to begin in 2020.

Recommended Actions for the McCullough Lake APM Plan
Action #10: Become familiar with and recognize the water quality and habitat values of ordinances and requirements on boating, septic, and property development. ***Objective:*** To protect native aquatic plants, water quality, and riparian habitat. ***Monitoring:*** Lake residents and other stakeholders. ***Status:*** Ongoing.
Action #11: Promote adherence to, and enforcement of, the Town of Presque Isle's 200 foot no-wake ordinances (from shoreline and islands). ***Objective:*** To minimize recreational impacts on the aquatic plant community and shoreline habitats, and promote safe boating. ***Monitoring:*** Town Lakes Committee oversees activity and assesses effectiveness. ***Status:*** Ongoing.
Action #12: Create an education plan for the property owners and other stakeholders that will address issues concerning aquatic and riparian plant communities. ***Objective:*** To educate stakeholders about issues and topics that affect the lake's aquatic and riparian plant communities, including topics such as: (1) the importance of the aquatic plant community; (2) no or minimal mechanical removal of plants along the shoreline is desirable and that any plant removal should conform to Wisconsin regulations; (3) the value of a natural shoreline in protecting the aquatic plant community and lake health; (4) nutrient sources to the lake and the role excess nutrients play in degradation of the aquatic plant community; (5) the importance of reducing or eliminating use of fertilizers on lake front property; (6) the importance of minimizing transfer of AIS to the lake by having dedicated watercraft and cleaning boats that visit the lake. ***Monitoring:*** Town Lakes Committee oversee(s) activity and assesses effectiveness. ***Status:*** Ongoing.

Recommended Actions for the McCullough Lake APM Plan

Action #13: Identify and highlight high quality areas of littoral zone and riparian areas through review of aquatic plant and shoreland assessment data through various reports and online tools.

Objective: To (1) educate lake users on the value of these areas and the importance of good stewardship to their maintenance, (2) recognize landowners who implement good practices (e.g., large percentage of buffer area intact; three vegetative layers intact – herbaceous, shrubs, trees; areas of high native aquatic plant diversity and abundance), and (3) encourage landowners to implement good practices.

Monitoring: Town Lakes Committee and/or lake association promotes and oversees activity.

Status: Ongoing.

Action #14: Lake leaders should encourage and assist landowners to take on lake shore/shallow water improvement projects to rehabilitate areas identified through formal shoreland/shallow water assessments and/or lake user observations (sites might include areas of active erosion, channelized flow, point source pollution, impervious surfaces, and lawns) *Vilas County Land and Water Conservation* looks for partners in this endeavor and can provide planning and sponsorship of projects.

Objective: To rehabilitate specific areas of shoreland to improve natural functions and values.

Monitoring: Lake groups and lake leaders monitor and report progress to Town Lakes Committee.

Status: Ongoing.

Action #15: As part of an education program, encourage commitment from property owners to adopt practices that maintain/improve health of shoreland areas. In many cases, these are "practices" that mean less or no work (e.g., now mowing, no weed whacking, no leaf blowing, no removing large woody material).

Objective: To engage landowners in simple practices that improve/maintain health of the lake and shoreland.

Monitoring: Each landowner can monitor changes in the shoreland over time by simple means (e.g., annual mid-summer photographs or a catalog of plants and animals seen over time).

Status: Anticipated to begin in 2020.

CHAPTER 6

Contingency Plan for AIS

Unfortunately, sources of aquatic invasive plants and other AIS are numerous in Wisconsin. Some infested lakes are quite close to Presque Isle Township. There is an increasing likelihood of accidental introduction of AIS to Presque Isle Township Lakes through conveyance of life stages by boats, trailers, and other vectors. It is important for the Town Lakes Committee and other lake stewards to be prepared for the contingency of aquatic invasive plant species colonization in a Presque Isle Township water body. As part of this grant an Aquatic Invasive Survey was conducted using the *Aquatic Invasive Species Early Detection Monitoring Standard Operating Procedure* (2014) and also an educational seminar was conducted. Further discussion is found in Appendix E.

For riparian owners and users of a lake ecosystem, the discovery of AIS is a tragedy that elicits an immediate desire to “fix the problem.” Although strong emotions may be evoked by such a discovery, a deliberate and systematic approach is required to appropriately and effectively address the situation. An aquatic plant management plan (one including a contingency plan for AIS) is the best tool by which the process can be navigated. In fact the APM plan is a requirement in Wisconsin for some kinds of aquatic plant management actions. One of the actions outlined in the previous chapter was to establish an Aquatic Invasive Species Rapid Response Team. This team and its coordinator are integral to the management process. It is important for this team to be multi-dimensional (or at least have quick access to the expertise that may be required). AIS invade not just a single lake, but an entire region since the new infestation is an outpost from which the AIS can more easily colonize other nearby water bodies. For this reason it is strategic for the Rapid Response Team to include representation from regional stakeholders.

Exhibit 9 provides a flowchart outlining an appropriate rapid response to the suspected discovery of an aquatic invasive plant species. The response will be most efficient if an AIS Rapid Response Team has already been established and is familiar with the contingency plan. In the remainder of this chapter we further describe the approach.

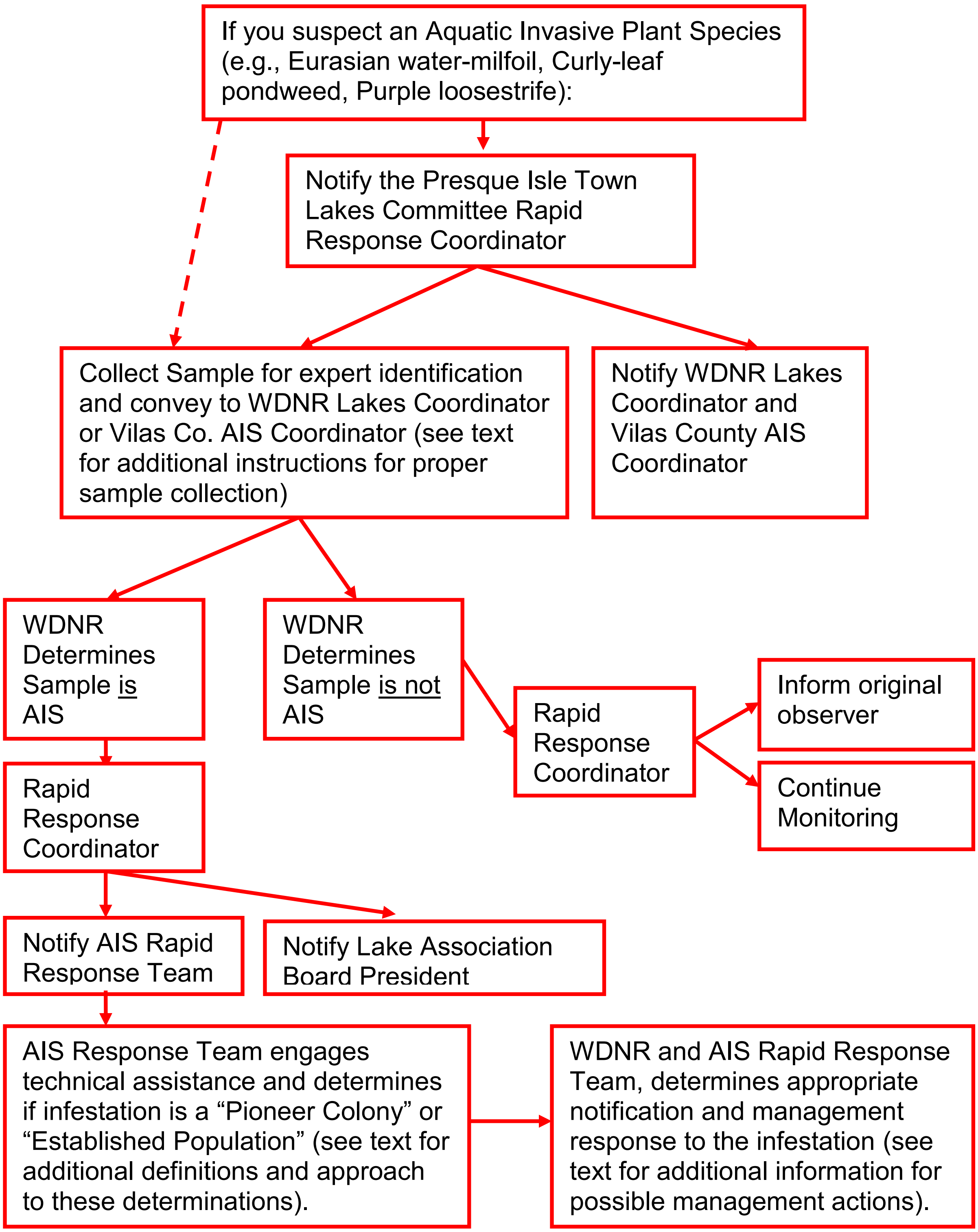
When a suspect aquatic invasive plant species is found, either the original observer or a member of the Rapid Response Team (likely the coordinator) should collect an entire plant specimen including roots, stems, and flowers (if present). The sample should be placed in a sealable bag with a small amount of water to keep it moist. Place a label in the bag written in pencil with date, time, collector's name, lake name, location, town, and county. Attach a lake map to the bag that has the location of the suspect AIS marked and GPS coordinates recorded (if GPS is available). The sample should be placed on ice in a cooler or in a refrigerator. Deliver the sample to the WDNR Water Resource Management Specialist (Kevin Gauthier in Woodruff) or the Vilas County AIS Coordinator (Alan Wirt) as soon as possible (at least within three days). The WDNR or their botanical expert(s) will determine the species and confirm whether or not it is an aquatic invasive plant species.

If the suspect specimen is determined to be an invasive plant species, the next step is to determine the extent and density of the population since the management response will vary accordingly. The Rapid Response Team should conduct (or have its consultant conduct) a survey to define the colony's perimeter and estimate density. If less than five acres (or <5% of the lake surface area), it is designated a "Pioneer Colony." If greater than five acres (or >5% of the lake surface area) then it is designated an "Established Population." Once the infestation is characterized, "at risk" areas should also be determined and marked on a map. For example, nearby boat landing sites and areas of high boat traffic should be indicated.

When "pioneer" or "established" status has been determined, it is time to consult with the WDNR Lakes Coordinator to determine appropriate notifications and management responses to the infestation. Determining whether hand-pulling or chemical treatment will be used is an important and early decision. Necessary notifications of landowners, governmental officials, and recreationists (at boat landings) will be determined. Whether the population's perimeter needs to be marked with buoys will be decided by the WDNR. Funding sources will be identified and consultants and contractors will be contacted where necessary. The WDNR will determine if a further baseline plant survey is required (depending on type of treatment). A post treatment monitoring plan will be discussed and established to determine the efficacy of the selected treatment.

Once the Rapid Response Team is organized, one of its first tasks is to develop a list of contacts and associated contact information (phone numbers and email addresses). At a minimum, this contact list should include: the Rapid Response Coordinator, members of the Rapid Response Team, County AIS Coordinator, WDNR Lakes Management Coordinator, Lake Association Presidents (or other points of contact), local WDNR warden, local government official(s), other experts, chemical treatment contractors, and consultant(s).

Exhibit 9. Aquatic Invasive Plant Species Rapid Response



Appendix A
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Appendix B

Aquatic Plant Survey Tables and Figures

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Table 1. Summary statistics for the 2018 point-intercept aquatic plant surveys for McCullough Lake.

Summary Statistic	Value	Notes
Total number of sites on grid	511	Total number of sites on the original grid (not necessarily visited)
Total number of sites visited	344	Total number of sites where the boat stopped, even if much too deep to have plants.
Total number of sites with vegetation	136	Total number of sites where at least one plant was found
Total number of sites shallower than maximum depth of plants	213	Number of sites where depth was less than or equal to the maximum depth where plants were found. This value is used for Frequency of occurrence at sites shallower than maximum depth of plants.
Frequency of occurrence at sites shallower than maximum depth of plants	68.85	Number of times a species was seen divided by the total number of sites shallower than maximum depth of plants.
Simpson Diversity Index	0.93	A nonparametric estimator of community heterogeneity. It is based on Relative Frequency and thus is not sensitive to whether all sampled sites (including non-vegetated sites) are included. The closer the Simpson Diversity Index is to 1, the more diverse the community.
Maximum depth of plants (ft.)	10.50	The depth of the deepest site sampled at which vegetation was present.
Number of sites sampled with rake on rope	7	
Number of sites sampled with rake on pole	254	
Average number of all species per site (shallower than max depth)	1.54	
Average number of all species per site (vegetated sites only)	2.40	
Average number of native species per site (shallower than max depth)	1.54	Total number of species collected. Does not include visual sightings.
Average number of native species per site (vegetated sites only)	2.40	Total number of species collected including visual sightings.
Species Richness	33	
Species Richness (including visuals)	36	
Floristic Quality Index (FQI)	39.9	

Table 2. Plant species recorded and distribution statistics for the 2018 McCullough Lake aquatic plant survey.

Common name	Scientific name	Frequency of occurrence at sites less than or equal to maximum depth of plants	Frequency of occurrence within vegetated areas (%)	Relative Frequency (%)	Number of sites where species found	Number of sites where species found (including visuals)	Average Rake Fullness
Slender naiad	*Najas flexilis*	24.41	38.24	15.90	52	54	1.00
Fern pondweed	*Potamogeton robbinsii*	17.84	27.94	11.62	38	39	1.11
Nitella	*Nitella sp.*	12.68	19.85	8.26	27	27	1.52
Wild celery	*Vallisneria Americana*	11.27	17.65	7.34	24	26	1.00
Common waterweed	*Elodea Canadensis*	10.80	16.91	7.03	23	27	1.04
Watershield	*Brasenia schreberi*	7.98	12.50	5.20	17	51	1.00
Muckgrasses	*Chara sp.*	7.98	12.50	5.20	17	17	1.00
White water lily	*Nymphaea odorata*	6.10	9.56	3.98	13	49	1.00
Small pondweed	*Potamogeton pusillus*	5.16	8.09	3.36	11	12	1.00
Common bladderwort	*Utricularia vulgaris*	4.69	7.35	3.06	10	14	1.00
Water star-grass	*Heteranthera dubia*	4.23	6.62	2.75	9	12	1.00
Spatterdock	*Nuphar variegata*	3.76	5.88	2.45	8	38	1.00
Large-leaf pondweed	*Potamogeton amplifolius*	3.76	5.88	2.45	8	27	1.13
Northern water-milfoil	*Myriophyllum sibiricum*	2.82	4.41	1.83	6	18	1.00
Ribbon-leaf pondweed	*Potamogeton epihydrus*	2.82	4.41	1.83	6	14	1.00
Water marigold	*Bidens beckii*	2.82	4.41	1.83	6	8	1.00
Creeping bladderwort	*Utricularia gibba*	2.82	4.41	1.83	6	8	1.17
Clasping-leaf pondweed	*Potamogeton richardsonii*	2.35	3.68	1.53	5	10	1.40
Coontail	*Ceratophyllum demersum*	2.35	3.68	1.53	5	5	1.00
Variable pondweed	*Potamogeton gramineus*	1.88	2.94	1.22	4	13	1.00
Flat-stem pondweed	*Potamogeton zosteriformis*	1.88	2.94	1.22	4	9	1.00
Slender waterweed	*Elodea nuttallii*	1.88	2.94	1.22	4	4	1.00
Leafy pondweed	*Potamogeton foliosus*	1.88	2.94	1.22	4	4	1.00
Hardstem bulrush	*Schoenoplectus acutus*	1.41	2.21	0.92	3	17	1.00

Frequency of occurrence within vegetated areas (%): Number of times a species was seen in a vegetated area divided by the total number of vegetated sites.

Table 2. Continued.

Common name	Scientific name	Frequency of occurrence at sites less than or equal to maximum depth of plants	Frequency of occurrence within vegetated areas (%)	Relative Frequency (%)	Number of sites where species found	Number of sites where species found (including visuals)	Average Rake Fullness
Floating-leaf bur-reed	*Sparganium fluctuans*	1.41	2.21	0.92	3	12	1.00
Floating-leaf pondweed	*Potamogeton natans*	1.41	2.21	0.92	3	6	1.00
Spiral-fruited pondweed	*Potamogeton spirillus*	1.41	2.21	0.92	3	3	1.00
Pickerelweed	*Pontederia cordata*	0.94	1.47	0.61	2	11	1.00
Quillwort	*Isoetes sp.*	0.94	1.47	0.61	2	2	1.00
Short-stemmed bur-reed	*Sparganium emersum*	0.47	0.74	0.31	1	4	1.00
Dwarf water-milfoil	*Myriophyllum tenellum*	0.47	0.74	0.31	1	1	1.00
Flat-leaf badderwort	*Utricularia intermedia*	0.47	0.74	0.31	1	1	1.00
Small bladderwort	*Utricularia minor*	0.47	0.74	0.31	1	1	1.00
Creeping spikerush	*Eleocharis palustris*				Visual	4	
White-stem pondweed	*Potamogeton praelongus*				Visual	1	
Broad-leaved cattail	*Typha latifolia*				Visual	1	
Hair grass	*Argostis scabra*				Boat Survey		
Bottle brush sedge	*Carex comosa*				Boat Survey		
Three-way sedge	*Dulichium arundinaceum*				Boat Survey		
Needle spikerush	*Eleocharis acicularis*				Boat Survey		
Water horsetail	*Equisetum fluviatile*				Boat Survey		
	Iris sp.				Boat Survey		
Common rush	*Juncus effuses*				Boat Survey		
Woolgrass	*Scirpus cyperinus*				Boat Survey		
Small bur-reed	*Sparganium natans*				Boat Survey		

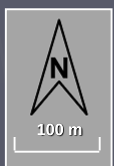
Frequency of occurrence within vegetated areas (%): Number of times a species was seen in a vegetated area divided by the total number of vegetated sites.

Voucher specimens were sent and verified by Dr. Freckmann (U.W. Stevens Point – Herbarium) January, 2019.

Table 3. Comparison of summary statistics for 2011 and 2018 point-intercept aquatic plant surveys in McCullough Lake.

Summary Statistic	**2011**	**2018**
Total number of sites on grid	511	511
Total number of sites visited	505	344
Total number of sites with vegetation	159	136
Total number of sites shallower than maximum depth of plants	173	213
Frequency of occurrence at sites shallower than maximum depth of plants	91.9	63.85
Simpson Diversity Index	0.92	0.93
Maximum depth of plants (ft.)	9.00	10.50
Number of sites sampled with rake on rope	10	7
Number of sites sampled with rake on pole	214	254
Average number of all species per site (shallower than max depth)	2.29	1.54
Average number of all species per site (vegetated sites only)	2.49	2.40
Average number of native species per site (shallower than max depth)	2.29	1.54
Average number of native species per site (vegetated sites only)	2.49	2.40
Species Richness	33	33
Species Richness (including visuals)	33	36
Floristic Quality Index (FQI)	39.5	39.9

Figure 1. Number of plant species recorded at McCullough Lake sample sites (2018).



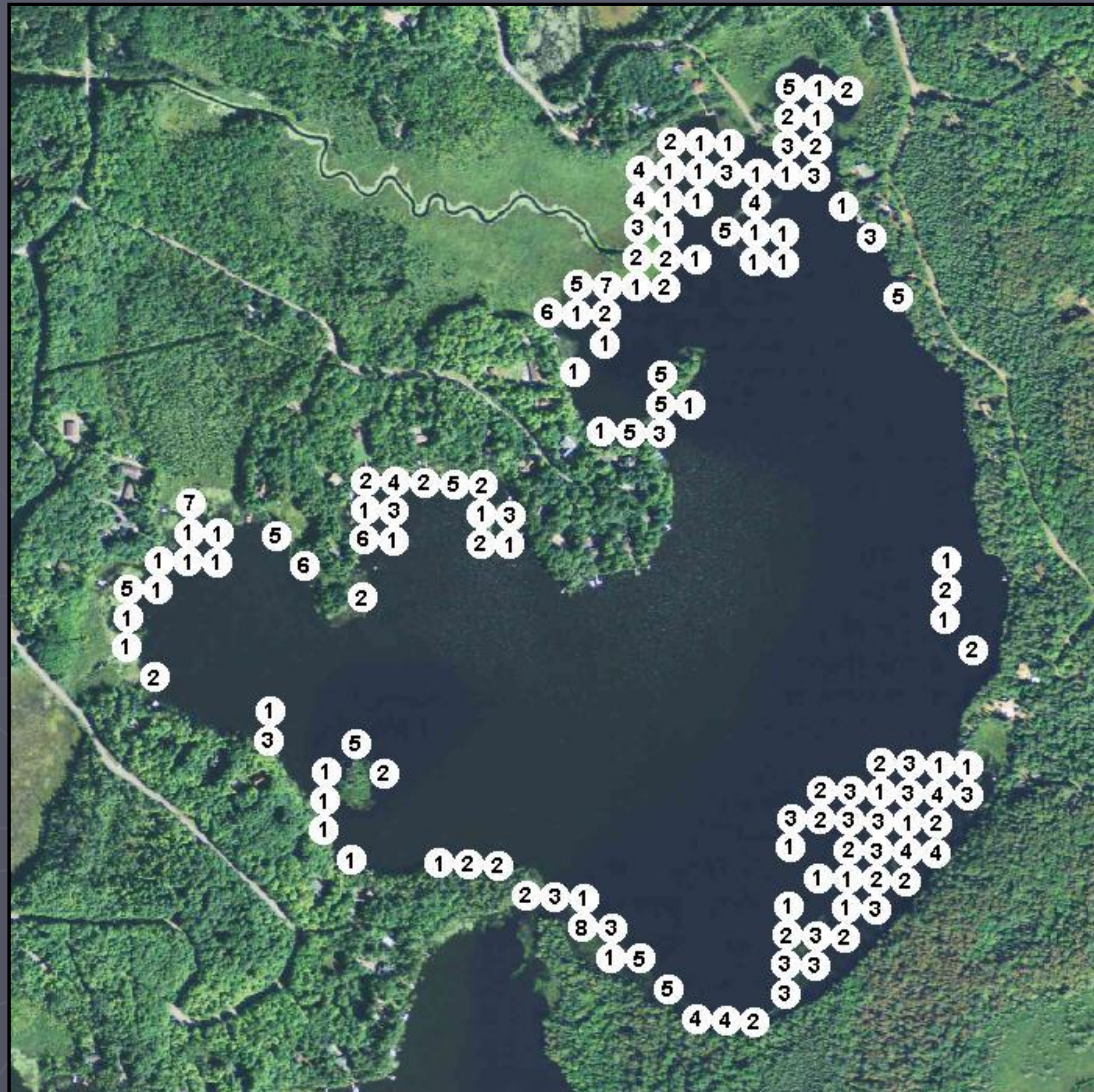
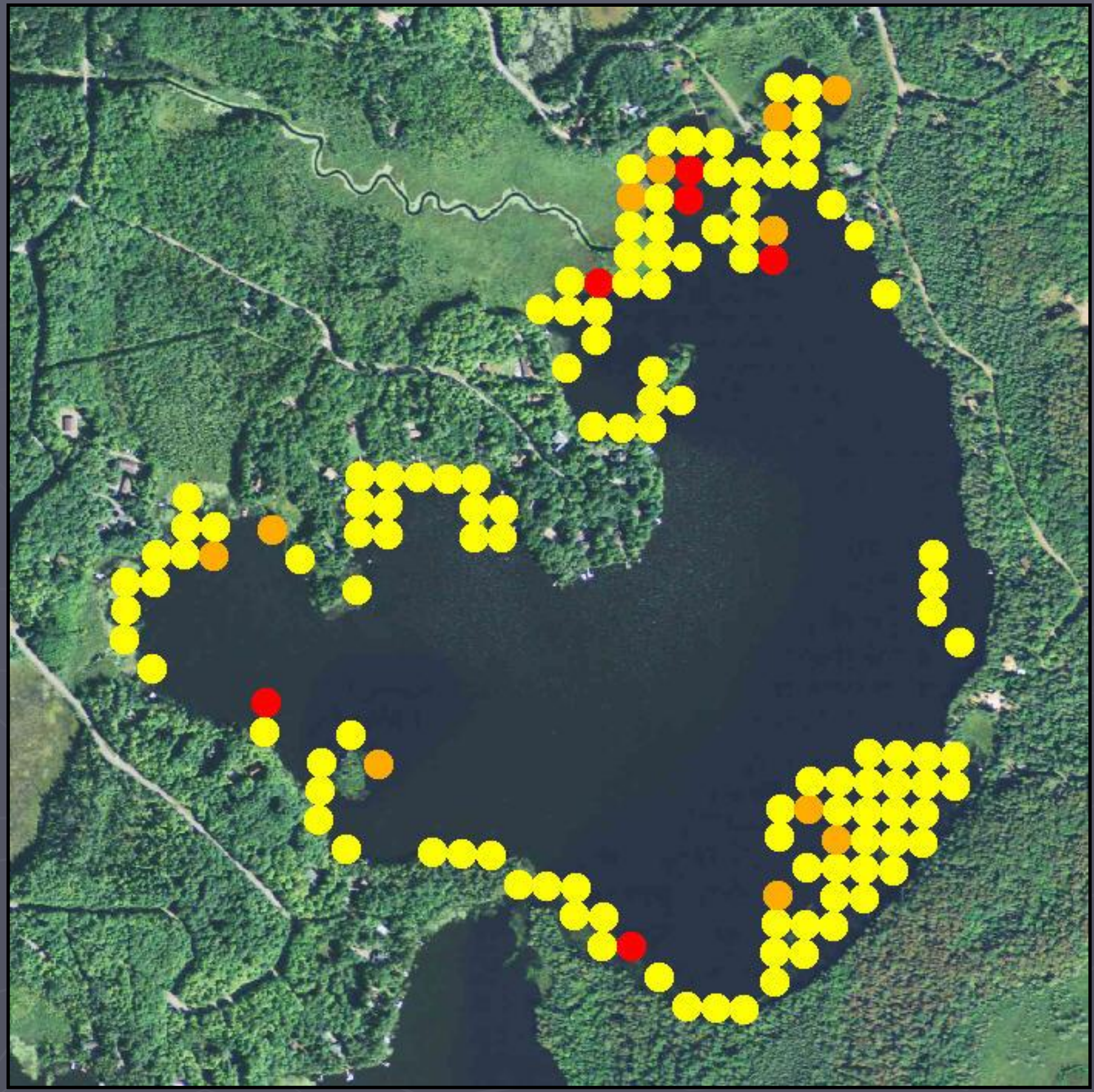


Figure 2. Rake fullness ratings for McCullough Lake sample sites (2018).



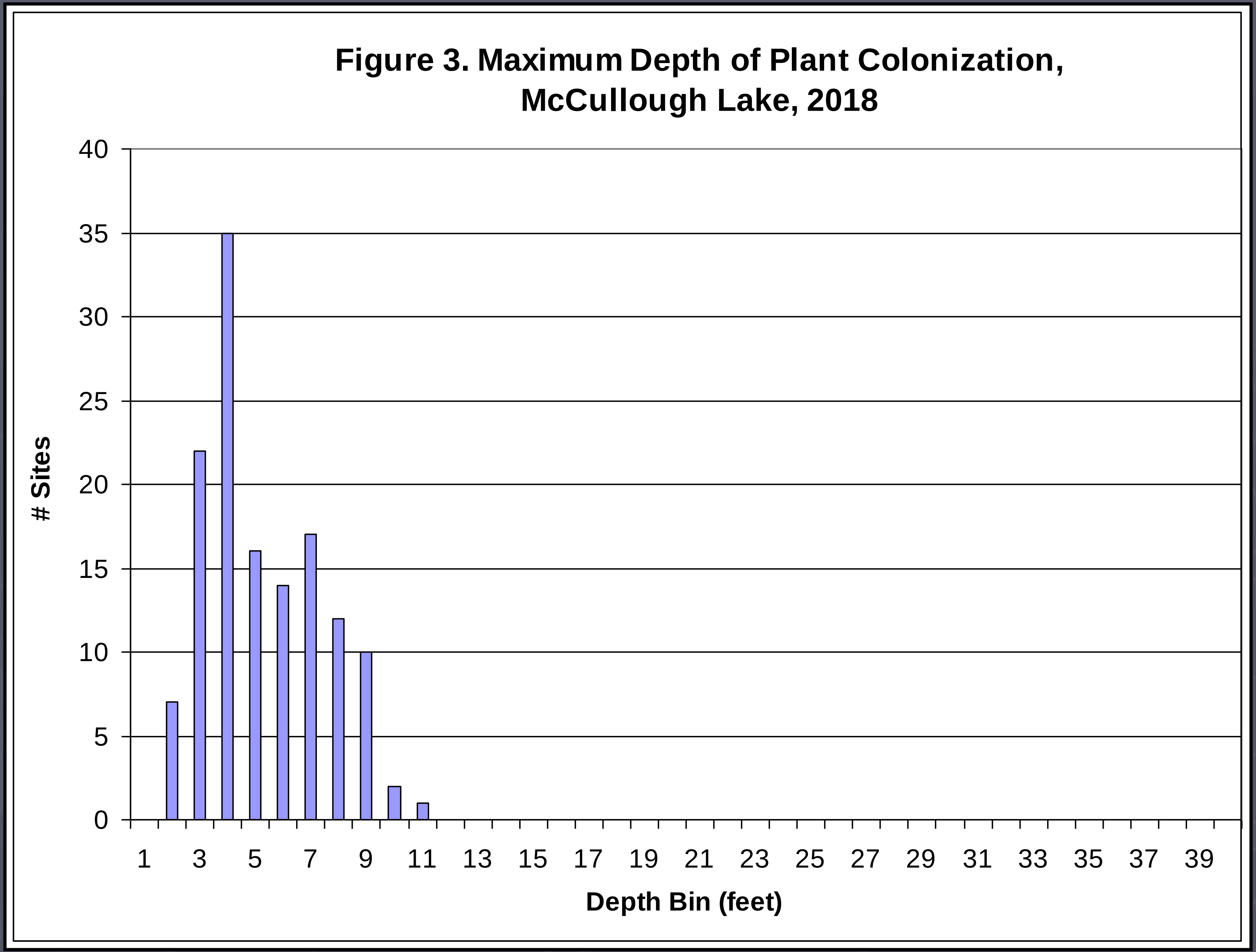
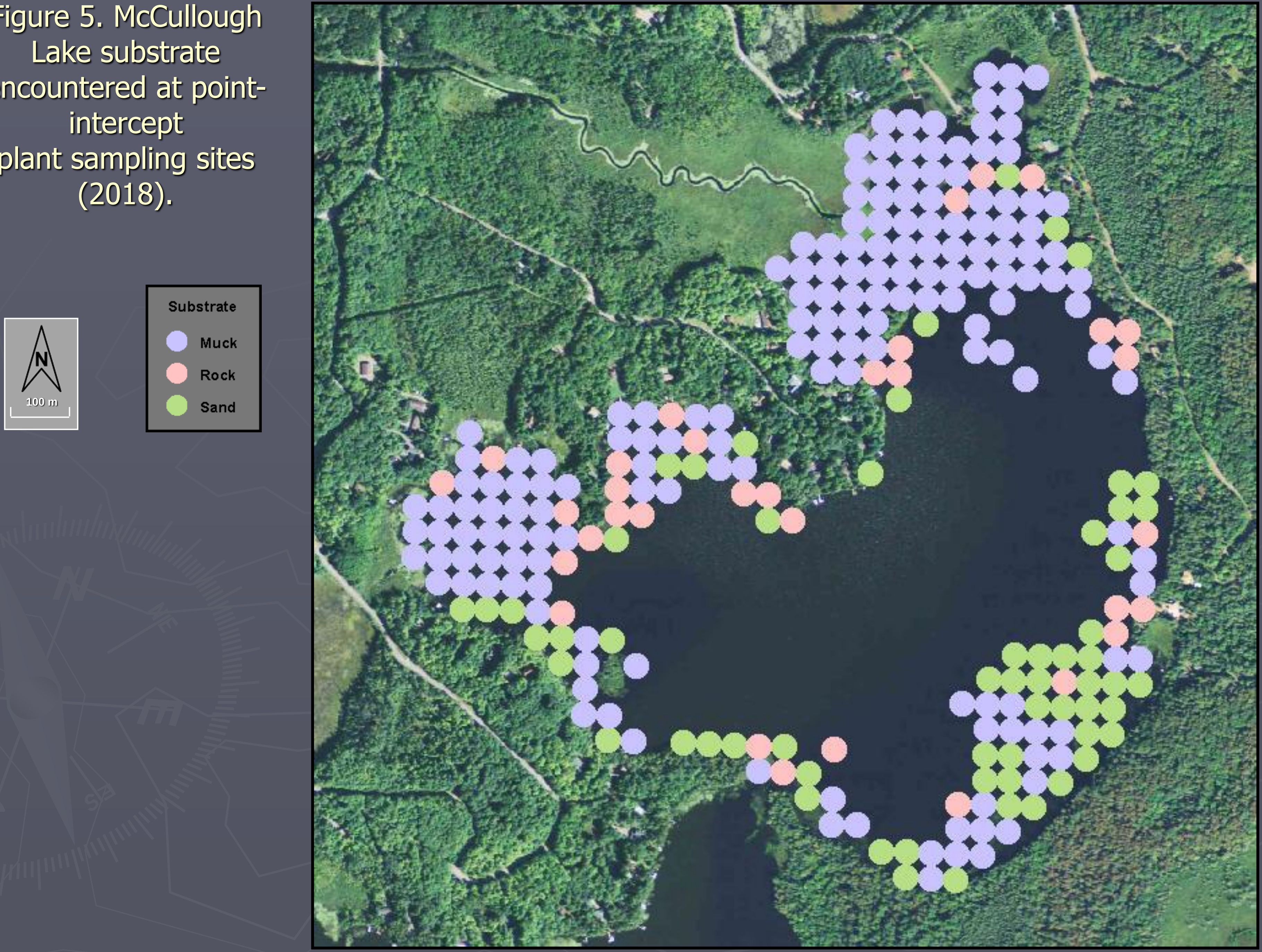


Figure 3. Maximum Depth of Plant Colonization,
McCullough Lake, 2018
Sites
Depth Bin (feet)
0
5
10
15
20
25
30
35
40
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33
35
37
39

Figure 4. McCullough Lake sampling sites less than or equal to maximum depth of rooted vegetation (2018).

Figure 5. McCullough Lake substrate encountered at point-intercept plant sampling sites (2018).



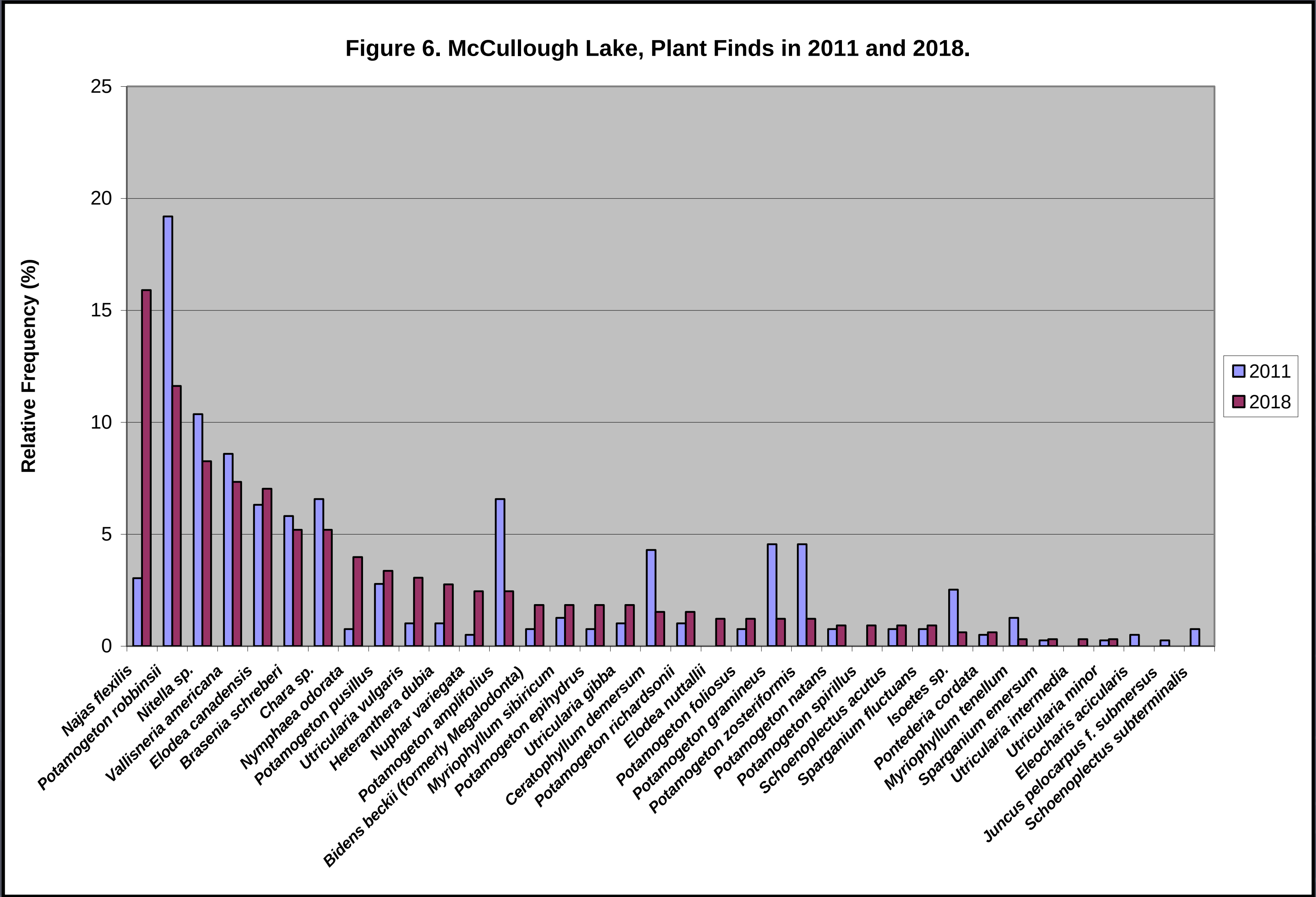


Figure 6. McCullough Lake, Plant Finds in 2011 and 2018.
Relative Frequency (%)
25
20
15
10
5
0
2011
2018
Najas flexilis
Potamogeton robbinsii
Nitella sp.
Vallisneria americana
Elodea canadensis
Brasenia schreberi
Chara sp.
Nymphaea odorata
Potamogeton pusillus
Utricularia vulgaris
Heteranthera dubia
Nuphar variegata
Potamogeton amplifolius
Bidens beckii (formerly Megalodonta)
Myriophyllum sibiricum
Potamogeton epihydrus
Utricularia gibba
Ceratophyllum demersum
Potamogeton richardsonii
Elodea nuttallii
Potamogeton foliosus
Potamogeton gramineus
Potamogeton zosteriformis
Potamogeton natans
Potamogeton spirillus
Schoenoplectus acutus
Sparganium fluctuans
Isoetes sp.
Pontederia cordata
Myriophyllum tenellum
Sparganium emersum
Utricularia intermedia
Utricularia minor
Eleocharis acicularis
Juncus pelocarpus f. submersus
Schoenoplectus subterminalis

Figure 7. McCullough Lake point-intercept plant sampling sites with
emergent and floating aquatic plants (2018).

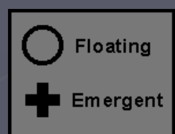


Figure 8. Distribution of plant species, McCullough Lake (2018).

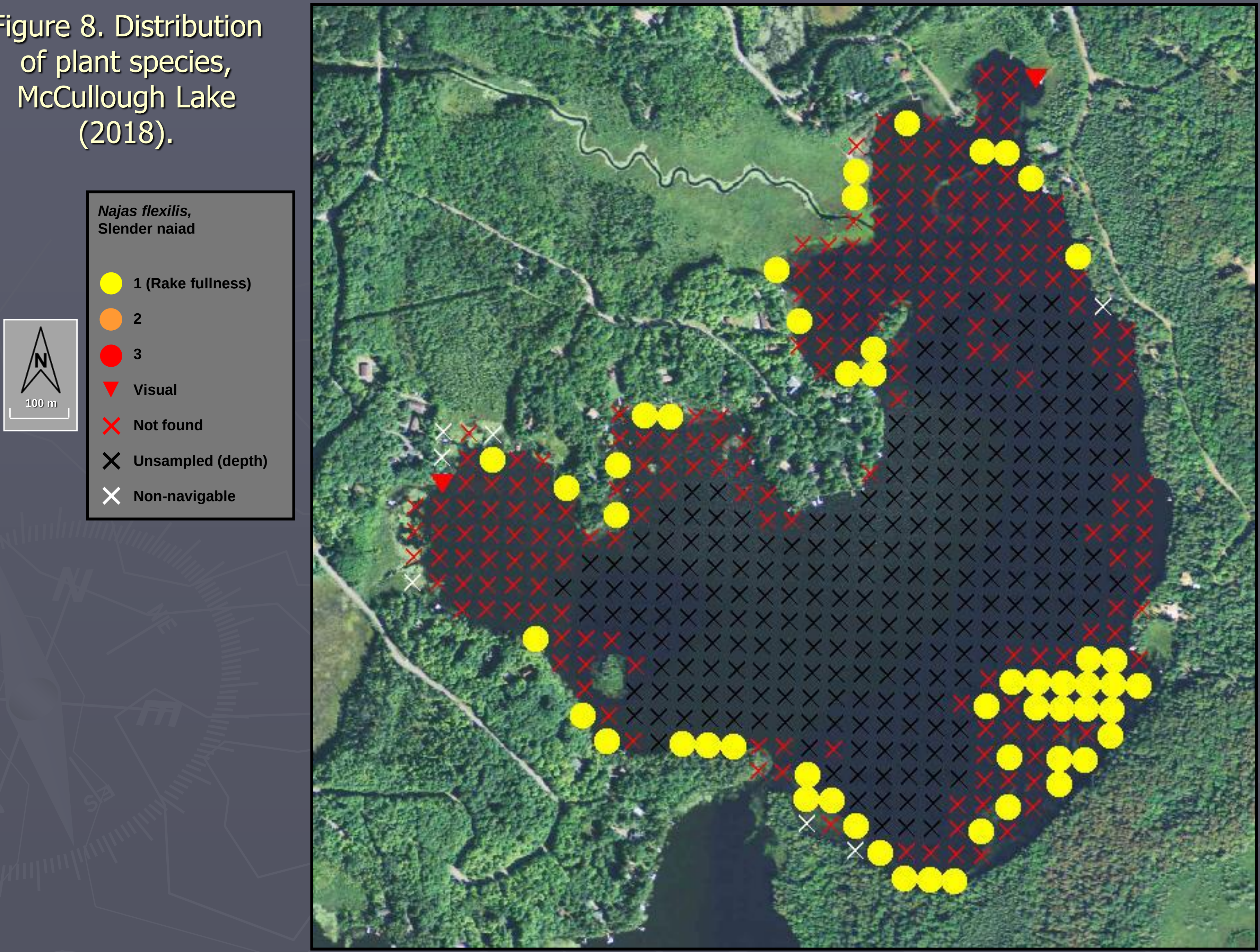


Figure 9. Distribution of plant species, McCullough Lake (2018).

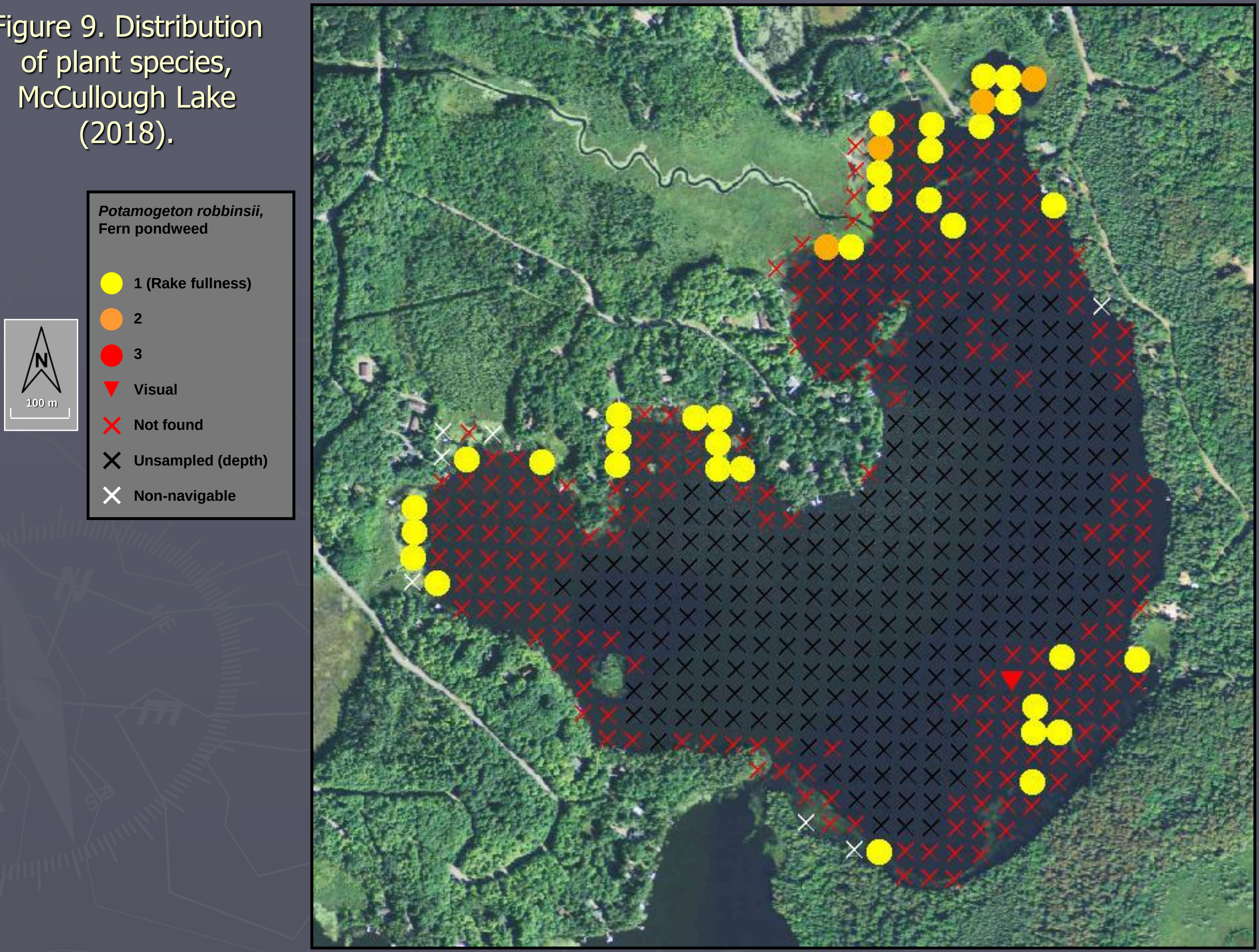


Figure 10. Distribution of plant species, McCullough Lake (2018).

***Nitella sp.*,**
Nitella

- 1 (Rake fullness)
- 2
- 3
- Visual
- Not found
- Unsampled (depth)
- Non-navigable

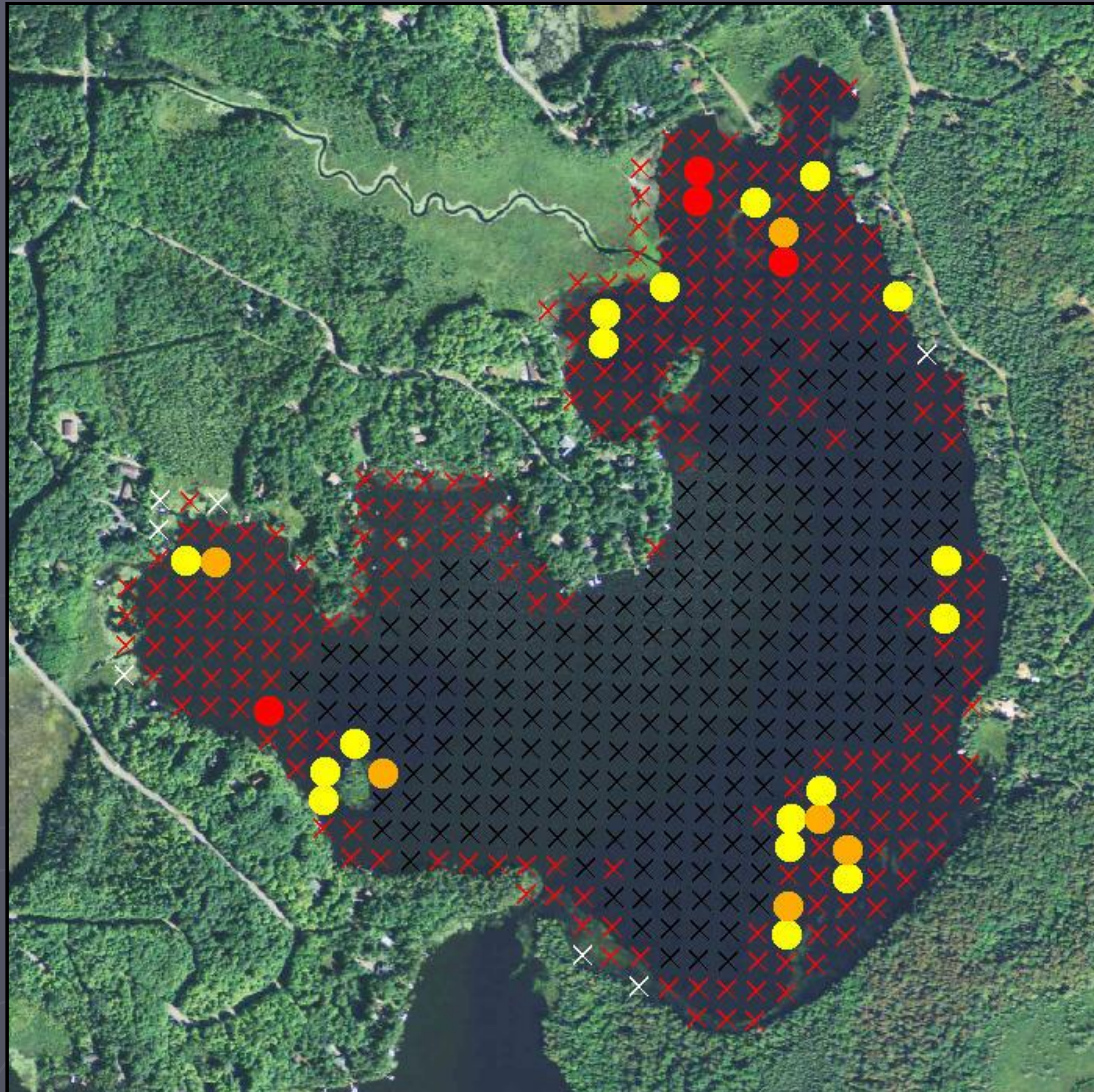


Figure 11. Distribution of plant species, McCullough Lake (2018).

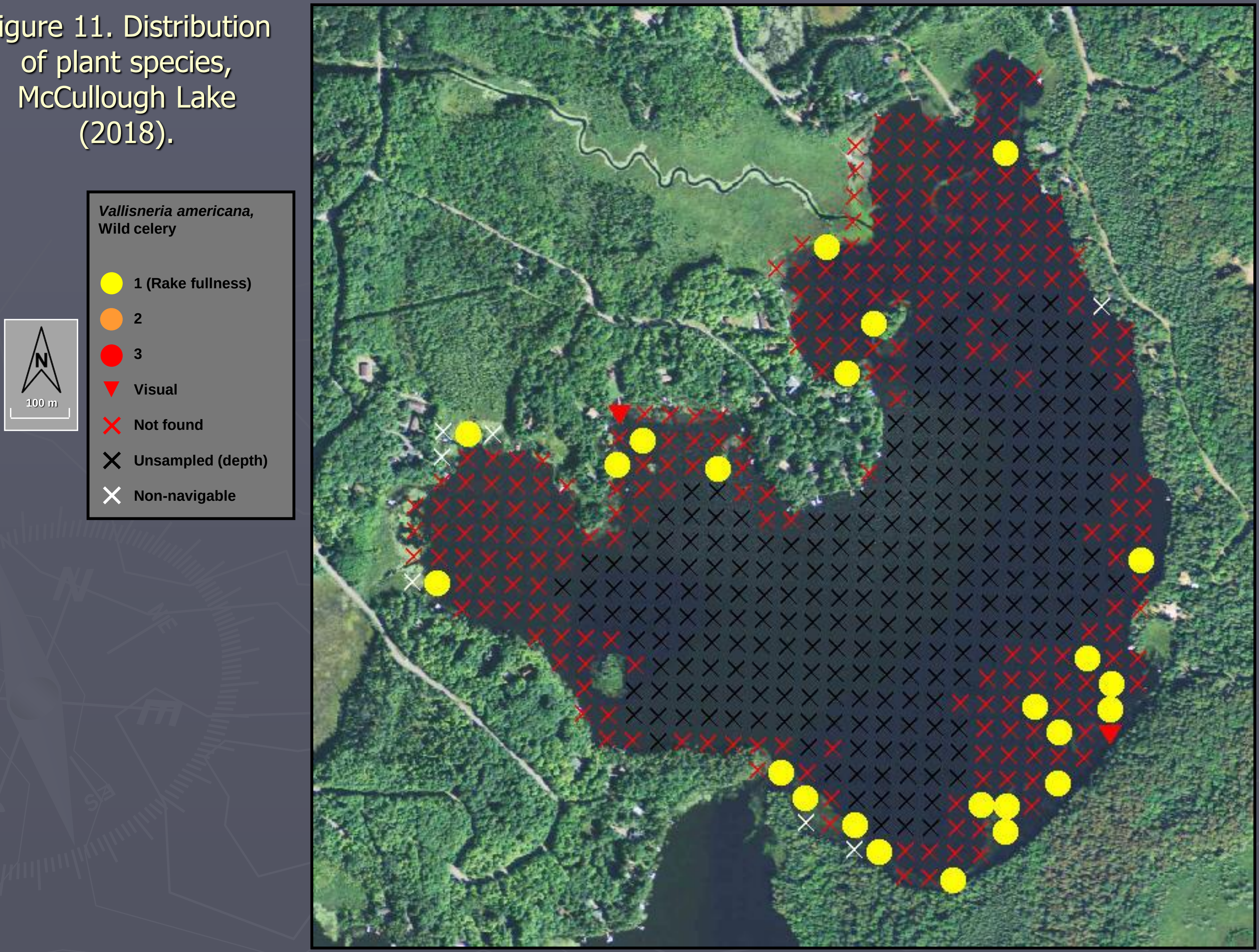


Figure 12. Distribution of plant species, McCullough Lake (2018).

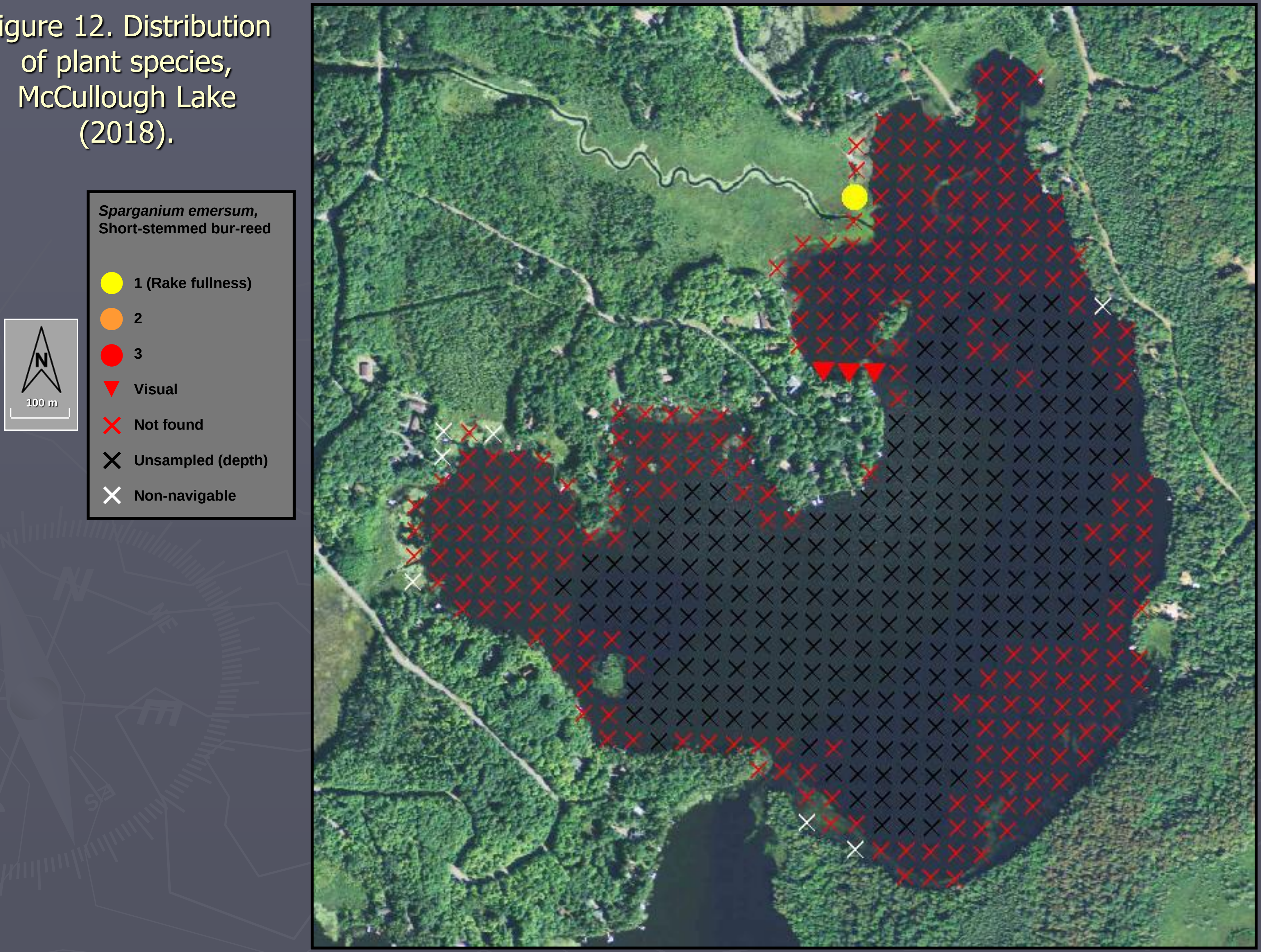


Figure 13. Distribution of plant species, McCullough Lake (2018).

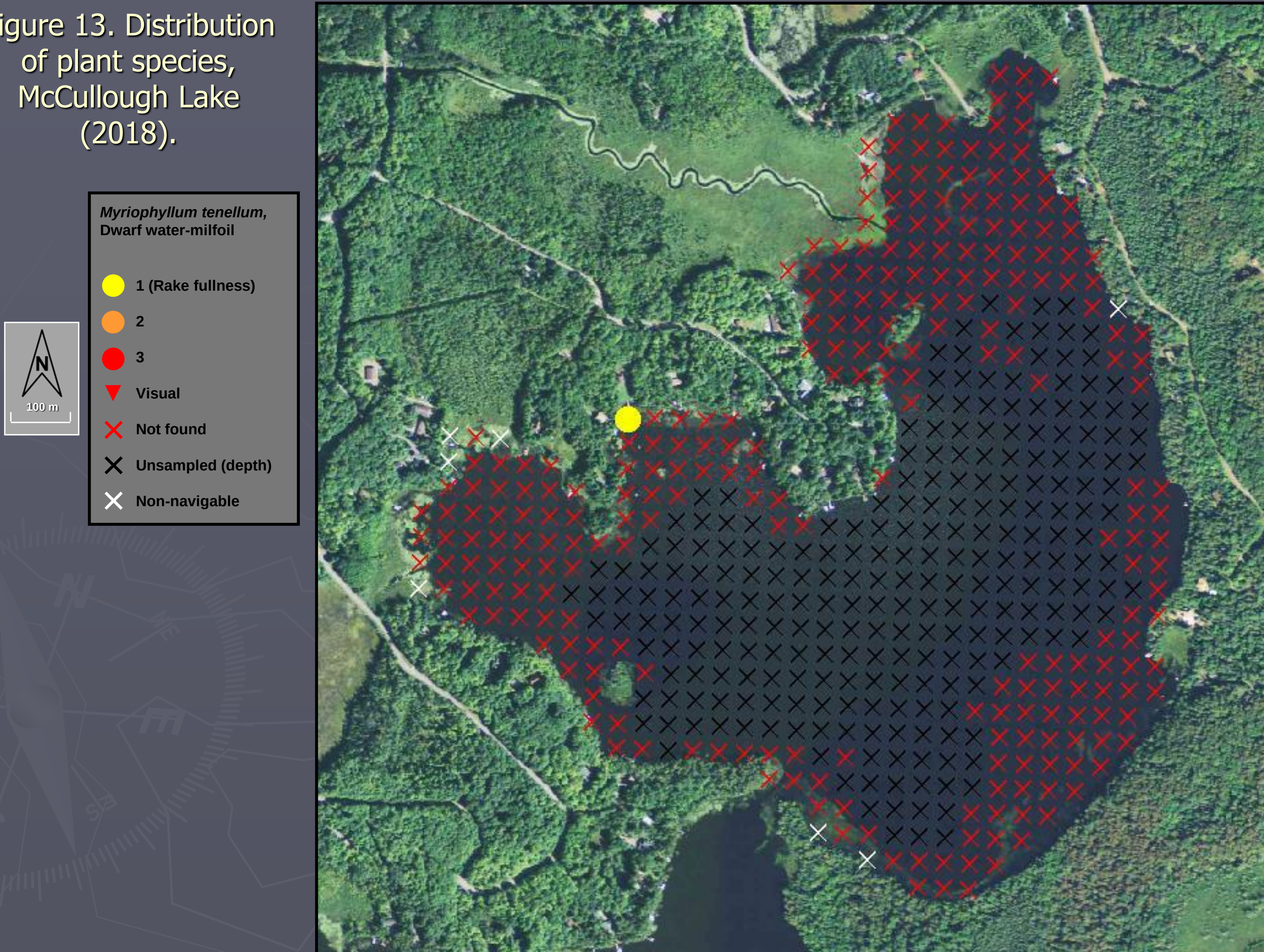
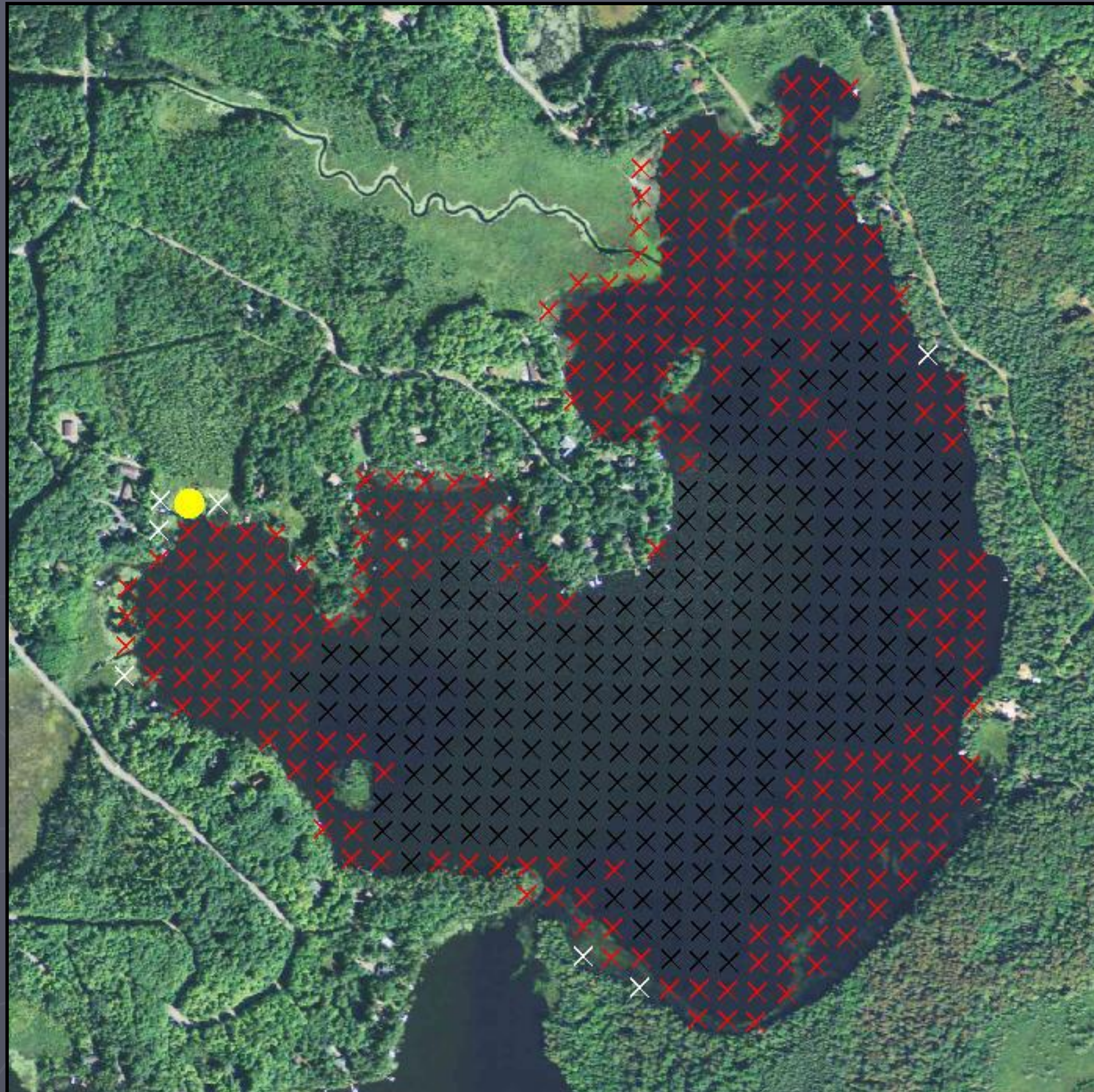


Figure 14. Distribution of plant species, McCullough Lake (2018).

***Utricularia intermedia*, Flat-leaf bladderwort**

- 1 (Rake fullness)
- 2
- 3
- Visual
- Not found
- Unsampled (depth)
- Non-navigable



Appendix C

McCullough Lake Water Quality Report

Appendix C

Review of Lake Water Quality

Table of Contents1

Review of McCullough Lake Water Quality

Prepared by Angie Stine, B.S., White Water Associates, Inc.

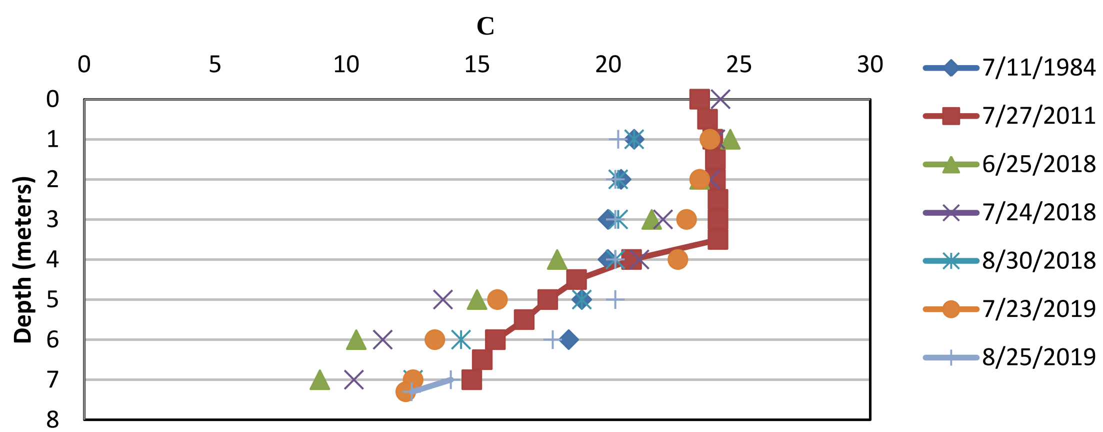
Introduction

McCullough Lake is a 221 acre drainage lake with a maximum depth of 27 feet. The Waterbody Identification Code (WBIC) is 2960400. For the purpose of this review, water quality data was collected in 1960 (Black, 1963); from the WDNR SWIMS database (collected in 1984 by Northern Lakes Monitoring); from the Citizen Lake Monitoring Network (CLMN) volunteers (collected in 1985, 1990, 1991, 1997, and 2001 to present); and 2011 and 2018 (collected by White Water Associates). In late August, 1989, and September 1, 1989, there were reports of a fishkill. It was documented by WDNR, and was said there was no likely source based on the water chemistry and shoreline data. The majority of fish killed were perch, but there were also many minnows, northern pike, walleyes, and crappies that perished.

Temperature

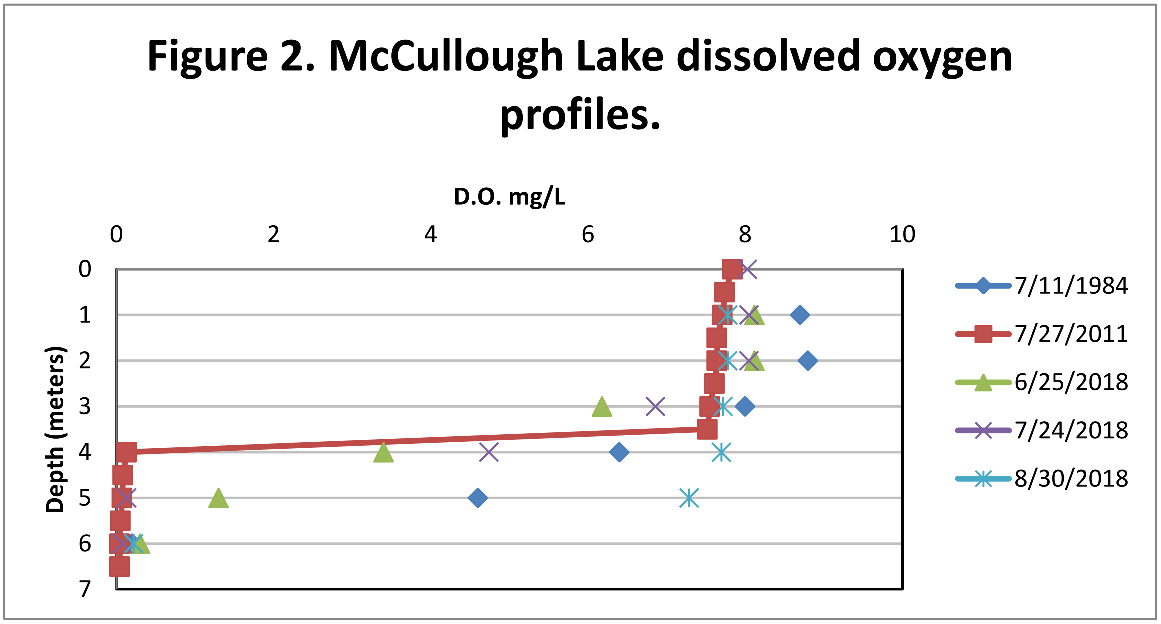
Measuring the temperature of a lake at different depths will determine the influence it has on the physical, biological, and chemical aspects of the lake. Lake water temperature influences the rate of decomposition, nutrient recycling, lake stratification, and dissolved oxygen (D.O.) concentration. Temperature can also affect the distribution of fish species throughout a lake. Figure 1 indicates that the lake stratified between 3 and 4 meters in June and July. Values are typical.

Figure 1. McCullough Lake temperature profiles.



Dissolved Oxygen

The dissolved oxygen content of lake water is vital in determining presence of fish species and other aquatic organisms. Dissolved oxygen also has a strong influence on the chemical and physical conditions of a lake. The amount of dissolved oxygen is dependent on the water temperature, atmospheric pressure, and biological activity. Oxygen levels are increased by aquatic plant photosynthesis, but reduced by respiration of plants, decomposer organisms, fish, and invertebrates. The amount of dissolved oxygen available in a lake, particularly in the deeper parts of a lake, is critical to overall health. In 1984, the D.O. level was near zero at 6.5 meters and in 2011 and June and July 2018, the level was near zero at 4.5 meters (Figure 2). Values are typical.



Water Clarity

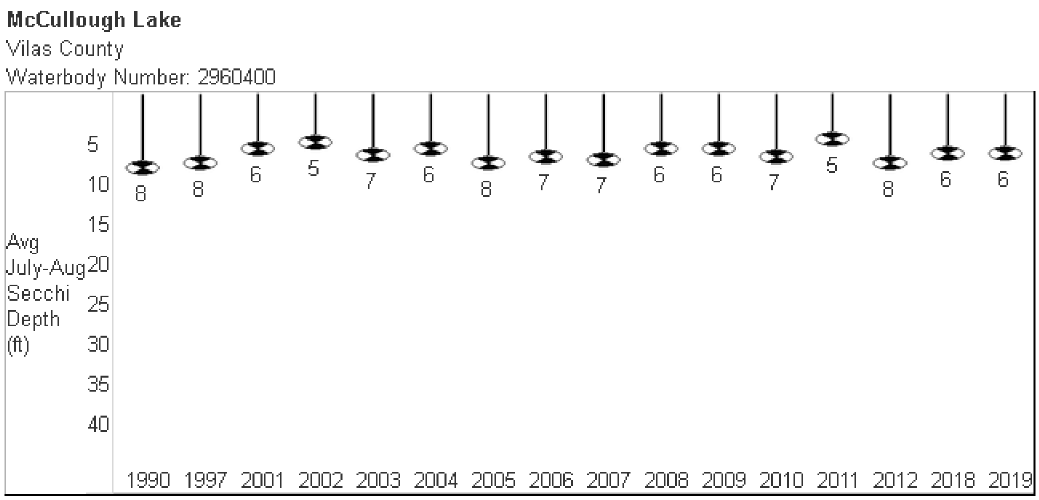
Water clarity has two main components: turbidity (suspended materials such as algae and silt) and true color (materials dissolved in the water) (Shaw et al., 2004). Water clarity gives an indication of the overall water quality in a lake. Water clarity is typically measured using a Secchi disk (black and white disk) that is lowered into the water column on a tether. In simple terms, the depth at which the disk is no longer visible is recorded as the Secchi depth.

Figure 3 represents the July and August Secchi depths over several years, and demonstrates year to year variability. In 2011, the mean Secchi disk of 4.73 feet was the lowest and in 1990 the mean Secchi depth was 8.33 feet. In 2019 the mean Secchi depth was 6.5 feet which indicates that McCullough Lake was "fair" (Table 1) with respect to water clarity.

Table 1. Water clarity index (Shaw et al., 2004).

Water clarity	Secchi depth (ft.)
Very poor	3
Poor	5
Fair	7
Good	10
Very good	20
Excellent	32

Figure 3. Secchi depth averages for McCullough Lake (July and August only).



Past secchi averages in feet (July and August only).

(WDNR, 2019)

Figure 4. McCullough Lake's July and August Secchi Data: Mean, Min, Max, and Secchi Count.

Year	Secchi Mean	Secchi Min	Secchi Max	Secchi Count
1990	8.33	7	10	3
1997	7.75	7.75	7.75	1
2001	5.94	4.9	7	5
2002	5.1	4	6.25	5
2003	6.85	5.75	8	5
2004	5.92	5	6.75	3
2005	7.75	6.75	8.75	5
2006	6.92	6	8.5	3
2007	7.33	6.5	8	3
2008	6.05	4.75	6.75	5
2009	5.94	5	6.75	4
2010	6.92	6	8	3
2011	4.73	4	5	4
2012	7.7	6.5	8.6	3
2018	6.5	6	7	4
2019	6.5	6.5	6.5	2

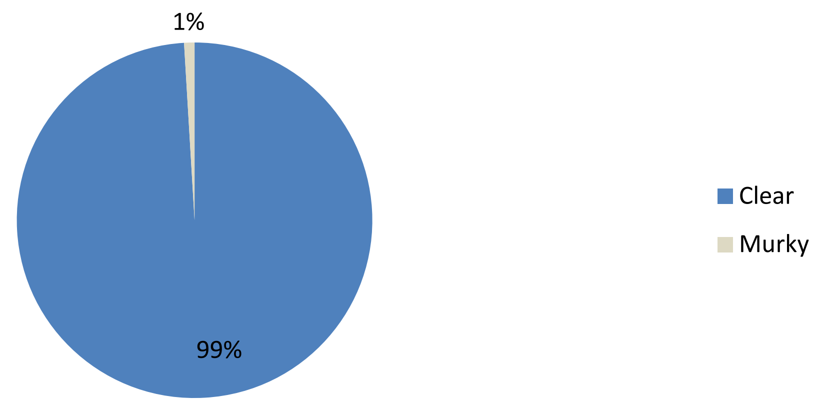
Report Generated: 12/09/2019

(WDNR, 2019)

Turbidity

Turbidity is another measure of water clarity, but is caused by suspended particulate matter rather than dissolved organic compounds (Shaw et al., 2004). Particles suspended in the water dissipate light and reduce the depth at which the light can penetrate. This affects the depth at which plants can grow. Turbidity also affects the aesthetic quality of water. Water that runs off the watershed into a lake can increase turbidity by introducing suspended materials. Turbidity caused by algae is the most common reason for low Secchi readings (Shaw et al., 2004). In terms of biological health of a lake ecosystem, measurements less than 10 Nephelometric Turbidity Units (NTU) represent healthy conditions for fish and other organisms. Turbidity has not been measured on McCullough Lake, but the clarity of the water has been evaluated by the CLMN (Figure 5), and they said that the lake was "clear" in appearance every time they went out (1990, 2001-2011, 2018), except in May, 2006, when it was "murky."

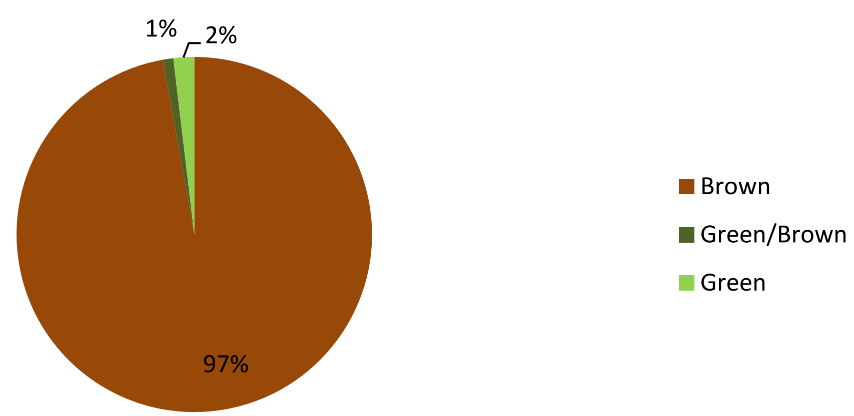
Figure 5. McCullough Lake water color, 1990, 2001-2011, and 2018.



Water Color

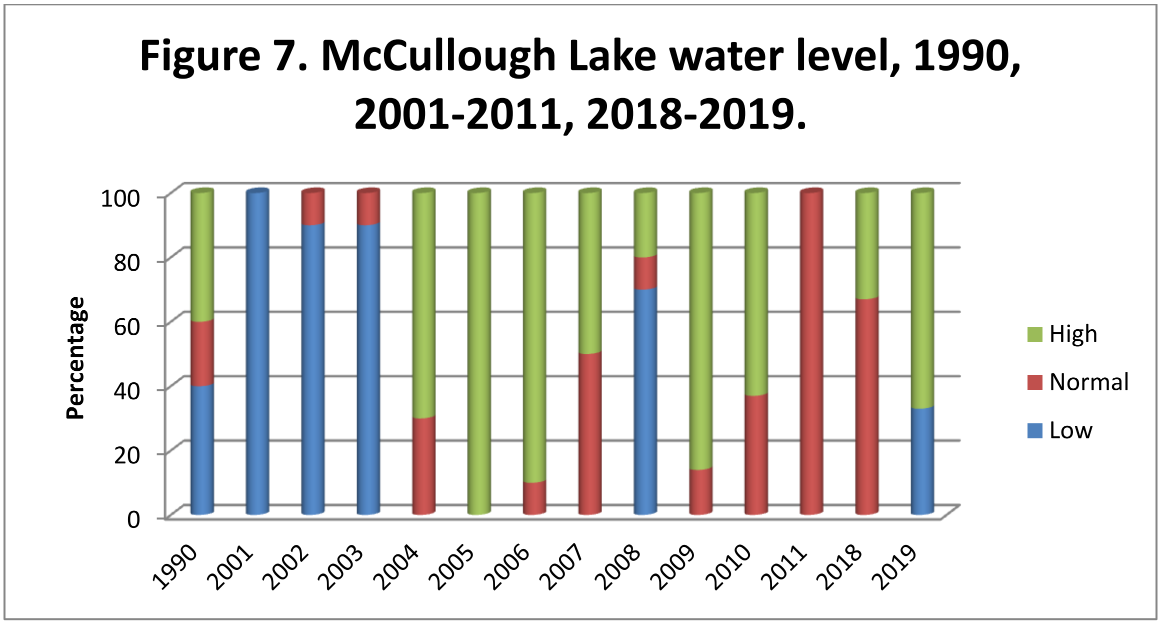
Color of lake water is related to the type and amount of dissolved organic chemicals. Its main significance is aesthetics, although it may also influence light penetration and in turn affect aquatic plant and algal growth. Many lakes have naturally occurring color compounds from decomposition of plant material in the watershed (Shaw et al., 2004). Units of color are determined from the platinum-cobalt scale and are therefore recorded as Pt-Co units. Shaw states that a water color between 0 and 40 Pt-Co units is low. McCullough Lake had a color October 2, 1985 (40 Pt-Co) and July 24, 2018 (50 SU) Figure 6 indicates that the lake is viewed by the majority of volunteers as “brown.”

Figure 6. McCullough Lake visual water color, 1990-91, 2001-2011, 2018-2019.



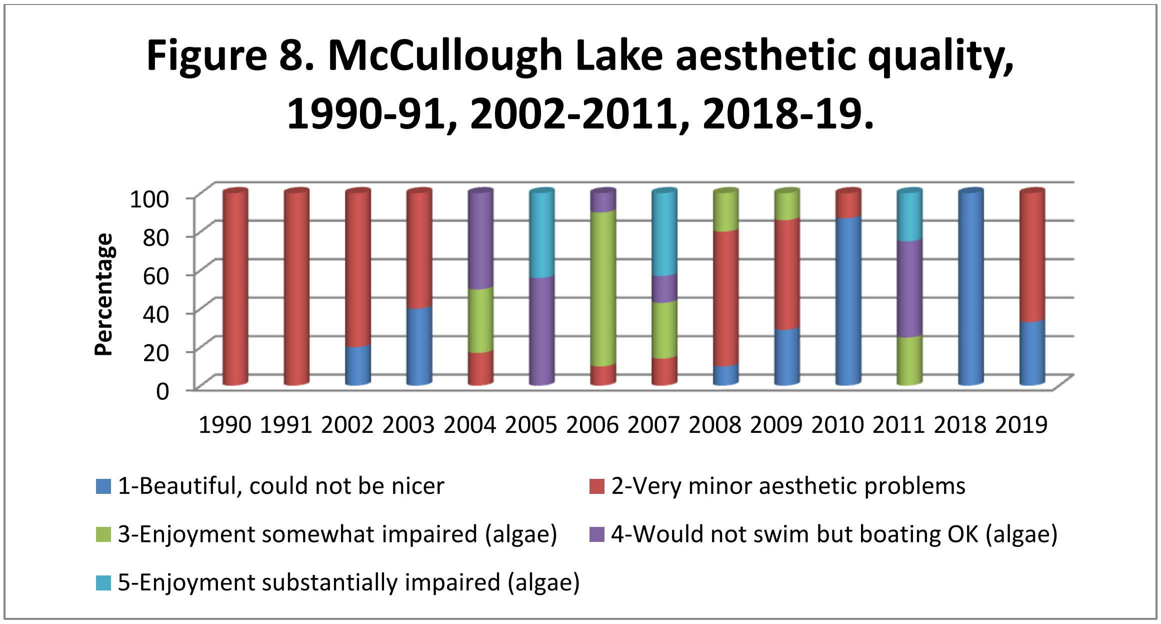
Water Level

McCullough Lake water levels were evaluated by Citizen Lake Monitoring Network volunteers in 1990, and from 2001-2011 and 2018-2019. Lake level was simply rated by the observer as "high," "normal," or "low," several times during the ice-free season. Figure 7 provides a percentage of these observations by year. In 2001, 100% of volunteers viewed the water level as "low," and in 2011, 100% viewed it as "normal."



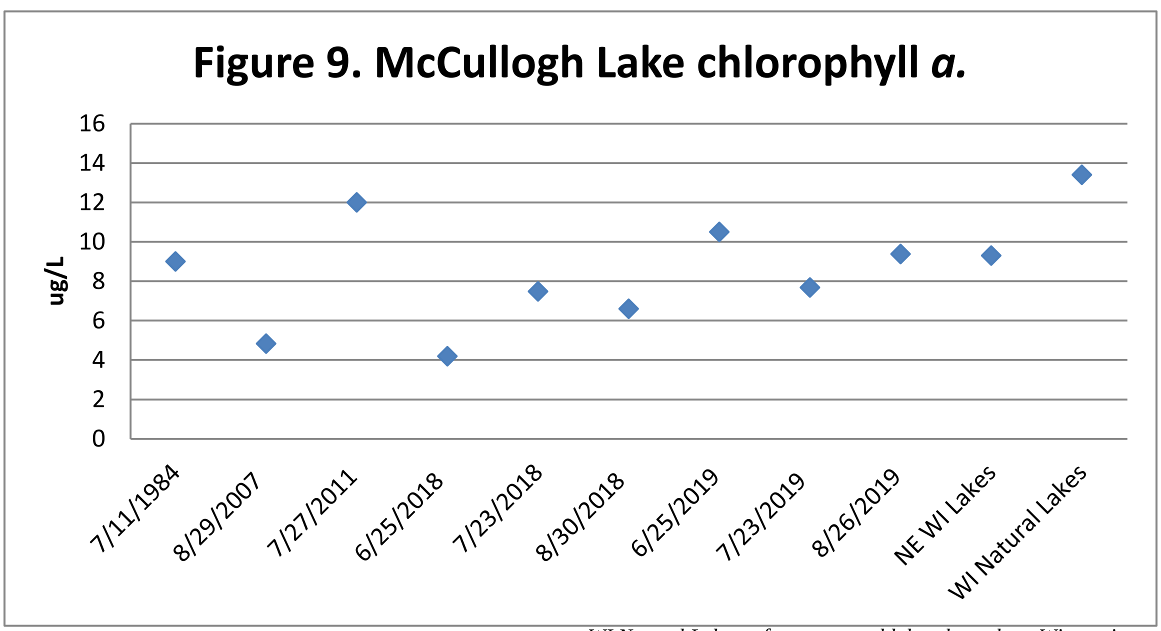
User Perceptions

When Secchi depth readings are collected, the CLMN record their perceptions of the water, based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake user would experience the lake at that time. When interpreting the transparency data, we see that when the Secchi depth decreases, the rating of the lake's physical appearance also decreases. These perceptions of recreational suitability are displayed by year in Figure 8. In 2018, 100% of the volunteers perceived McCullough Lake as "beautiful, could not be better."



Chlorophyll *a*

Chlorophyll *a* is the photosynthetic pigment that makes plants and algae green. Chlorophyll *a* in lake water is therefore an indicator of the amount of algae. Chlorophyll *a* concentrations greater than 10 µg/L are perceived as a mild algae bloom, while concentrations greater than 20 µg/L are perceived as a nuisance. Chlorophyll *a* has been monitored in McCullough Lake 1984, 2007, 2011, 2018 and 2019 (Figure 9). In 2011 and June 2019, chlorophyll *a* values were above 10 µg/L, indicating a possibility of an algae bloom.

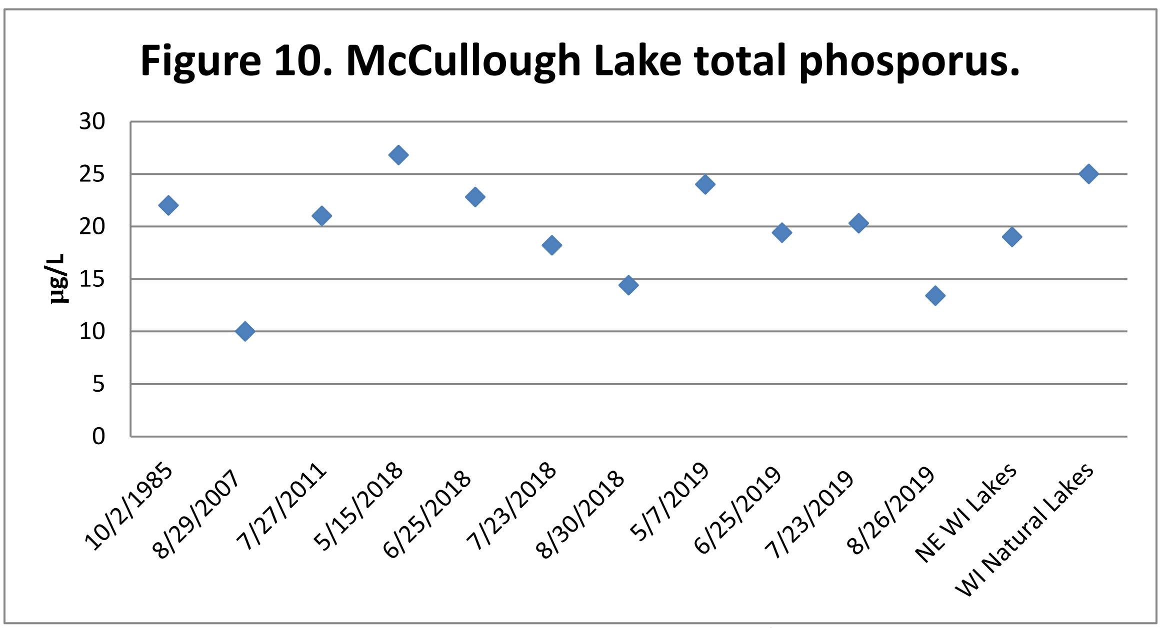


WI Natural Lakes refers to natural lakes throughout Wisconsin.

Phosphorus

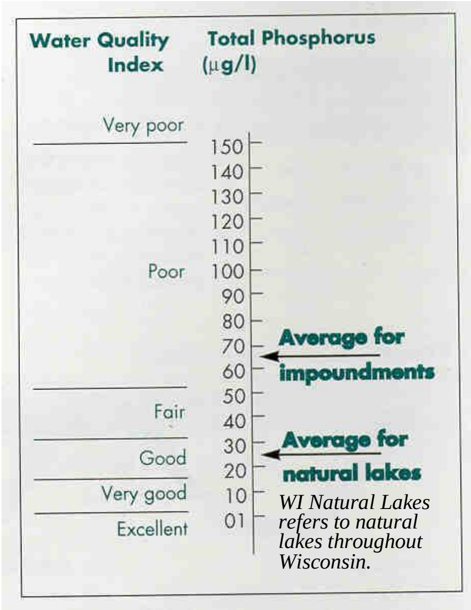
In more than 80% of Wisconsin's lakes, phosphorus is the key nutrient affecting the amount of algae and plant growth. If phosphorus levels are high, excessive aquatic plant growth can occur.

Phosphorus originates from a variety of sources, many of which are related to human activities. Major sources include human and animal wastes, soil erosion, detergents, septic systems and runoff from farmland or lawns (Shaw et al., 2004). Phosphorus provokes complex reactions in lakes. An analysis of phosphorus often includes both soluble reactive phosphorus and total phosphorus. Soluble reactive phosphorus dissolves in the water and directly influences plant growth (Shaw et al., 2004). Its concentration varies in most lakes over short periods of time as plants take it up and release it. Total phosphorus is considered a better indicator of a lake's nutrient status than soluble reactive phosphorus because its levels remain more stable (Shaw et al., 2004). Total phosphorus includes soluble phosphorus and the phosphorus in plant and animal fragments suspended in lake water. Ideally, soluble reactive phosphorus concentrations should be 10 µg/L or less at spring turnover to prevent summer algae blooms (Shaw et al., 2004). A concentration of total phosphorus below 20 µg/L for lakes should be maintained to prevent nuisance algal blooms (Shaw et al., 2004). McCullough Lake has been tested for total phosphorus over the years (Figure 10). In 1985, 2011, May and June 2018, and May 2019 the total phosphorous was slightly higher than 20 µg/L. Figure 11 indicates the water quality index, under a range of phosphorus concentrations, and shows that McCullough Lake, in terms of total phosphorus, ranges from "good," to "very good."



WI Natural Lakes refers to natural lakes throughout Wisconsin.

Figure 11. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments (Shaw et al., 2004).

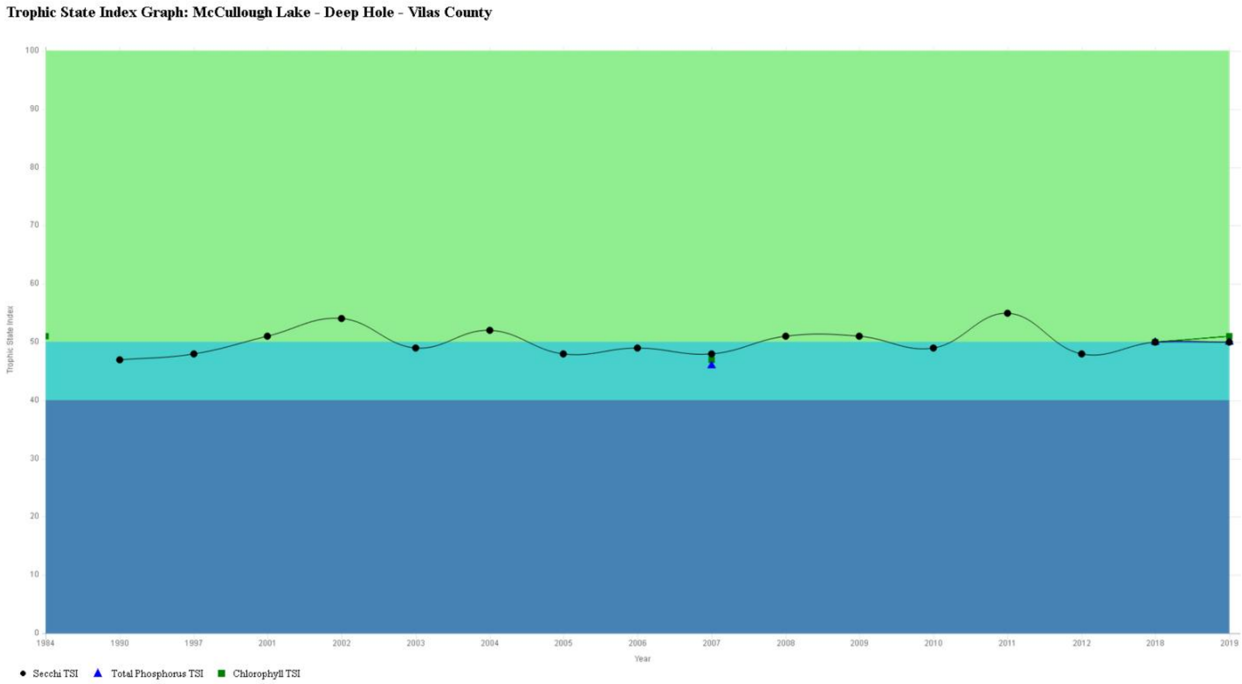


Trophic State

Trophic state is another indicator of water quality (Carlson, 1977). Lakes can be divided into three categories based on trophic state – oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels (Shaw et al., 2004).

Trophic State Index (TSI) was calculated by the WDNR using only Secchi measurements from CLMN (Figure 12). The Trophic State Index was consistent over the years, and shows McCullough Lake to be "mesotrophic" to "mildly eutrophic" (Table 2).

Figure 12. McCullough Lake Trophic State Index (1984, 1990, 1997, 2001-2019).



(WDNR, 2019)

Table 2. Trophic State Index.	
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

(WDNR, 2019)

Researchers use various methods to calculate the trophic state of lakes. Common characteristics used to make the determination are: total phosphorus (important for algae growth), chlorophyll *a* concentration (a measure of the amount of algae present), and Secchi disk readings (an indicator of water clarity) (Shaw et al., 2004) (Table 3).

Table 3. Trophic classification of Wisconsin Lakes based on chlorophyll *a*, water clarity measurements, and total phosphorus values (Shaw et al., 2004).

Trophic class	Total phosphorus µg/L	Chlorophyll *a* µg/L	Secchi Disk (ft.)
Oligotrophic	3	2	12
	10	5	8
Mesotrophic	18	8	6
	27	10	6
Eutrophic	30	11	5
	50	15	4

Nitrogen

Nitrogen is second only to phosphorus as an important nutrient for aquatic plant and algae growth (Shaw et al., 2004). Human activities on the landscape greatly influence the amount of nitrogen in a lake. Nitrogen may come from lawn fertilizer, septic systems near the lake, or from agricultural activities in the watershed. Nitrogen may enter a lake from surface runoff or groundwater sources.

Nitrogen exists in lakes in several forms. McCullough Lake was analyzed for total Kjeldahl nitrogen 10/2/1985 (0.8 mg/L) and 7/24/2018 (0.472 mg/L), nitrate-nitrite 10/2/1985 (0.02 mg/L), 7/27/2011 (no detection) and on 7/24/2018 (0.02 mg/L), and ammonia 10/2/1985 (0.03 mg/L) and on 7/24/2018 (no detection). These values are within the normal range of northern Wisconsin Lakes. Nitrogen is a major component of all organic (plant and animal) matter. Decomposing organic matter releases ammonia, which is converted to nitrate if oxygen if present (Shaw et al., 2004). All inorganic forms of nitrogen can be used by aquatic plants and algae (Shaw et al., 2004). If these inorganic forms of nitrogen exceed 0.3 mg/L (as N) in spring, there is sufficient nitrogen to support summer algae blooms (Shaw et al., 2004). Elevated concentrations of ammonium, nitrate, and nitrite, derived from human activities, can stimulate or enhance the development, maintenance and proliferation of primary producers (phytoplankton, benthic algae, marcrophytes), contributing to the widespread phenomenon of the cultural (human-made) eutrophication of aquatic ecosystems (Camargo et al., 2007). The nutrient enrichment can cause important ecological effects on aquatic communities, since the overproduction of organic matter, and its subsequent decomposition, usually lead to low dissolved oxygen concentrations in bottom waters, and sediments of eutrophic and hypereutrophic aquatic ecosystems with low turnover rates (Camargo et al., 2007).

Chloride

The presence of chloride (Cl^-) where it does not occur naturally indicates possible water pollution (Shaw et al., 2004). Chloride does not affect plant and algae growth and is not toxic to aquatic organisms at most of the levels found in Wisconsin (Shaw et al., 2004). Chloride was tested on October 2, 1985 and there were trace amounts found, with a value of 0.3 mg/L. Chloride was also analyzed on 7/24/2018 with a value of 1.47 mg/L. Chloride concentrations in McCullough Lake were well below the generalized distribution gradient of chloride found in surface waters in natural lakes in Wisconsin (4 mg/L) and in Northeast Wisconsin lakes with a mean value of 2 mg/L.

Sulfate in lake water is primarily related to the types of minerals found in the watershed, and to acid rain (Shaw et al., 2004). Sulfate concentrations are noted to be less than 10 mg/L in Vilas County (Lillie and Mason, 1983). Sulfate was collected on 10/2/1985, with a value of 3 mg/L and on 7/24/2018 with the value was below detection limits (both values are within normal range of northern Wisconsin Lakes).

Conductivity

Conductivity is a measure of the ability of water to conduct an electric current. Conductivity is reported in micromhos per centimeter **(**µmhos/cm) and is directly related to the total dissolved inorganic chemicals in the water. Usually, values are approximately two times the water hardness, unless the water is receiving high concentrations of human-induced contaminants (Shaw et al., 2004). McCullough Lake had a conductivity reading of 65 µmhos/cm on October 2, 1985 and 274 µmhos/cm on 7/24/2018. These values are within the normal range of northern Wisconsin Lakes.

pH

The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid, bog lakes to 8.4 in hard water, marl lakes (Shaw et al., 2004). Rainfall in Wisconsin averages a pH of 5.6. Some minerals become available under low pH (especially aluminum, zinc, and mercury) and can inhibit fish reproduction and/or survival. Mercury and aluminum are not only toxic to many kinds of wildlife, but also to humans (especially those that eat tainted fish). The pH scale is logarithmic, so every 1.0 unit change in pH increases the acidity tenfold. Water with a pH of 6 is 10 times more acidic than water with pH of 7. A lake's pH level is important for the release of potentially harmful substances and affects plant growth, fish reproduction and survival. A lake with neutral or slightly alkaline pH is a good lake for fish and plant survival. McCullough Lake was slightly alkaline, with pH values of 7.2 SU (1960), 7.5 SU (1985), and 8.76 SU (2018).

Alkalinity

Alkalinity levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). Alkalinity is important in a lake to buffer the effects of acidification from the atmosphere. Acid rain has long been a problem with lakes that have low alkalinity levels and high potential sources of acid deposition. Alkalinity in McCullough Lake was 30 mg/L $CaCO_3$ on 9/2/1960 and 128 mg/L on 7/24/2018. Based on this value, McCullough Lake is "not-sensitive" to acid rain, although new samples should be collected (Table 4).

Table 4. Sensitivity of Lakes to Acid Rain (Shaw et al., 2004)

Sensitivity to acid rain	*Alkalinity value (mg/L or ppm $CaCO_3$)*
High	0-2
Moderate	2-10
Low	10-25
Non-sensitive	>25

Hardness

Hardness levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). One method of evaluating hardness is to test for calcium carbonate ($CaCO_3$). Total hardness of McCullough Lake was sampled in 10/2/1985 (34.8 mg/L) and 7/24/2018 (33.4 mg/L). Both values are within the normal range of northern Wisconsin Lakes. The surface water of McCullough Lake can be categorized as "soft water" (Table 5).

Table 5. Categorization of hardness (mg/L of calcium carbonate ($CaCO_3$)) (Shaw et al., 2004).

Soft water	0-60
Moderately hard water	61-120
Hard water	121-180
Very hard water	>180

Calcium and Magnesium Hardness

The carbonate system provides acid buffering through two alkaline compounds: bicarbonate and carbonate. These compounds are usually found with two hardness ions: calcium and magnesium (Shaw et al., 2004). Calcium is the most abundant cation found in Wisconsin lakes. Its abundance is related to the presence of calcium-bearing minerals in the lake watershed (Shaw et al., 2004). Aquatic organisms such as native mussels use calcium in their shells. The aquatic invasive zebra mussel tends to need calcium levels greater than 20 mg/L to maintain shell growth. McCullough Lake has low calcium levels 9 mg/L (1985) and 9.26 mg/L (2018), which are an indication that zebra mussels would not do well (the calcium level is considered "borderline suitable"). Magnesium was 3 mg/L (1985) and 2.5 mg/L (2018). Calcium mean levels in Wisconsin natural lakes was 10 mg/L and in Northeast Wisconsin lakes was 10 mg/L. Magnesium mean levels in Wisconsin natural lakes was 7 mg/L and in Northeast Wisconsin lakes was 5 mg/L.

Sodium and Potassium

Sodium and potassium are possible indicators of human pollution in a lake, since naturally occurring levels of these ions in soils and water are very low. Sodium is often associated with chloride and gets into lakes from road salting, fertilizations, and human and animal waste (Shaw et al., 2004). Potassium is the key component of commonly-used potash fertilizer, and is abundant in animal waste. Both of these elements are held by soils to a greater extent than is chloride or nitrate; therefore, they are not as useful as indicators of pollution impacts (Shaw et al., 2004). Although not normally toxic themselves, they provide a strong indication of possible contamination by more damaging compounds (Shaw et al., 2004). Sodium values were 1 mg/L (1985) and 1.02 mg/L (2018) and potassium values were 1 mg/L (1985) and 1.02 mg/L (2018). These values are within the normal range of northern Wisconsin Lakes.

Dissolved Organic Carbon

Dissolved Organic Carbon (DOC) is a food supplement, supporting growth of microorganisms, and plays an important role in global carbon cycle through the microbial loop (Kirchman et al., 1991). In general, organic carbon compounds are a result of decomposition processes from dead organic matter such as plants. When water contacts highly organic soils, these components can drain into rivers and lakes as DOC. DOC is also extremely important in the transport of metals in aquatic systems. Metals form extremely strong complexes with DOC, enhancing metal solubility while also reducing metal bioavailability. Baseflow concentrations of DOC in undisturbed watersheds generally range from 1 to 20 mg/L carbon. Because DOC has not been sampled in McCullough Lake.

Silica

The earth's crust is abundant with silicates or other compounds of silicon. The water in lakes dissolves the silica and pH can be a key factor in regulating the amount of silica that is dissolved. Silica concentrations are usually within the range of 5 to 25 mg/L. Generally lakes that are fed by groundwater have higher levels of silica. Silica has not been sampled in McCullough Lake.

Aluminum

Aluminum occurs naturally in soils and sediments. In low pH (acidic) environments aluminum solubility increases greatly. With a low pH and increased aluminum values, fish health can become impaired. This can have impacts on the entire food web. Aluminum also plays an important role in phosphorus cycling in lakes. When aluminum precipitates with phosphorus in lake sediments, the phosphorus will not dissolve back into the water column as readily. Aluminum has not been sampled in McCullough Lake.

Iron

Iron also forms sediment particles that bind with and store phosphorus when dissolved oxygen is present. When oxygen concentration gets low (for example, in winter or in the deep water near sediments) the iron and phosphorus dissolve in water. This phosphorus is available for algal blooms. Iron levels have not been measured for McCullough Lake.

Manganese

Manganese is a mineral that occurs naturally in rocks and soil. In lakes, manganese is usually in particulate form. When the dissolved oxygen levels decrease, manganese can convert from an insoluble form to soluble ions. A manganese concentration of 0.05 mg/L can cause color and staining problems. Manganese levels are not known for McCullough Lake.

Sediment

Lake bottom sediments are sometimes analyzed for chemical constituents that they contain. This is especially true for potentially toxic metals such as mercury, chromium, selenium, and others. Lake sediments also tend to record past events as particulates settle down and become part of the sediment.

Biological clues for the historic conditions in the lake can be gleaned from sediment samples. Examples include analysis of pollen or diatoms that might help understand past climate or trophic states in the lake. Sediment data was not collected for McCullough Lake.

Total Suspended Solids

Total suspended solids are all particles suspended in lake water. Silt, plankton, and wastes are examples of these solids and can come from runoff of agricultural land, erosion, and can be produced by bottom-feeding fish. As the suspended solid levels increase, they absorb heat from sunlight which can increase the water temperature. They can also block the sunlight that plants need for photosynthesis. These events can in turn affect the amount of dissolved oxygen in the lake. Lakes with total suspended solids levels less than 20 mg/L are considered "clear," while levels between 40 and 80 mg/L are "cloudy." Total suspended solids have not been tested in McCullough Lake.

Aquatic Invasive Species

On July 14, 2003, the rusty crayfish was found in McCullough Lake, and was confirmed by the WDNR The 2018 AIS survey did not document this species, nor does there seem to be vegetative damage caused by rusty crayfish in McCullough Lake.

The University of Wisconsin-Madison's Aquatic Invasive Species Smart Prevention program classifies McCullough Lake as "borderline suitable" for zebra mussels, based on calcium and conductivity levels found in the lake (UW-Madison). On 8/2/2018, White Water Associates, Inc. biologist surveyed McCullough Lake for aquatic invasive species and no new AIS were found. A more detailed report can be found in Appendix E.

Clean boats, clean waters were conducted on McCullough Lake in 2019. There were 13 boats inspected and 30 people contacted in 16 hours. Only 31 out of 100 people were contacted before about AIS and 100 percent of people contacted were willing to discuss AIS.

Resources

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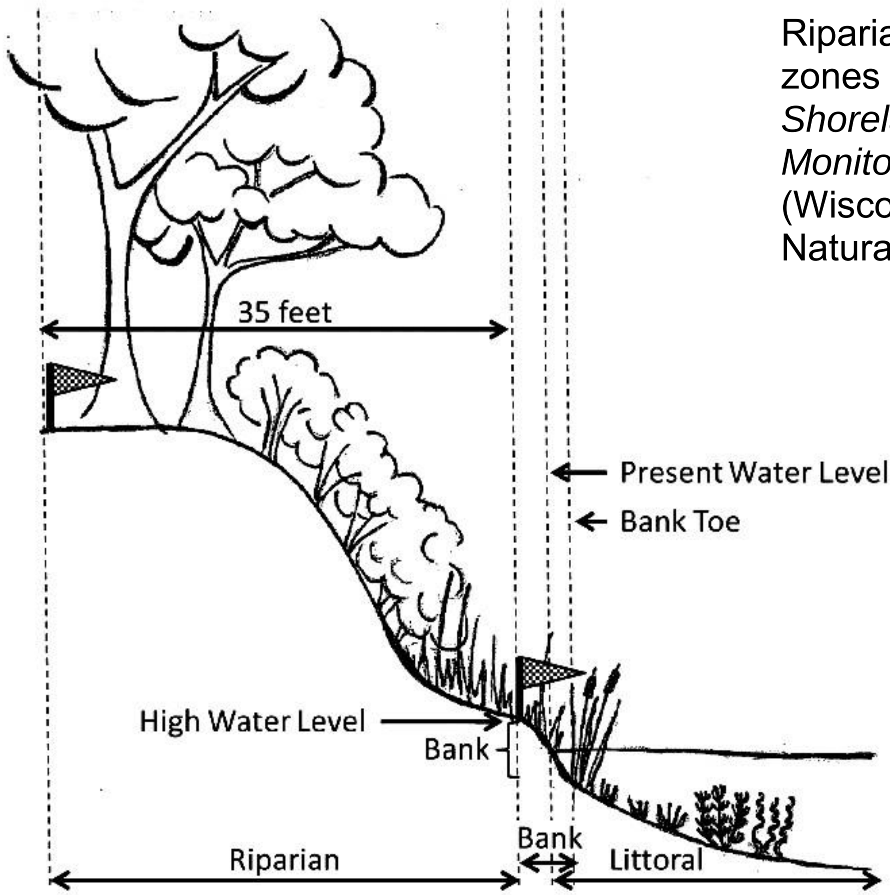
Appendix D

McCullough Lake Shoreland and Shallows

Habitat Monitoring Report

McCullough Lake (Vilas County, Wisconsin)

Shoreland and Shallows Habitat Monitoring Report



Riparian, bank, and littoral zones covered by the *Shoreland & Shallows Habitat Monitoring Field Protocol* (Wisconsin Department of Natural Resources 2016)

WHITE WATER ASSOCIATES, INC.

Date: March 2019

INTRODUCTION

White Water Associates, Inc. is retained by the Presque Isle Town Lakes Committee (PITLC) as a consultant for the *Presque Isle Wilderness Waters Program.* A recent Wisconsin Department of Natural Resources (WDNR) lake planning grant to the PITLC included an assessment of the shoreland area and shallows habitat for McCullough Lake (Vilas County, Wisconsin). The assessment was conducted using the *Lake Shoreland and Shallows Habitat Monitoring Field Protocol* (WDNR 2016)[1]. This protocol provides a standard methodology for surveying, assessing, and mapping habitat in lakeshore areas, including the riparian buffer, bank, and littoral zone (WDNR 2016). This information will be useful to local and regional resource managers, community stakeholders, and others interested in protecting and enhancing Wisconsin's lakes and rivers (WDNR 2016).

METHODS

There are three principal components to the shoreland and shallows habitat monitoring: (1) obtain georeferenced photos of the entire lake shoreline area, (2) assess the riparian, bank, and littoral habitat by ownership parcel, and (3) count and map all pieces of large woody material in water less than 2 feet deep. In this section, we describe each of these components.

The photographic component of the monitoring documented shoreland habitat conditions around the lake at the time of the survey. Results may be referred to in future years (WDNR 2016). Digital photos were taken with the intent to slightly overlap, thus capturing the entire shoreline. The survey crew used the boat to circumnavigate the lake at a distance of approximately 50 feet perpendicular from shore where conditions permitted. This standardized relative position on the lake allowed the photos to include the water's edge and understory vegetation 35 feet inland. A digital camera with an internal GPS was used to capture the photos. Exhibit 1 provides an example photograph. In the laboratory, photos were processed, georeferenced, and provided as part of the data package to the WDNR.

---

[1] Wisconsin Department of Natural Resources. May 27, 2016. *Draft Lake Shoreland & Shallows Habitat Monitoring Field Protocol.* WDNR 2016.

Exhibit 1. Photo of the water's edge and understory vegetation on McCullough Lake (White Water Associates, Inc., 2018)

The shoreline habitat assessment was conducted for every ownership parcel on the lake. To facilitate this effort, parcel data was obtained March 2017 via the Wisconsin Statewide Parcel Map, which can be found at https://maps.sco.wisc.edu/Parcels/. Parcel IDs and shoreline lengths were derived from these spatial data files. Parcel IDs and parcel lines, together with a "riparian buffer" line at 35 feet from the shoreline, were layered onto aerial photography maps saved as a georeferenced image file viewed on the Avenza Maps application on an Apple® iPad Pro 9.7 equipped with GPS for offline navigation. The GPS function of the iPad allowed the survey crew to know their position relative to the shoreline and specific parcels. Data sheets were prepared that included parcel ID numbers and frontage feet of each parcel (an example data sheet is shown in Exhibit 2). Exhibit 2 also shows the categories that were documented for each parcel. Back in the laboratory, data recorded on field data sheets were input to a Microsoft Office Excel spreadsheet and later conveyed to the WDNR as part of the data package to be included in a publicly available database.

The woody habitat component of the assessment was conducted on a separate circumnavigation of the lake. Before starting, a Secchi depth was measured. The protocol specifies that if the Secchi depth is less than two feet, no woody habitat survey will be conducted due to poor visibility (WDNR 2016). In addition to the Secchi depth, lake water level was documented relative to the lake's *high water level* (HWL). As the lake was circumnavigated, large wood was enumerated. The protocol defines "large wood" as wood greater than 4 inches in diameter somewhere along its length and at least 5 feet long. Eligible large wood was that which was located between the high water level and the 2 foot depth contour and the large wood section must be in the water or below the high water level. Tree "branchiness" ranking was recorded as "0" (no branches), "1" (few branches), or "2" (tree trunk with full crown). Additional details on eligible large wood are provided in the protocol document (WDNR 2016). A GPS was used to document each eligible piece of large wood. A datasheet entry corresponded to each large wood piece. An example datasheet is provided as Exhibit 3.

FINDINGS

The data and photos for the assessment of shoreland area and shallows habitat for McCullough Lake have been delivered to the WDNR. Any user can view the results in the Wisconsin Department of Natural Resources Lakes and AIS Mapping Tool found at: https://dnr.wi.gov/lakes/viewer/. In this section we summarize a few of the data and provide some example maps that illustrate the findings from the assessment.

The assessment was conducted on May 31, 2018. At the time of the survey there were 65 ownership parcels on McCullough Lake. The shoreline perimeter of McCullough Lake is 3.82 miles. Exhibit 4 summarizes some of the McCullough Lake data. Exhibits 5 through 13 provide maps of findings on McCullough Lake. Any interested party can access the data in the database and create maps of this type or maps specific to detailed areas of shoreland and shallow water habitat.

In general, the assessment shows the shoreland and shallow water habitat of McCullough Lake to be of high quality. There is excellent tree canopy coverage as well as shrub and herbaceous coverage. That being said, there is evidence of human influence in the riparian buffer zone and bank zone. The number of large wood pieces per mile of shoreline is somewhat low.

LAKE STRATEGY

McCullough Lake is a high quality lake with good shallow water habitat and intact riparian area. Lake stewardship could primarily be directed toward protection of the current conditions and monitoring to detect changes over time. Although McCullough Lake is in a mostly natural state, there are a few parcels that could undertake some restoration to ameliorate possible runoff and erosion issues. These areas can be identified by investigating the 2018 monitoring data in maps and tables in this report as well as in the WDNR database (link given previously). The Healthy Lakes program in Wisconsin provides simple, practical, and inexpensive best practices that improve habitat and water quality on lakeshore property (see https://healthylakeswi.com/ for additional information and guidance on funding projects).

Habitat Assessment Data Sheet (one per parcel)

Date _____________ Lake name __________________________ WBIC__________

Parcel ID_________________ Observers____

RIPARIAN BUFFER ZONE		
Percent Cover	Percent	
Canopy		(0-100)
Shrub ☐ Herbaceous ☐		
Shrub/Herbaceous		sum=100
Impervious surface		
Manicured lawn		
Agriculture		
Other (e.g. duff, soil, mulch)		
description:________________________		

Human Structures	Number
Buildings	
Boats on shore	
Fire pits	
Other	
description:________________________	

Runoff Concerns in Riparian or Entire Parcel	Present in Riparian	Present out of Riparian
Point source	☐	☐
Channelized water flow/gully	☐	☐
Stair/trail/road to lake	☐	☐
Lawn/soil sloping to lake	☐	☐
Bare soil	☐	☐
Sand/silt deposits	☐	☐
Other	☐	☐
description:________________________		

Notes:

BANK ZONE	Length (ft)
Vertical sea wall	
Rip rap	
Other erosion control structures	
Artificial beach	
Bank erosion > 1 ft face	
Bank erosion < 1 ft face	

LITTORAL ZONE	
Human Structures	Number
Piers	
Boat lifts	
Swim rafts/water trampolines	
Boathouses (over water)	
Marinas	
Other	
description:____________________	

Aquatic Plants	Present
Emergents	☐
Floating	☐
Plant Removal	☐

If Applicable (low water level):	
EXPOSED LAKE BED ZONE	
Plants	Present
Canopy	☐
Shrubs	☐
Herbaceous	☐
Disturbed	
Plants (mowed or removed)	☐
Sediment (tilled or dug)	☐

Exhibit 2. Example habitat assessment data sheet.

Exhibit 3. Coarse woody habitat inventory data sheet.

Date ______________ Lake name __________________________ WBIC___________

Observers____

Present water level is ☐ Below ☐ At ☐ Above the High Water Level Secchi depth ______ ft

ID	Branch	Touch Shore	In Water	ID	Branch	Touch Shore	In Water	ID	Branch	Touch Shore	In Water	ID	Branch	Touch Shore	In Water
1				26				51				76			
2				27				52				77			
3				28				53				78			
4				29				54				79			
5				30				55				80			
6				31				56				81			
7				32				57				82			
8				33				58				83			
9				34				59				84			
10				35				60				85			
11				36				61				86			
12				37				62				87			
13				38				63				88			
14				39				64				89			
15				40				65				90			
16				41				66				91			
17				42				67				92			
18				43				68				93			
19				44				69				94			
20				45				70				95			
21				46				71				96			
22				47				72				97			
23				48				73				98			
24				49				74				99			
25				50				75				100			

Branch: 0 = no branches, 1 = a few branches, 2 = full tree crown

Touch Shore: 0 = entirely below High Water Level (HWL), 1 = crosses HWL

In Water: 0 = less than 5 ft of log is currently underwater, 1 = at least 5 ft of log is currently underwater

Exhibit 4. Summary of shoreland and shallow water habitat for McCullough Lake.		
Date of Survey: May 31, 2018	Miles of shoreline: 3.82	
Number of ownership parcels: 65	Mean parcel frontage feet: 310	
Riparian Buffer Zone	# of parcels	% of parcels
Impervious surfaces	37	57%
Manicured lawn	14	22%
Agriculture	0	0%
Other (duff, soil, mulch)	49	75%
Human structures (buildings, boats on shore, fire pit, other)	43	66%
Broad runoff concerns (incl. point source; channelized water flow; strait stair, trail, or road to lake; lawn or soil sloping; bare soil; sand/silt deposits; other erosion). Note: Exhibit 10 is less inclusive.	45	69%
Bank Zone	# of parcels	% of parcels
Concerns in the bank zone (e.g., vertical sea wall, rip rap, other erosion control structures, artificial beach, active erosion)	18	28%
Littoral Zone	# of parcels	% of parcels
Human structures in littoral zone (e.g., piers, boat lifts, swim rafts, water trampolines, boat houses over water, marinas, other)	49	75%
Emergent and/or floating aquatic plants	59	91%
Evidence of aquatic plant removal	0	0%
Large Wood Habitat		
Total Number of large wood pieces	209	
Number of large wood pieces per mile of shoreline	54.7	

Exhibit 5. McCullough Lake Riparian Coverage - % Canopy - 2018

Notes

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Exhibit 6. McCullough Lake Riparian Coverage - % Shrub Herbaceous - 2018

Legend

Percent Shrub Herbaceous
- 0 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Shoreland Parcels
County Boundary
Municipality
State Boundaries
County Boundaries

Major Roads
- Interstate Highway
- State Highway
- US Highway

County and Local Roads
- County HWY
- Local Road

Railroads
Tribal Lands
Rivers and Streams
Intermittent Streams
Open Water
Great Lakes

Notes

0.3 | 0 | 0.13 | 0.3 Miles

NAD_1983_HARN_Wisconsin_TM

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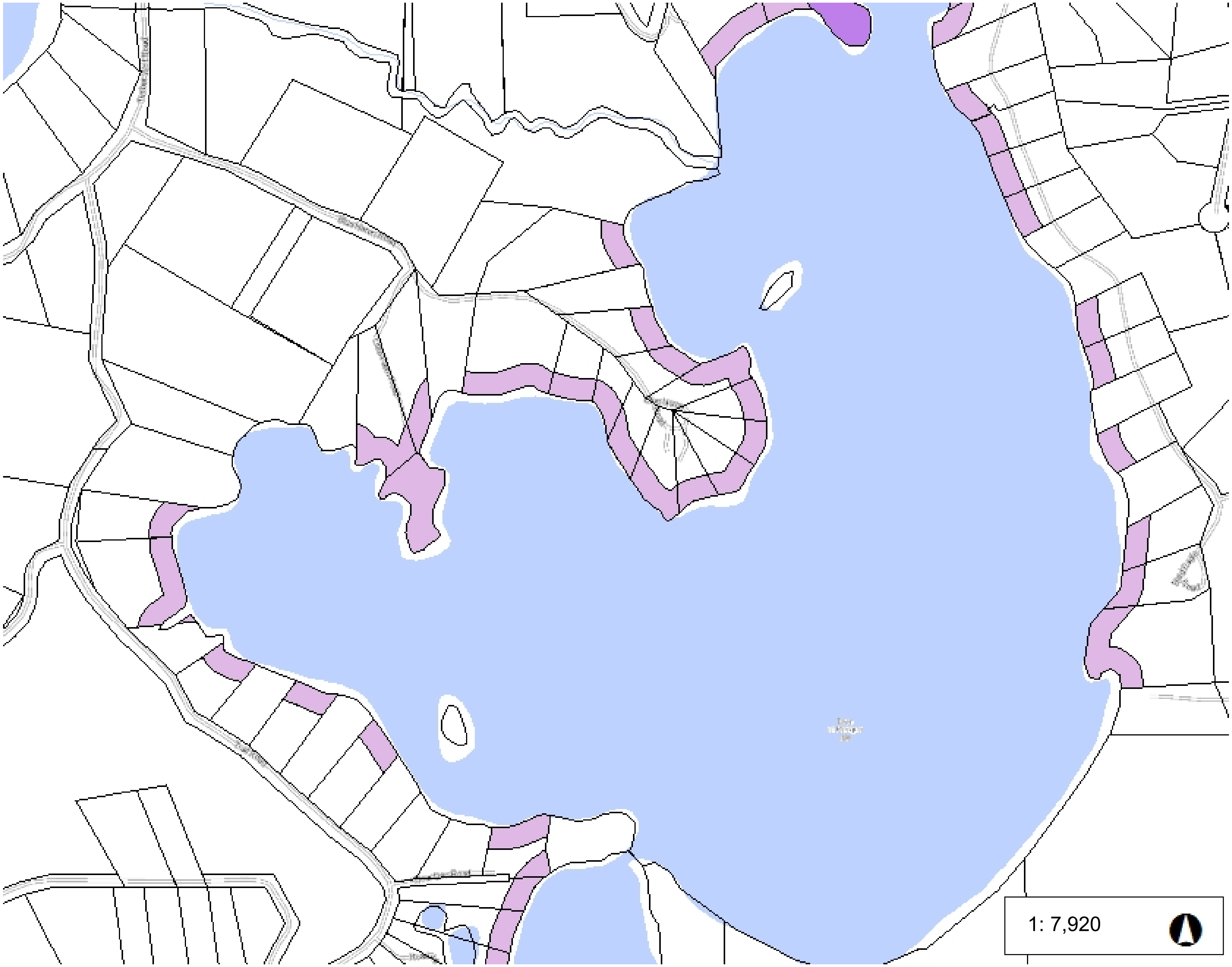
Exhibit 7. McCullough Lake Riparian Coverage - % Impervious - 2018



Legend

Percent Impervious

- 1 - 5
- 6 - 15
- 16 - 35
- 36 - 100

Shoreland Parcels

County Boundary

Municipality

State Boundaries

County Boundaries

Major Roads

- Interstate Highway
- State Highway
- US Highway

County and Local Roads

- County HWY
- Local Road

Railroads

Tribal Lands

Rivers and Streams

Intermittent Streams

Open Water

Great Lakes

1: 7,920

Notes

0.3 | 0 | 0.13 | 0.3 Miles

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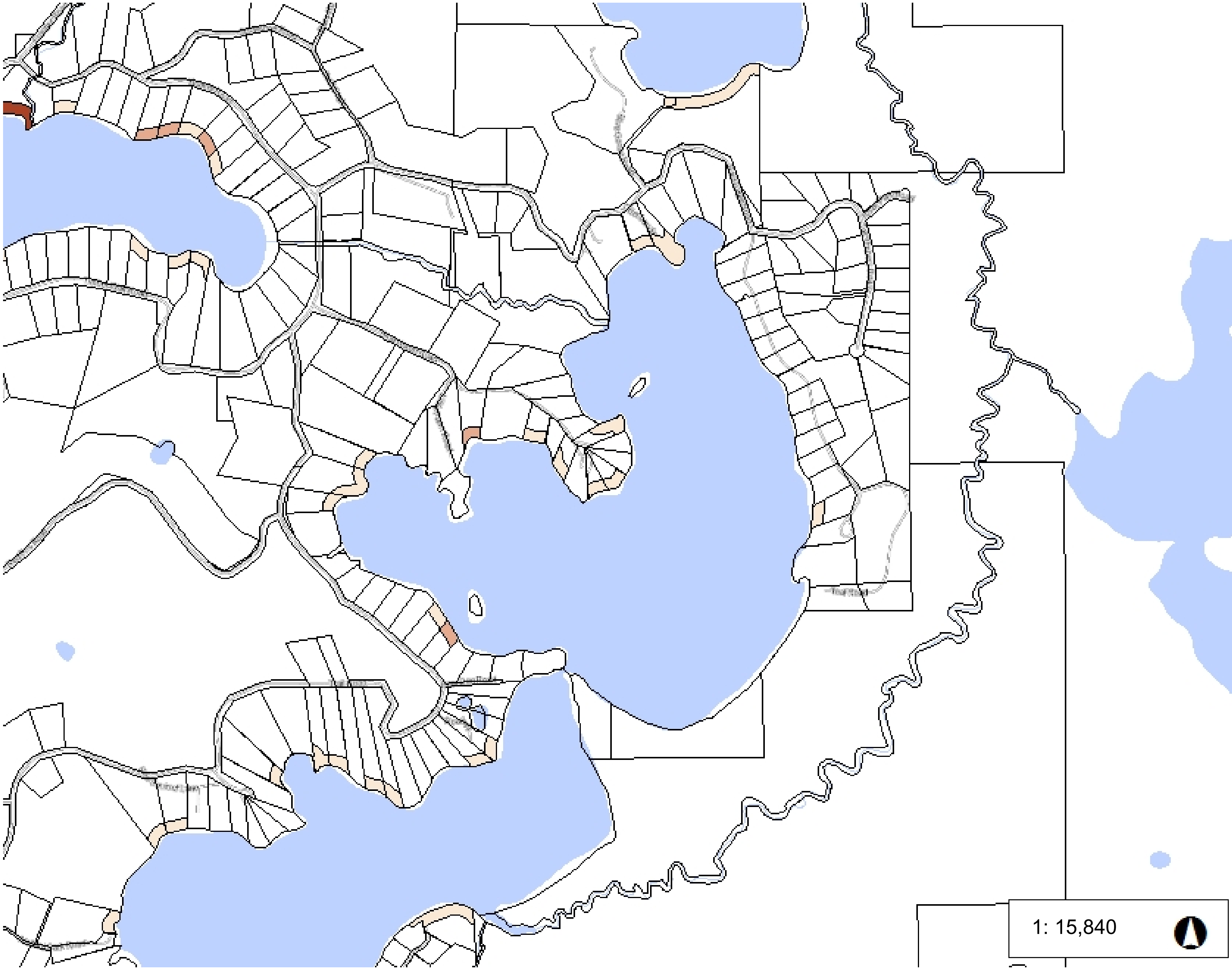
Exhibit 8. Riparian Coverage- % Manicured Lawn- 2018



Legend

Percent Manicured Lawn
- 1 - 25
- 26 - 50
- 51 - 75
- 76 - 100

Shoreland Parcels

Municipality

State Boundaries

County Boundaries

Major Roads
- Interstate Highway
- State Highway
- US Highway

County and Local Roads
- County HWY
- Local Road

Railroads

Tribal Lands

Rivers and Streams

Intermittent Streams

Open Water

Great Lakes

1: 15,840

Notes

0.5 0 0.25 0.5 Miles

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Exhibit 9. McCullough Lake Bank Erosion and Modifications - 2018

Legend

- Bank Erosion >1ft
- Bank Erosion <1ft

Vertical Sea Wall
- 1 - 50 ft
- 51 - 100 ft
- 101 - 200 ft
- 200 + ft

Rip Rap
- 1 - 50 ft
- 51 - 100 ft
- 101 - 200 ft
- 200+ ft

Other Bank Modifications
- 10 - 50 ft
- 51 - 100 ft
- 101 - 200 ft
- 200+ ft

Artificial Beach
- 0 - 50 ft
- 51 - 100 ft
- 101 - 200 ft
- 200+ ft

Shoreland Parcels

County Boundary

Municipality

State Boundaries

1: 7,920

Notes

0.3 0 0.13 0.3 Miles

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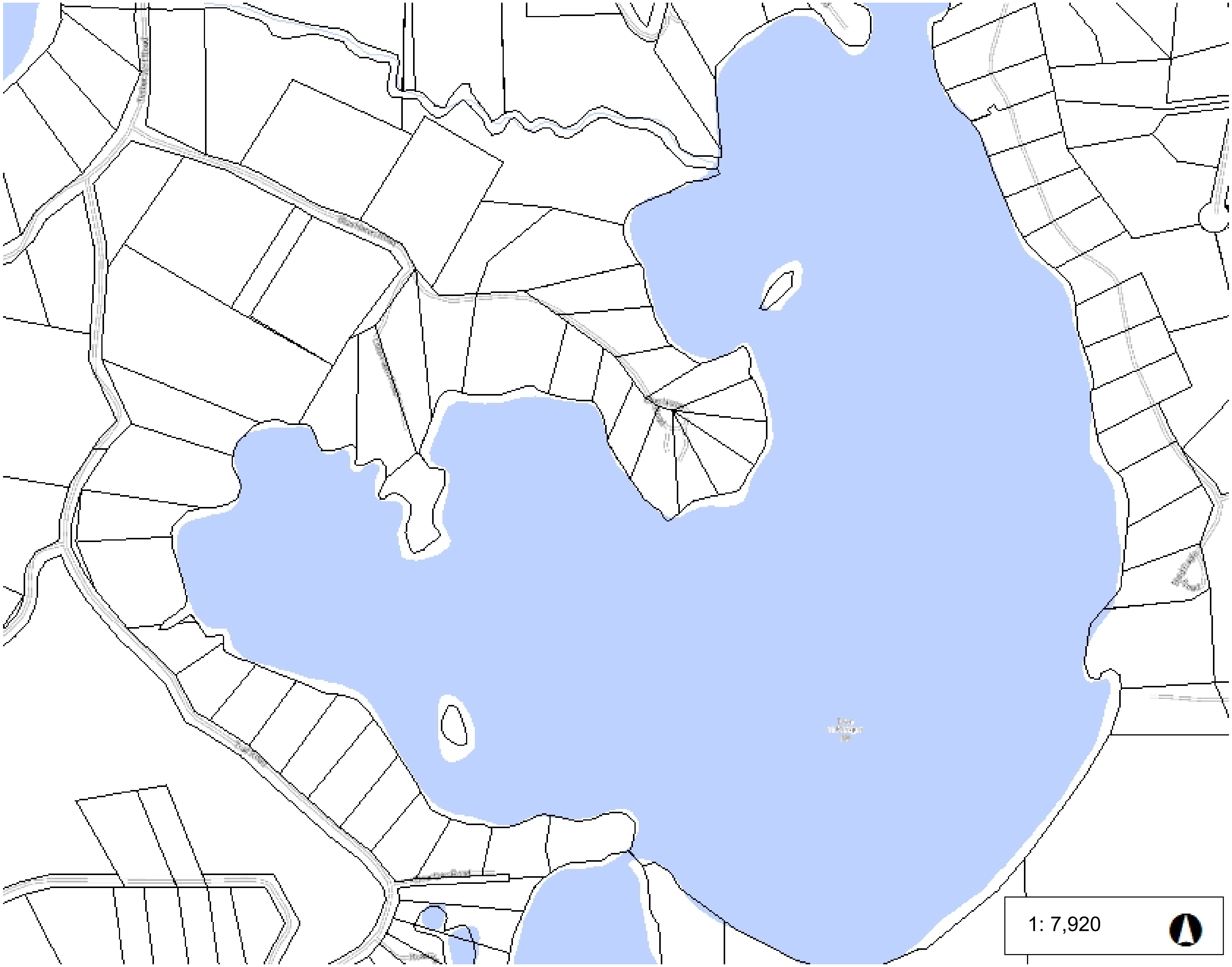
Exhibit 10. McCullough Lake Runoff Concerns - 2018



Legend

- Channelized Flow
- Point Source
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local Road
- Railroads
- Tribal Lands
- Rivers and Streams
- Intermittent Streams
- Open Water
- Great Lakes

1: 7,920

0.3 0 0.13 0.3 Miles

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Notes

Exhibit 11. McCullough Lake Littoral Zone - Aquatic Plants - 2018

Legend

- Aquatic Plant Removal
- Floating & Emergent Plants
- Emergent Plants
- Floating Plants
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local Road
- Railroads
- Tribal Lands
- Rivers and Streams
- Intermittent Streams
- Open Water
- Great Lakes

1: 7,920

Notes

0.3 0 0.13 0.3 Miles

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Exhibit 12. McCullough Lake Littoral Zone - Human Structures - 2018

Legend

Swim Rafts
- 1
- 2
- 3 - 5
- 6+

Boat Lifts
- 1
- 2
- 3 - 5
- 6+

Piers
- 1
- 2
- 3 - 5
- 6+

Boat Houses
- 1
- 2
- 3 - 5
- 6+

Marinas
- 1
- 2
- 3 - 5
- 6+

Shoreland Parcels

Notes

0.3 0 0.13 0.3 Miles

NAD_1983_HARN_Wisconsin_TM

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Exhibit 13. McCullough Lake Woody Habitat - 2018

Legend

WH Branchiness
- No branches
- Few branches
- Full tree crown

- WH Touching Shore
- WH In Water
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries
- County Boundaries

Major Roads
- Interstate Highway
- State Highway
- US Highway

County and Local Roads
- County HWY
- Local Road

- Railroads
- Tribal Lands
- Rivers and Streams
- Intermittent Streams
- Open Water
- Great Lakes

1: 7,920

Notes

0.3 0 0.13 0.3 Miles

NAD_1983_HARN_Wisconsin_TM

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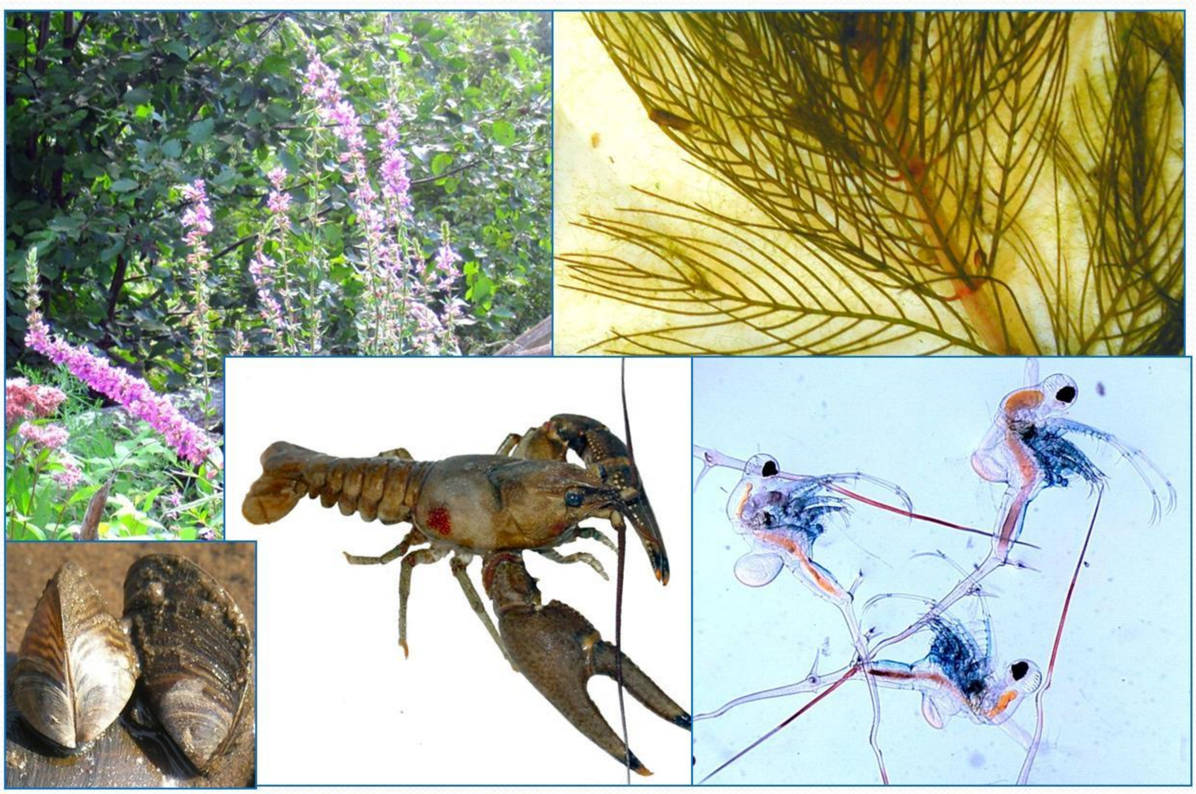
Appendix E

McCullough Lake Aquatic Invasive Species Report

McCullough Lake (Vilas County, Wisconsin)

Aquatic Invasive Species Report



WHITE WATER ASSOCIATES, INC.

2019

INTRODUCTION

White Water Associates, Inc. has been retained by the Presque Isle Town Lakes Committee through a Wisconsin Department of Natural Resources (WDNR) Education, Prevention, and Planning Grant for lake consulting services on McCullough Lake (Vilas County, Wisconsin). Some tasks for this grant focused on aquatic invasive species (AIS). Efforts are intended to increase the understanding of AIS as well as native species in McCullough Lake. This work prepares the McCullough Lake stakeholders to conduct actions that serve lake health. As part of this effort White Water staff monitored McCullough Lake for AIS using WDNR protocol. This approach assesses the lake as to its vulnerability to AIS and documents aquatic invasive plant species as detected. Findings from the survey were entered into the SWIMS database. A *floating workshop* on lake health, riparian ecology, and AIS was conducted for interested McCullough Lake stewards.

AQUATIC INVASIVE SPECIES EARLY DETECTION MONITORING

In order to determine if other aquatic invasive species (AIS) were present in study areas, biologists followed the *Aquatic Invasive Species Early Detection Monitoring Standard Operating Procedure* (WDNR, 2014). This procedure outlines several types of monitoring techniques, including: boat landing searches, sample site searches, targeted searches, waterflea tows and/or a Ponar dredge, and a meander search. The McCullough Lake survey took place August 2, 2018.

Five sites around the lake shoreline were thoroughly searched and a meander search was conducted while traveling from one site to another. The public boat landing was surveyed for 30 minutes by checking the dock and walking 200 feet of shoreline. The other four shoreline sites were randomly selected and are identified in Exhibit 1 and 2. Snorkeling was not used to search for AIS due to unsuitable weather at the time of the survey. A long rake was used to collect any suspicious aquatic plants for closer inspection and identification. A D-net was used to collect invertebrate animals to look for AIS. Any invasive species observed were recorded. In the event of a new AIS record, specimens are collected for verification.

Spiny water fleas are an aquatic invasive zooplankton that is found in a few lakes in Wisconsin. They can be monitored by way of plankton tow nets or by an examination of sediment for dead waterflea exoskeleton fragments. In McCullough Lake, a Ponar dredge was used to collect a sediment sample in the middle of the lake (Exhibit 1 and 3). The sample was brought back to the lab and filtered to look for spiny water flea spines under magnification. None were found.

The rusty crayfish is the only reported AIS in McCullough Lake prior to this survey. Despite this, no rusty crayfish were observed. No new AIS were documented in 2018.

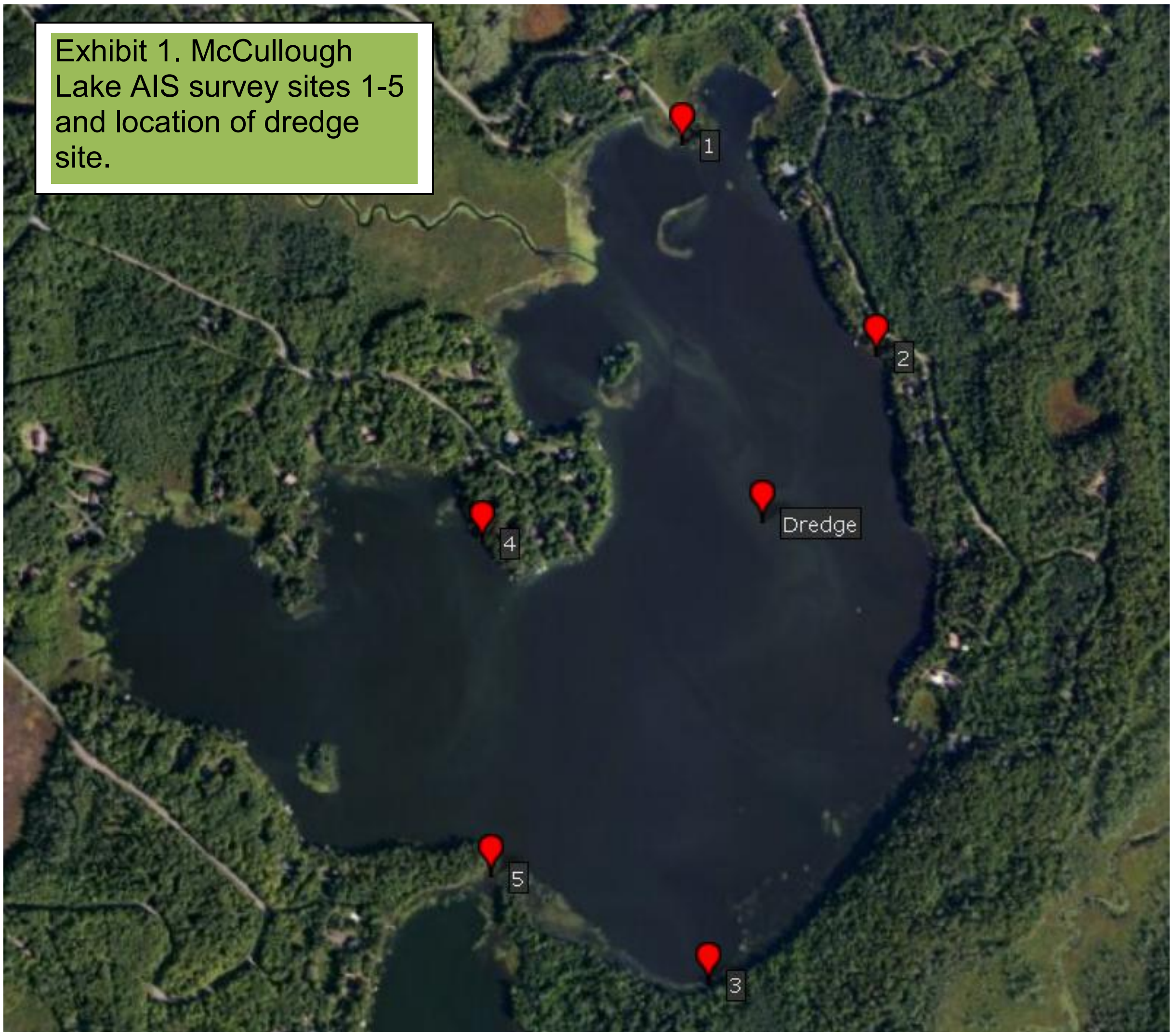


Exhibit 1. McCullough Lake AIS survey sites 1-5 and location of dredge site.

Exhibit 2. AIS Survey on McCullough Lake 8/2/2018. **Density (1-5), and live (L) or dead (D).**			
Site	**Latitude**	**Longitude**	**Species found**
1	46.20439	-89.56875	None
2	46.20153	-89.56491	None
3	46.19299	-89.56822	None
4	46.19900	-89.57265	None
5	46.19444	-89.57247	None

Exhibit 3. Spiny Water Flea Sediment Sample from McCullough Lake			
Date: 8/2/2018	**GPS Coordinates**		**Depth of sample (feet)**
Dredge Site	46.19927	-89.56717	22

Rusty crayfish are native to parts of Ohio, Tennessee, Kentucky and Indiana, and were likely introduced to Wisconsin waters by fishermen using the crayfish as bait (Gunderson, 2014). Rusty crayfish negatively affect other native crayfish species, cause destruction to aquatic plant beds, reduce fish populations by eating eggs, and cause shoreland owners recreational problems (Gunderson, 2014). It is illegal to possess both live crayfish and angling equipment simultaneously on any inland Wisconsin water (except Mississippi River) (WDNR, 2018). It is also illegal to release crayfish into a water body without a permit (WDNR, 2018).

McCullough Lake stakeholders are the first line of defense when it comes to protecting the lake from introduction and establishment of AIS. Early detection and action is critical. The Wisconsin DNR has a very informative website on aquatic invasive species: https://dnr.wi.gov/topic/Invasives/.

FLOATING WORKSHOP

A floating workshop for McCullough Lake stewards was conducted by Dean Premo (White Water Associates). This field trip discussed lake and riparian ecology including ways AIS might impact these important ecosystems. The workshop took place on July 15, 2019. Participants were in watercraft and learned about the point-intercept plant survey and shoreland survey conducted on McCullough Lake and how the information gathered from these surveys could influence lake stewardship. The McCullough Lake aquatic plant community was discussed at length. Other aspects of the McCullough Lake Stewardship Program were also discussed (wildlife observations, water quality, and more).

Literature Cited

Wisconsin Department of Natural Resources. 2014. *Aquatic Invasive Species Early Detection Monitoring Standard Operating Procedure*. Retrieved 2017. <http://dnr.wi.gov/water/wsSWIMSDocument.ashx?documentSeqNo=99459630>

Wisconsin Department of Natural Resources. 2018. *Rusty Crayfish*. Retrieved 2019. <http://dnr.wi.gov/lakes/invasives/AISDetail.aspx?roiseq=22588740>