Presque Isle Wilderness Waters Program

Aquatic Plant Management Plan – Crab Lake

Prepared for:

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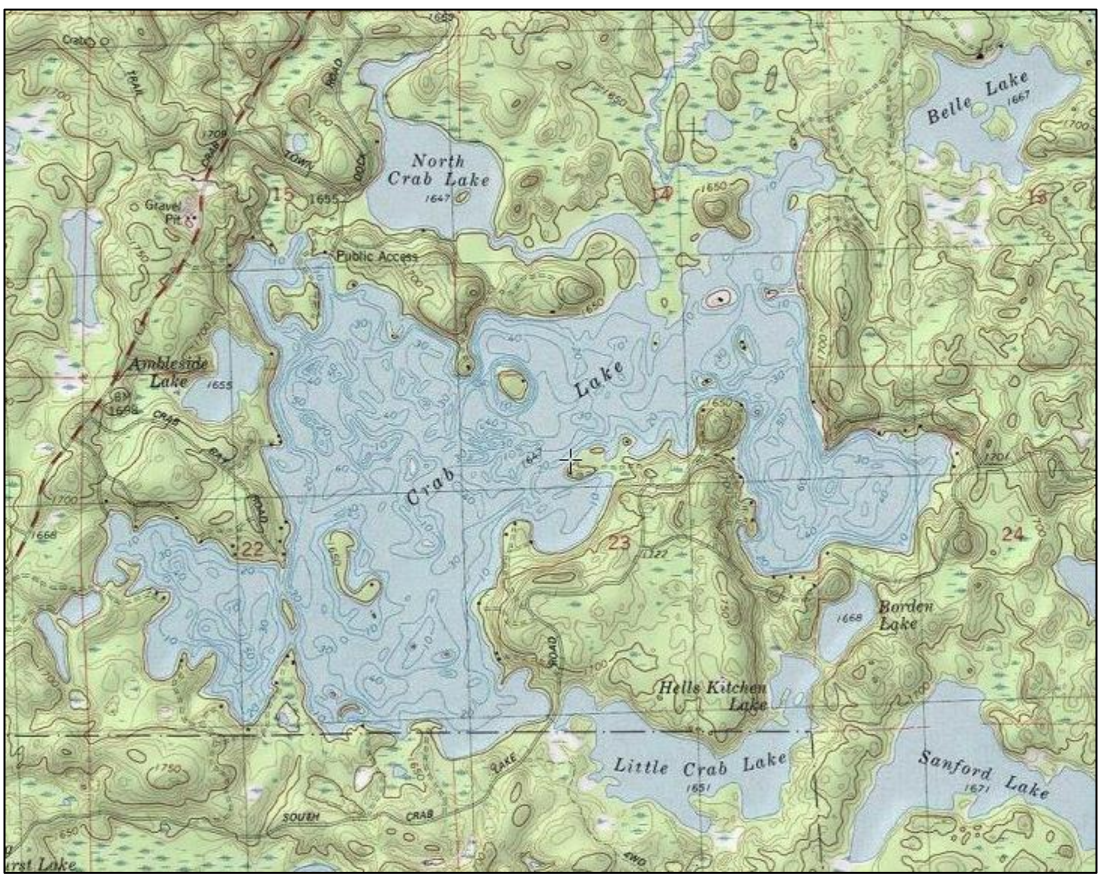

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This plan is a product of a WDNR Lake Planning Grant awarded to:

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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 addresses Crab Lake. 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., 2022) provides additional overarching waterscape level examination that allows greater opportunity and efficiency in water resource management and education.

A 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 come to dominate a water body to the exclusion of a healthy diversity of native species. Eurasian water-milfoil (*Myriophyllum spicatum*) is one of the better known examples of these so-called aquatic invasive plant species. 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.

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. 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]

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 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;

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

- ***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 first five steps in 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.

Besides this introductory chapter, this plan is organized in six Chapters. The study area is described in Chapter 2. Chapter 3 states the purpose and goals for the plan. Chapter 4 presents an inventory and analysis of information that pertain to the plan including the results of the aquatic 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. Appendix A contains literature cited, Appendix B contains tables and figures for the aquatic plant survey, Appendix C contains a *Review of Crab Lake Water Quality*, Appendix D contains the *Lake Shoreland and Shallows Habitat Monitoring Report*, and Appendix E contains the *Aquatic Invasive Species Report*.

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 (Crab 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 Crab Lake.

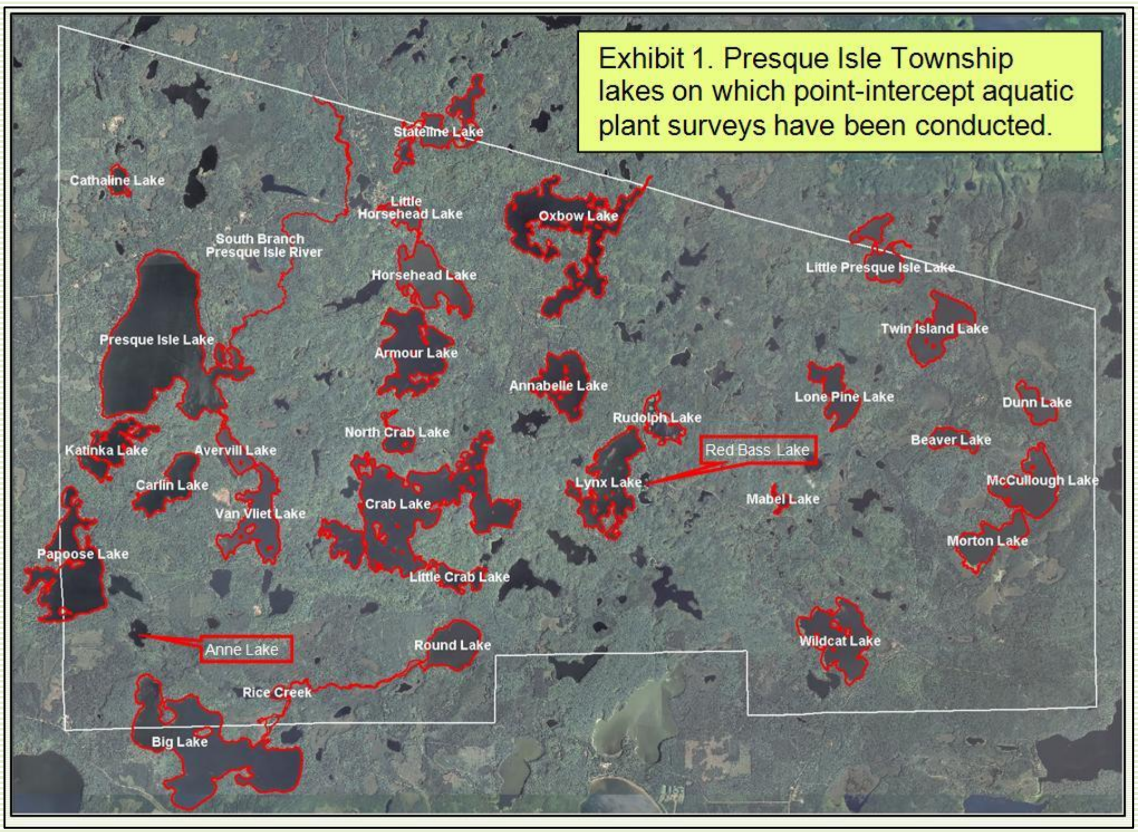


Exhibit 1. Presque Isle Township lakes on which point-intercept aquatic plant surveys have been conducted.

“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 recreationists 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 Crab Lake.

Descriptive parameters for Crab Lake are in Exhibit 3. It is a drainage lake of about 909 acres and maximum depth of 60 feet. The shoreline development index values for thirteen lakes of the Wilderness Waters Program lakes surveyed in 2019/2020 ranged from 1.3 to 3.7 (average = 2.1). Crab Lake's SDI value is above this average (3.7 SDI). The shoreline development index is a quantitative expression derived from the shape of the lake. It is 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 would have an index of 1. Increasing irregularity of shoreline development in the form of bays and projections of the shore is shown by numbers greater than 1. For example, fjord lakes with extremely irregularly shaped 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	Crab
County	Vilas
Township/Range/Section	T43N-R06E-S13,14,15,21,22,23,24
Water Body Identification Code	2953500
Lake Type	Drainage
Surface Area (acres)	909
Maximum Depth (feet)	60
Maximum Length (miles)	1.2
Maximum Width (miles)	1.5
Shoreline Length (miles)	15.8
Shoreline Development Index	3.7
Total Number of Piers (2020 Shoreland)	122
Number of Piers / Mile of Shoreline	7.72
Total Number of Homes (2022 aerial)	76
Number of Homes / Mile of Shoreline	4.81

Crab Lake has one public access site. We observe a total of 122 piers on the shoreline of Crab Lake from the 2020 shoreland survey or about 7.72 piers per mile of shoreline. The riparian area consists of both upland and wetland areas (Exhibit 4). Crab Lake is considered an Outstanding Resource Water (ORW) (WI Admin. Code, 2010). An ORW is a body of water that provides outstanding recreational opportunities, supports valuable fisheries and wildlife habitat, has good water quality, and is not significantly impacted by human activities. It does not typically have any point sources discharging pollutants directly into the water, though it may receive runoff from nonpoint sources. Also, new discharges may be permitted only if their effluent quality is equal to or better than the background water quality of that waterway at all times—no increases of pollutant levels are allowed (WDNR, 2013).

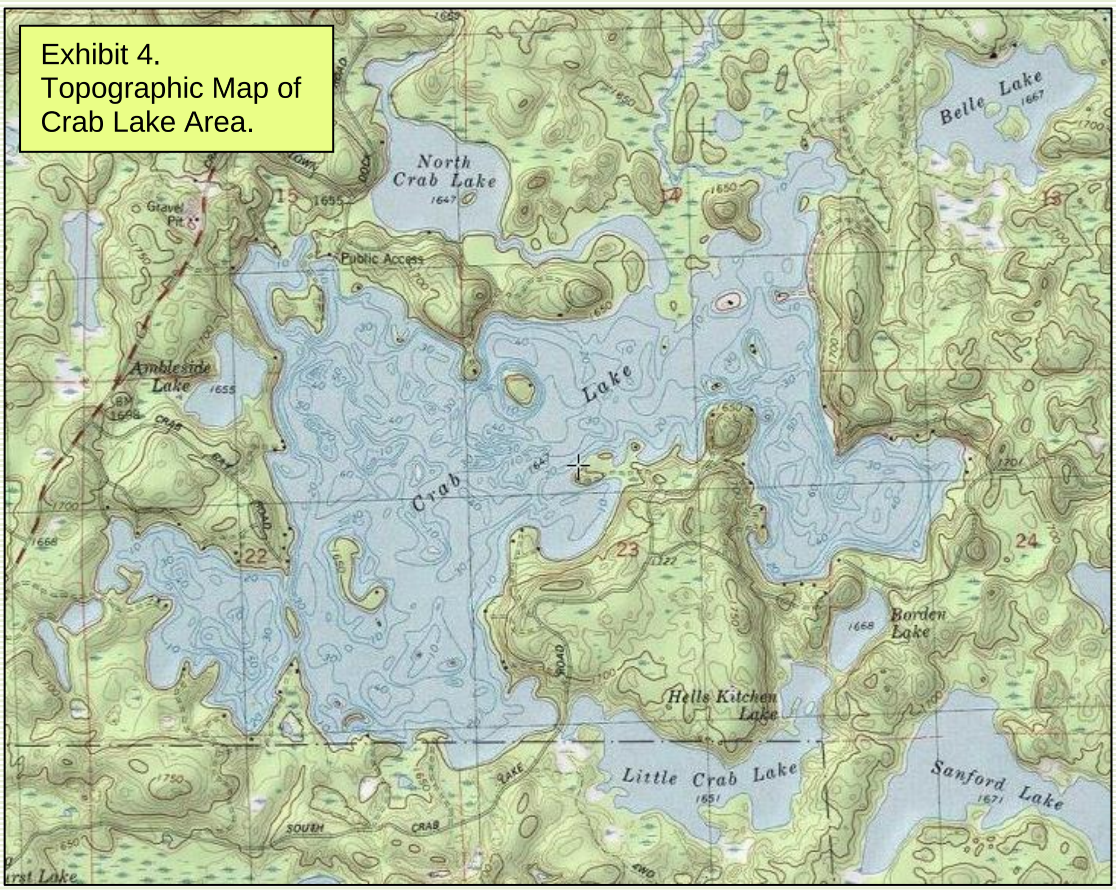


Exhibit 4. Topographic Map of Crab Lake Area.

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:

> ***Crab Lake has a native aquatic plant community that was documented by a point-intercept aquatic plant survey. This plant community is essential to, and part of, a high quality aquatic ecosystem that benefits the human community with its recreational and aesthetic features. The purpose of this aquatic plant management plan is to maintain the aquatic plant community in its present high quality state.***

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

> ***(1) Monitor and protect the native aquatic plant community;***
> ***(2) Prevent establishment of AIS and nuisance levels of native plants;***
> ***(3) Promote and interpret APM efforts; and***
> ***(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that potentially alter the plant community, and minimizing physical removal of native riparian and littoral zone 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 Crab Lake stewards.

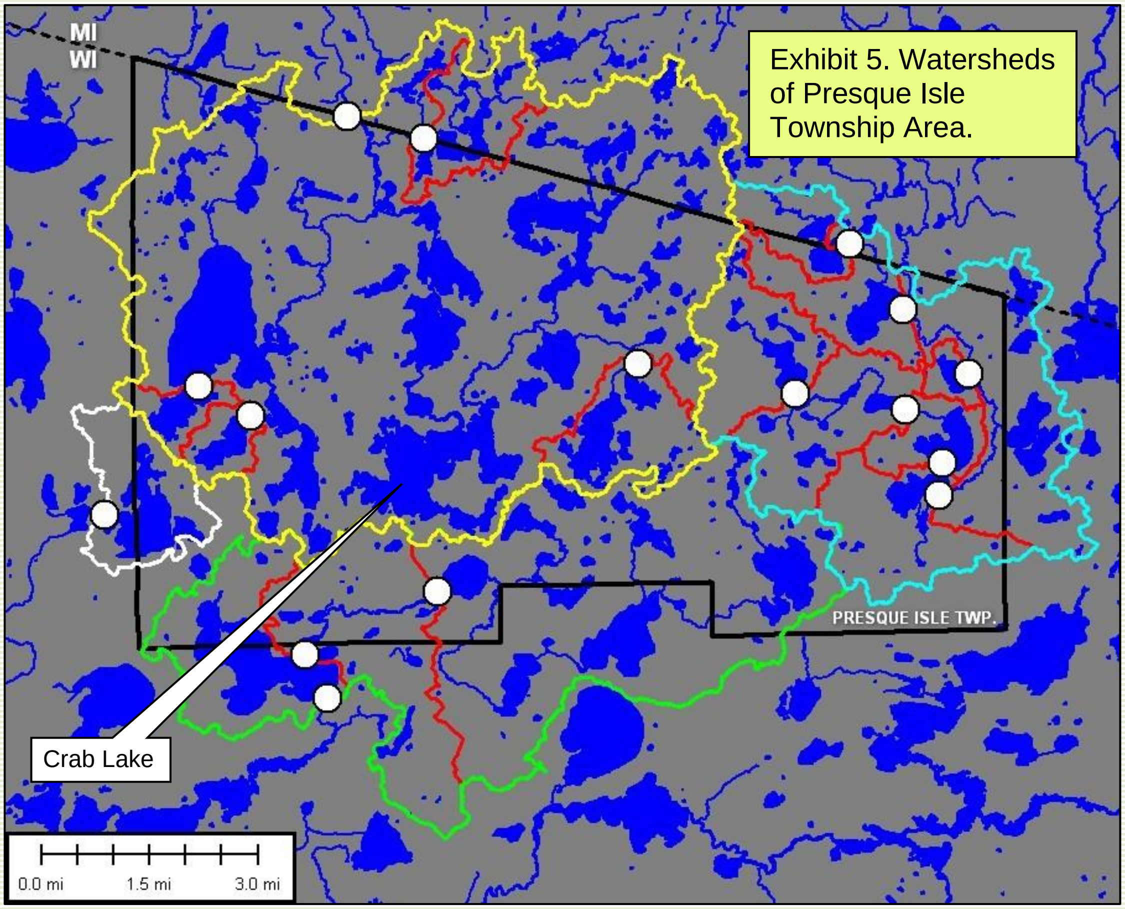
CHAPTER 4

Information and Analysis

Our efforts in the Wilderness Waters Program have compiled information about historical and current conditions of the Crab 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 Flambeau 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. Crab Lake is contained within the South 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 and, in the case of Papoose Lake, bounded by white). 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.

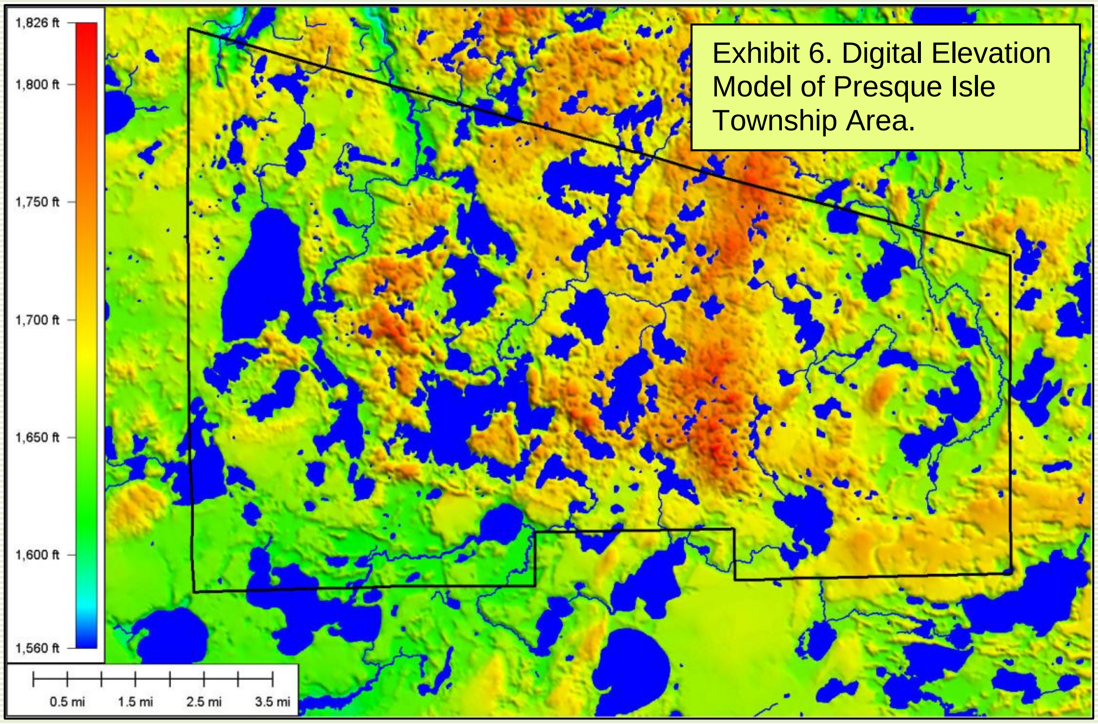


Exhibit 6. Digital Elevation Model of Presque Isle Township Area.

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 Crab Lake watershed is about 12,990 acres. The cover types in the watershed are presented in Exhibit 7. Forest and surface water comprise the largest components. Soil group B is most prevalent, followed by group D, while groups A and C make up a small percentage of the watershed. Soil group A has the highest infiltration capacity, and the lowest runoff potential. Conversely, soil group D has the lowest infiltration capacity, and the highest runoff potential. The watershed to lake area ratio is 14:1. 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.

Exhibit 7. Cover Types and Soil Groups of the Crab Lake Watershed.

Cover Type	Acres	Percent
Agriculture	0	0
Commercial	0	0
Forest	7163.3	55.1
Grass/Pasture	9.1	0.1
High-density Residential	0	0
Low-density Residential	845.8	6.5
Water	4972.7	38.3
Total	12991.1	100.0

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	956.0	7.4	**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	6957.5	53.6	**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	361.8	2.8	**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	4715.8	36.3	**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 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 Crab Lake. Over the years, no particular nuisance issues have demanded control action. In 2007, 2014, and 2020 Aquatic plant surveys were conducted on Crab Lake in 2007, 2014, and 2020. Findings from the 2007, 2014, and 2020 surveys are discussed in the next section (Part 3). Since 2019, yellow iris has been removed by volunteers (see more information in Appendix E).

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.

Aquatic plant surveys have been conducted on Crab Lake by aquatic plant specialists in 2007, 2014, and 2020. In each of these surveys, WDNR point-intercept protocol and methodology was followed. This formal survey assesses the plant species composition on a grid of several hundred points distributed evenly over the lake. Using latitude-longitude coordinates and a handheld GPS unit, scientists navigate to the points and use a rake mounted on a pole or rope to sample plants. Plants are identified, recorded and put into a dedicated spreadsheet for storage and data analysis. This systematic survey provides baseline data about the lake.

Although Crab Lake has been surveyed for aquatic plants three times, the 2007 plant data available to us is incomplete. We are, however, able to compare the plant communities between the 2014 and 2020 surveys. 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 (Part 3) we provide a report of the findings of the 2020 point-intercept aquatic plant survey. Table 1 displays summary statistics for the survey and Table 2 provides a list of the species encountered, including common and scientific name along with summarizing statistics. We also summarize the aquatic plant findings for the 2014 and 2020 surveys in Table 3. Supporting tables and figures for the aquatic plant surveys are provided in Appendix B.

Species richness refers to the total number of species recorded. In 2020, we recorded 39 species of aquatic plants.[2] Of these, 27 were sampled at the points and the others observed from the boat. The number of species encountered at any given sample point ranged from 0 to 5 and 79 sample points were found to have aquatic vegetation present. The average number of species encountered at these vegetated sites was 1.62. The actual number of species encountered at each of the vegetated sites is graphically displayed on Figure 1. Plant density is estimated by a "rake fullness" metric (3 being the highest possible density). These densities (considering all species) are displayed for each sampling site on Figure 2 and reflect a very low density of plant biomass.

The 2020 maximum depth of plant colonization is 11.5 feet (Table 1 and Figure 3). Rooted vegetation was found at 79 of the 259 sample sites with depth ≤ the maximum depth of plant

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[2] *If you are interested in learning more about the plant species found in the lake, visit the University of Wisconsin Stevens 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)."*

colonization (30.50 % 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 2020. 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 are graphically displayed in descending order on Figure 6 (data for both 2014 and 2020 are included for comparison). This display shows that fern pondweed (*Potamogeton robbinsii)* had the highest relative frequency followed by spiral-fruited pondweed (*Potagmogeton spirillus)* in 2020. The lowest relative frequencies are at the far right of the graph. Figure 7 shows the distribution of floating and emergent plant forms in the lake. As examples of individual species distributions in 2020, we show the occurrences of a few of the most frequently and least frequently encountered plants in Figures 8-15.

Species richness (total number of plants recorded at the lake) is a measure of species diversity, but it 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 2020 Simpson Diversity Index for Crab Lake aquatic plants is 0.92 (Table 1) indicating a highly diverse aquatic plant community.

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 Crab Lake FQI (36.8) compares to other lakes and regions. The statewide medians for number of species and FQI are 13 and 22.2, respectively. Crab Lake values are significantly higher than these statewide values. 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. Crab 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. Crab Lake data is much higher than that find. Finally, the Crab Lake FQI (36.8) is significantly higher than the median value for the Northern Lakes and Forests lakes group (24.3). This analysis supports the contention that the Crab Lake plant community is healthy and diverse and indicative of an undisturbed environment.

We found no state or federally listed species. We observed no aquatic plants in Crab Lake that would be considered a nuisance-level population density/distribution. We did observe a small patch of *Phragmites* (this had been previously reported on the WDNR website). We collected a specimen and delivered it to the UWSP herbarium. Dr. Freckmann said it appeared to be the native *Phragmites*. This patch deserves some further monitoring and sampling to verify this observation. We also observed some stands of cattails that should be further monitored and species determined. In the 2020 aquatic plant survey, a hybrid of native and non-native cattail (*Tyhpa angustifolia* x *glauca*) was vouchered and confirmed by Dr. Freckmann (U.W. Steven's Point). Reed canary grass (*Phalaris arundinacea*) was also confirmed at a few locations. Two new AIS were noted in the AIS survey, the aquatic forget-me-not (*Myosotis scorpioides*) and the yellow iris (*Iris pseudacoris*). See Appendix E.

When we compare statistics from the 2014 and 2020 Crab Lake aquatic plant surveys, we conclude that the plant community is diverse, high quality, and stable. The important statistics displayed in Table 3 show only minor differences between the two surveys. Both the Simpson Diversity Index and the Floristic Quality Index are very high. This indicates the plant community has a great diversity of species and is little impacted by humans.

Part 4. Fish Community

It was beyond the scope of the current Wilderness Waters 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 50% sand, 30% gravel, 20% rock, and 0% muck and that fish species present include musky, panfish, largemouth bass, smallmouth bass, northern pike, and walleye.

Part 5. Water Quality and Trophic Status

Crab Lake is a 909 acre drainage lake with a maximum depth of 60 feet. Existing water quality information includes data was retrieved from the Wisconsin DNR SWIMS database between 1992 and 2020. On November 13, 2012 UW Stevens Point monitored various water quality parameters on Crab Lake. Secchi disk measurements were collected by Citizen Lake Monitoring Network (CLMN) volunteers from 1992 to 2020. The water quality information is briefly summarized in this section, but more fully interpreted in Appendix C.

Temperature and dissolved oxygen showed stratification in Crab Lake in the ice-free season. Average water clarity is considered “fair to good.” User perception of Crab Lake aesthetic quality is generally regarded as “beautiful, could not be nicer.” The trophic state is mesotrophic. Water quality would be classified as “very good” with respect to phosphorus concentrations. Chlorophyll *a*, turbidity, nitrogen, chloride, alkalinity, calcium, magnesium, sodium, and potassium are considered low. Crab Lake is also considered an Outstanding Resource Water (WI Admin. Code, 2010).

Part 6. Water Use

Crab Lake has one public access site, and is used by riparian owners and recreationists for a variety of activities. A small part of the southwestern shoreline is owned by the State of Wisconsin, along with six state-owned islands.

Part 7. Riparian Area

Part 1 (Watershed) describes the larger riparian area context of Crab 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 2022 aerial photography reveals 76 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. Crab Lake has instituted an Adopt-a-Shoreline program that divides the lake shoreline area into segments that are monitored by volunteers for aquatic invasive species and other shoreland issues.

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). 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 more 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 to investigate in the future. 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 and osprey. Also, of special importance would be monitoring the populations of aquatic invasive animal species that already exist in the lake (rusty crayfish) and monitoring for the presence of aquatic invasive animal species (for example, New Zealand mud snail, spiny water flea, or zebra mussel) and fish species (for example, rainbow smelt or common carp).

Crab Lake is currently designated as a *priority navigable water* (PNW) and an *area of special natural resource interest* (ASNRI) (WI Admin. Code, 2020). Priority Navigable Waters meet any of these standards: navigable waterways, or portions thereof, that are considered ORW/ERW 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 (WI Admin. Code, 2020). Crab Lake is considered a PNW because it is an ORW and has self-sustaining musky and walleye populations.

A water body designated as an Area of Special Natural Resource Interest can be any of the following: WDNR 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 (WI Admin. Code, 2020). Crab Lake is an ASNRI because it is an Outstanding Resource Water and it is habitat for state/federally designated threatened or endangered species. The Wisconsin Natural Heritage Inventory (NHI) lists plants and animals as rare or sensitive and communities that are considered high quality and significant natural features. Exhibit 8 lists rare or sensitive species or communities found in the same town/range as Crab Lake (NHI, 2022).

Crab Lake has been a part of the Northland College's Project Loon Watch for well over 40 years. Each year reports are filled out for nesting patterns, number of loon chicks, migration dates and more. Crab Lake regularly hosts 5 nesting pairs.

Exhibit 8. Rare Species and Communities located near Crab Lake.			
Common Name	*Scientific Name*	*State Status*[3]	*Group Name*
Bird Rookery	Bird Rookery	SC	Other
Black Spruce Swamp	Black Spruce Swamp	NA	Community~
Boreal rich fen	Boreal Rich Fen	NA	Community~
Calypso Orchid	*Calypso bulbosa*	THR	Plant~
Ephemeral Pond	*Ephemeral Pond*		Other~
Downy Willow-herb	*Epiliobium strictum*	SC	Plant~
Four-toed Salamander	*Hemidactylium scutatum*	SC/H	Salamander~
Lake—Deep, Soft, Seepage	*Lake—deep, soft, seepage*	NA	Community~
Lake—Spring	*Lake—spring*	NA	Community~
Mink Frog	*Lithobates septentrionalis*	SC/H	Frog~
Smith's Melic Grass	*Melica smithii*	END	Plant
Northern Mesic Forest	*Northern mesic forest*	NA	Community
Northern Wet Forest	*Northern wet forest*	NA	Community~
Northern Wet-mesic Forest	*Northern wet-mesic forest*	NA	Community~
Canada Jay	*Perisoreus canadensis*	SC/M	Bird~
Poor Fen	*Poor fen*	NA	Community~
American Water Shrew	*Sorex palustris*	SC/N	Mammal~
Wild Rice Marsh	*Wild rice marsh*	NA	Community~

Part 9. Stakeholders

At this juncture in the ongoing aquatic plant management planning process, the Town Lakes Committee has represented the Crab 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. Volunteers have been active in yellow iris control in the near shore areas of Crab Lake since 2019, see Appendix E for detailed information.

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

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) Prevent establishment of AIS and nuisance levels of native plants;

(3) Promote and interpret APM efforts; and

(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that potentially alter the plant community, and minimizing physical removal of native riparian and littoral zone plants.

Since Crab Lake is a healthy ecosystem, we could simply recommend an alternative of "no action." In other words, Crab Lake continues without any effort or intervention on part of the 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 Crab Lake. Crab Lake stakeholders are working on measures to control the yellow iris populations.

Recommended Actions for the Crab 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 oversees activity and maintains the plan. ***Status:*** Planned for 2022.
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 and maintains data. ***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: Continue with the 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.

Recommended Actions for the Crab Lake APM Plan
Action #6: Conduct quantitative plant survey every five years using WDNR Point-Intercept Methodology. ***Objective:*** To watch for changes in native species diversity, floristic quality, plant abundance, and plant distribution and to check for the occurrence of non-native, invasive plant species. ***Monitoring:*** Town Lakes Committee (Wilderness Waters Program) oversees and maintains data; copies to WDNR. ***Status:*** Anticipated in 2025.
Action #7: 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 #8: Continue with 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:*** Ongoing.
Action #9: 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.

Recommended Actions for the Crab Lake APM Plan
Action #10: 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 #11: 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:*** Anticipated to begin in 2022.
Action #12: Monitor the lake watershed for purple loosestrife and aquatic forget-me-not. ***Objective:*** Identify populations before they reach large size. ***Monitoring:*** The Lake Association and/or Town Lakes Committee oversees activity. ***Status:*** Anticipated in 2022.
Action #13: Monitor the cattail and *Phragmites* patches. ***Objective:*** Confirm species identification and patches are increasing in area. ***Monitoring:*** The Lake Association and/or Town Lakes Committee oversees activity with help from a consulting specialist as needed. ***Status:*** Anticipated in 2022.

Recommended Actions for the Crab 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 oversee(s) activity and assesses effectiveness ***Status:*** Anticipated to begin in 2022.
Action #14: Lake leaders should encourage and assist landowners to take on shoreland and 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 Department* looks for partners in this endeavor and can provide planning and sponsorship of projects. Funding for eligible projects is available from WDNR. Example projects on active lake stewards' properties would serve as valuable demonstration projects and encourage others to participate. ***Objective:*** For high quality areas, maintain this condition through protection. For degraded areas, rehabilitate specific shoreland areas to improve natural functions and values. ***Monitoring:*** Town Lakes Committee oversee(s) activity and assesses effectiveness. ***Status:*** Anticipated to begin in 2022.
Action #15: Continue in the control efforts for yellow iris and investigate possibility for a grant for financial assistance from the Wisconsin Department of Natural Resources. ***Objective:*** Volunteers use various efforts to control the yellow iris populations. ***Monitoring:*** The Lake Association and/or Town Lakes Committee oversees activity, specifically Boyd Zander (resident volunteer) and other volunteers on Crab Lake. ***Status:*** Ongoing from 2019 to 2025.

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.

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.

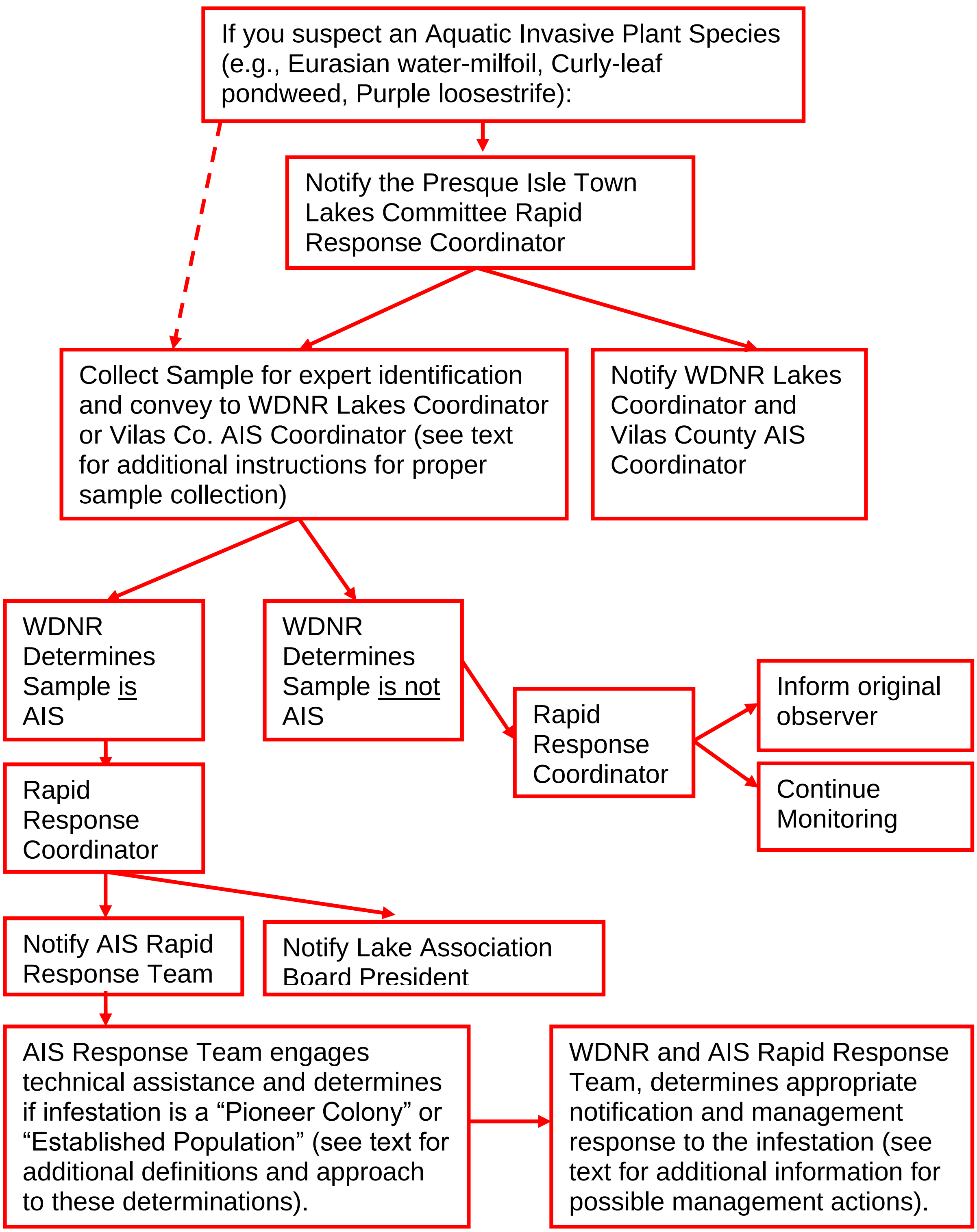
When a suspect aquatic invasive plant species is found, either the original observer or a member of the Rapid Response Team (likely the coordinator) should collect an entire plant specimen including roots, stems, and flowers (if present). The sample should be placed in a sealable bag with a small amount 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 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

Table of Contents

Table 1. Summary statistics for the 2020 point-intercept aquatic plant surveys for Crab Lake.

Summary Statistic	Value	Notes
Total number of sites on grid	1204	Total number of sites on the original grid (not necessarily visited)
Total number of sites visited	358	Total number of sites where the boat stopped, even if much too deep to have plants.
Total number of sites with vegetation	79	Total number of sites where at least one plant was found
Total number of sites shallower than maximum depth of plants	259	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	30.50	Number of times a species was seen divided by the total number of sites shallower than maximum depth of plants.
Simpson Diversity Index	0.92	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.)	11.50	The depth of the deepest site sampled at which vegetation was present.
Number of sites sampled with rake on rope	13	
Number of sites sampled with rake on pole	305	
Average number of all species per site (shallower than max depth)	0.49	
Average number of all species per site (vegetated sites only)	1.62	
Average number of native species per site (shallower than max depth)	0.49	Total number of species collected. Does not include visual sightings.
Average number of native species per site (vegetated sites only)	1.62	Total number of species collected including visual sightings.
Species Richness	27	
Species Richness (including visuals)	39	
Floristic Quality Index (FQI)	36.8	

Table 2. Plant species recorded and distribution statistics for the 2020 Crab 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
Fern pondweed	*Potamogeton robbinsii*	8.11	26.58	16.41	21	21	1.0
Spiral-fruited pondweed	*Potamgoeton spirillus*	6.95	22.78	14.06	18	27	1
Wild celery	*Vallisneria americana*	4.63	15.19	9.38	12	18	1
Muskgrasses	*Chara sp.*	3.86	12.66	7.81	10	10	1
Needle spikerush	*Eleocharis acicularis*	2.70	8.86	5.47	7	8	1
Slender naiad	*Najas flexilis*	2.70	8.86	5.47	7	7	1
Creeping spikerush	*Eleocharis palustris*	2.32	7.59	4.69	6	18	1
Large-leaf pondweed	*Potamogeton amplifolius*	1.93	6.33	3.91	5	23	1
Dwarf water-milfoil	*Myriophyllum tenellum*	1.54	5.06	3.13	4	6	1
Nitella	*Nitella sp.*	1.54	5.06	3.13	4	4	1
White water lily	*Nymphaea odorata*	1.54	5.06	3.13	4	25	1
Variable pondweed	*Potamogeton gramineus*	1.54	5.06	3.13	4	6	1
Watershield	*Brasenia schreberi*	1.16	3.80	2.34	3	25	1
Spiny spored-quillwort	*Isoetes echinospora*	1.16	3.80	2.34	3	3	1
Narrow-leaved bur-reed	*Sparganium angustifolium*	1.16	3.80	2.34	3	13	1
Slender waterweed	*Elodea nuttallii*	0.77	2.53	1.56	2	2	1
Pipewort	*Eriocaulon aquaticum*	0.77	2.53	1.56	2	5	1
Spatterdock	*Nuphar variegata*	0.77	2.53	1.56	2	10	1
Ribbon-leaf pondweed	*Potamogeton epihydrus*	0.77	2.53	1.56	2	24	1
Large purple bladderwort	*Utricularia purpurea*	0.77	2.53	1.56	2	3	1.5
Water horsetail	*Equisetum fluviatile*	0.39	1.27	0.78	1	14	1
Brown-fruited rush	*Juncus pelocarpus f. submersus*	0.39	1.27	0.78	1	3	1
Southern naiad	*Najas guadalupensis*	0.39	1.27	0.78	1	1	1
Berchtold's pondweed	*Potamogeton berchtoldii*	0.39	1.27	0.78	1	4	1
Floating-leaf pondweed	*Potamogeton natans*	0.39	1.27	0.78	1	4	1
Small pondweed	*Potamogeton pusillus*	0.39	1.27	0.78	1	1	1
Softstem bulrush	*Schoenoplectus tabernaemontani*	0.39	1.27	0.78	1	8	1

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
Aquatic moss	Aquatic moss	1.16	3.80		3	3	1
Freshwater sponge	Freshwater sponge	0.39	1.27		1	1	1
Filamentous algae	Filamentous algae	0.77	2.53		2	2	1
Pickerelweed	*Pontederia cordata*				Visual	32	
Three-way sedge	*Dulichium arundinaceum*				Visual	14	
Water lobelia	*Lobelia dortmanna*				Visual	9	
Common arrowhead	*Sagittaria latifolia*				Visual	8	
Fringed sedge	*Carex crinita*				Visual	3	
Blue joint grass	*Calamagrostis canadensis*				Visual	2	
Water smartweed	*Persicaria amphibium*				Visual	2	
Water marigold	*Bidens beckii*				Visual	1	
Swamp candles	*Lysimacia terrestris*				Visual	1	
Creeping spearwort	*Ranunculus flammula*				Visual	1	
Hardstem bulrush	*Schoenoplectus acutus*				Visual	1	
Woolgrass	Scirpus cyprinius				Visual	1	
Common beaked sedge	*Carex utriculata*				Boat survey		
Smooth saw-sedge	*Cladium meriscoides*				Boat survey		
Reed canary grass	*Phalaris arundinacea*				Boat survey		
Common reed	*Pharagmites sp.*				Boat survey		
Arrowhead	*Sagittaria rigida*				Boat survey		
Woolgrass	*Scirpus cyprinius*				Boat survey		
Mosquito bulrush	*Scirpus hattorianus*				Boat survey		
Broadleaf cattail	*Typha lattifolia*				Boat survey		
Broadleaf x narrow-leaf	*Typha sp. x glauca (hybrid)*				Boat survey		
Bulrush	*Typha sp.*				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.

Dr. Freckman (U.W. Stevens Point – Herbarium) verified voucher specimens January 2021.

Phalaris arundinacea (reed canary grass) and *Typha sp. x glauca* (hybrid) (Broadleaf x narrow-leaf) are restricted species in Wisconsin.

Table 3. Comparison of summary statistics for 2014 and 2020 point-intercept aquatic plant surveys in Crab Lake.

Summary Statistic	**2014**	**2020**
Total number of sites on grid	1204	1204
Total number of sites visited	564	358
Total number of sites with vegetation	58	79
Total number of sites shallower than maximum depth of plants	239	259
Frequency of occurrence at sites shallower than maximum depth of plants	24.27	30.50
Simpson Diversity Index	0.92	0.92
Maximum depth of plants (ft.)	10.50	11.50
Number of sites sampled with rake on rope	26	13
Number of sites sampled with rake on pole	287	305
Average number of all species per site (shallower than max depth)	0.47	0.49
Average number of all species per site (vegetated sites only)	1.93	1.62
Average number of native species per site (shallower than max depth)	0.47	0.49
Average number of native species per site (vegetated sites only)	1.93	1.62
Species Richness	29	27
Species Richness (including visuals)	35	39
Floristic Quality Index (FQI)	37.2	36.8

Figure 1. Number of plant species recorded at Crab Lake sample sites (2020).

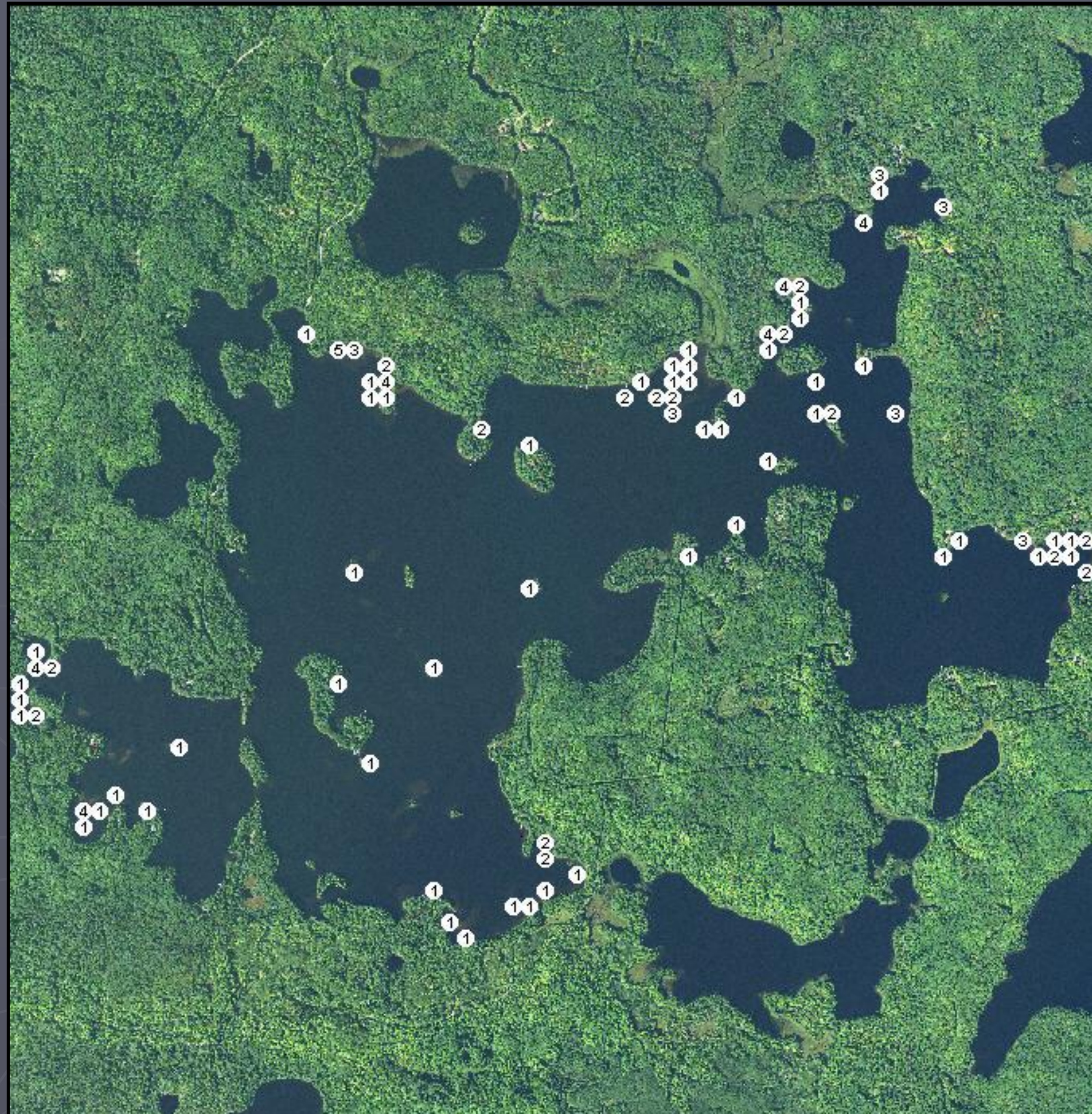


Figure 2. Rake fullness ratings for Crab Lake sample sites (2020).

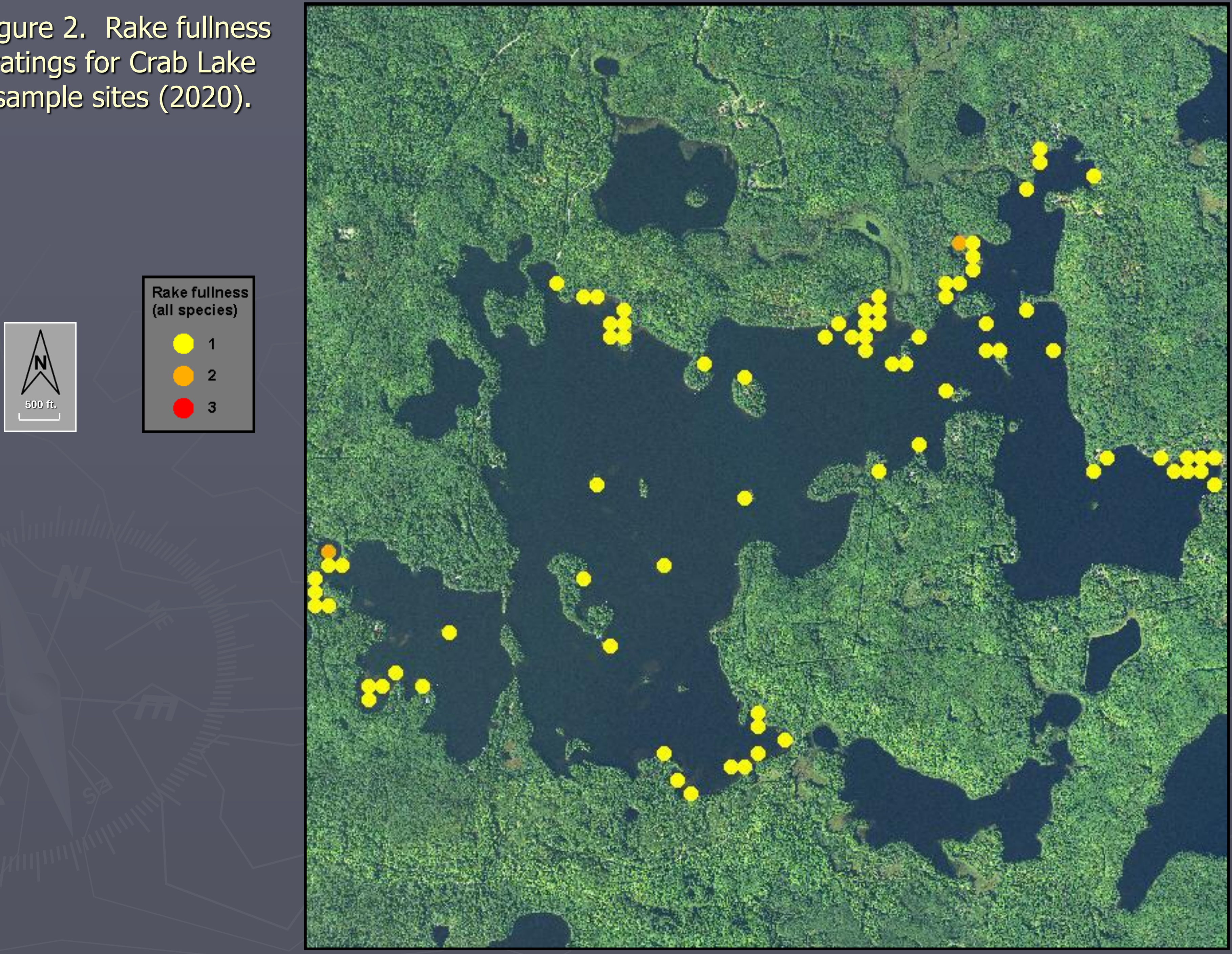


Figure 3. Maximum Depth of Plant Colonization, Crab Lake, 2020

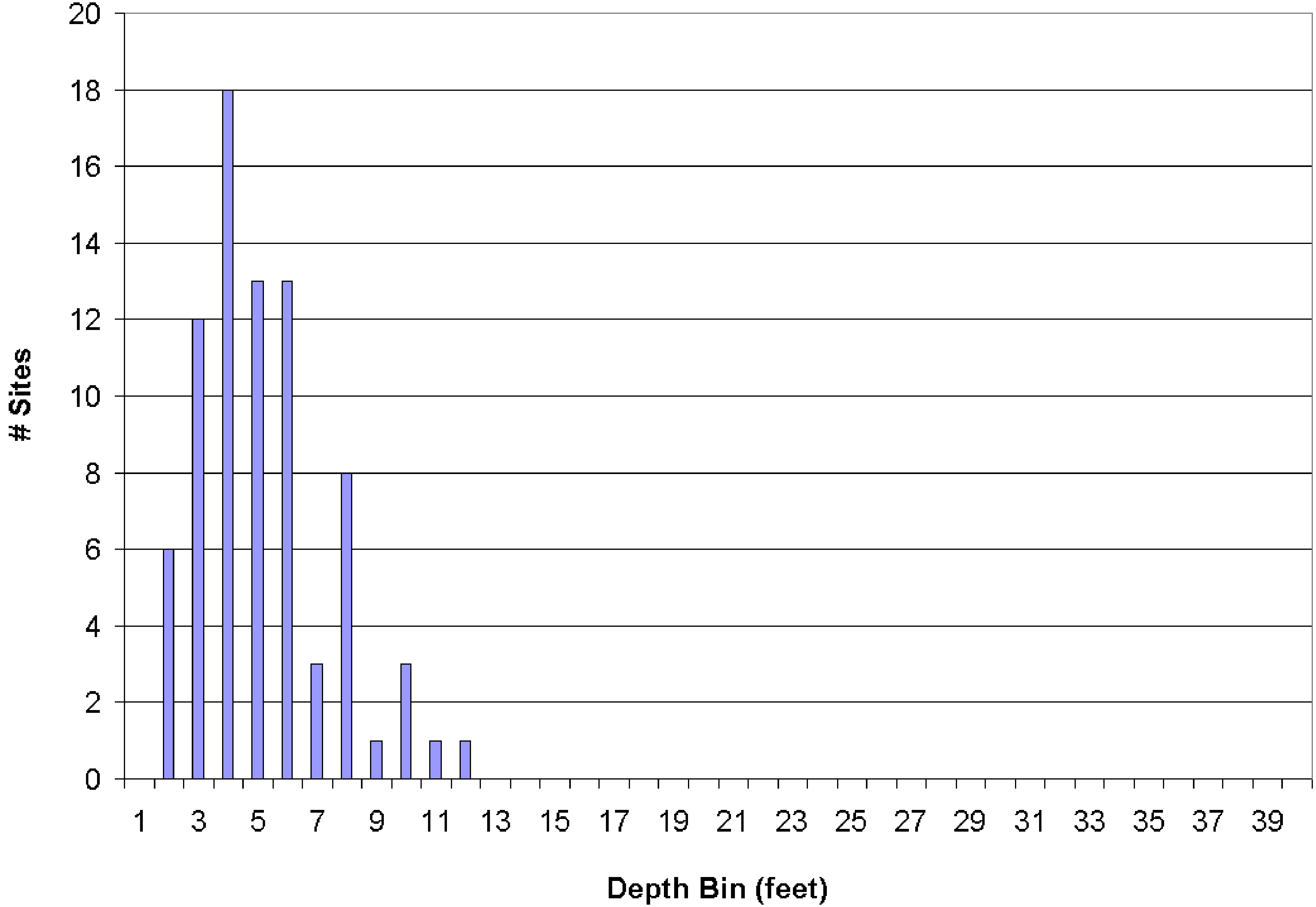


Figure 4. Crab Lake sampling sites less than or equal to maximum depth of rooted vegetation (2020).

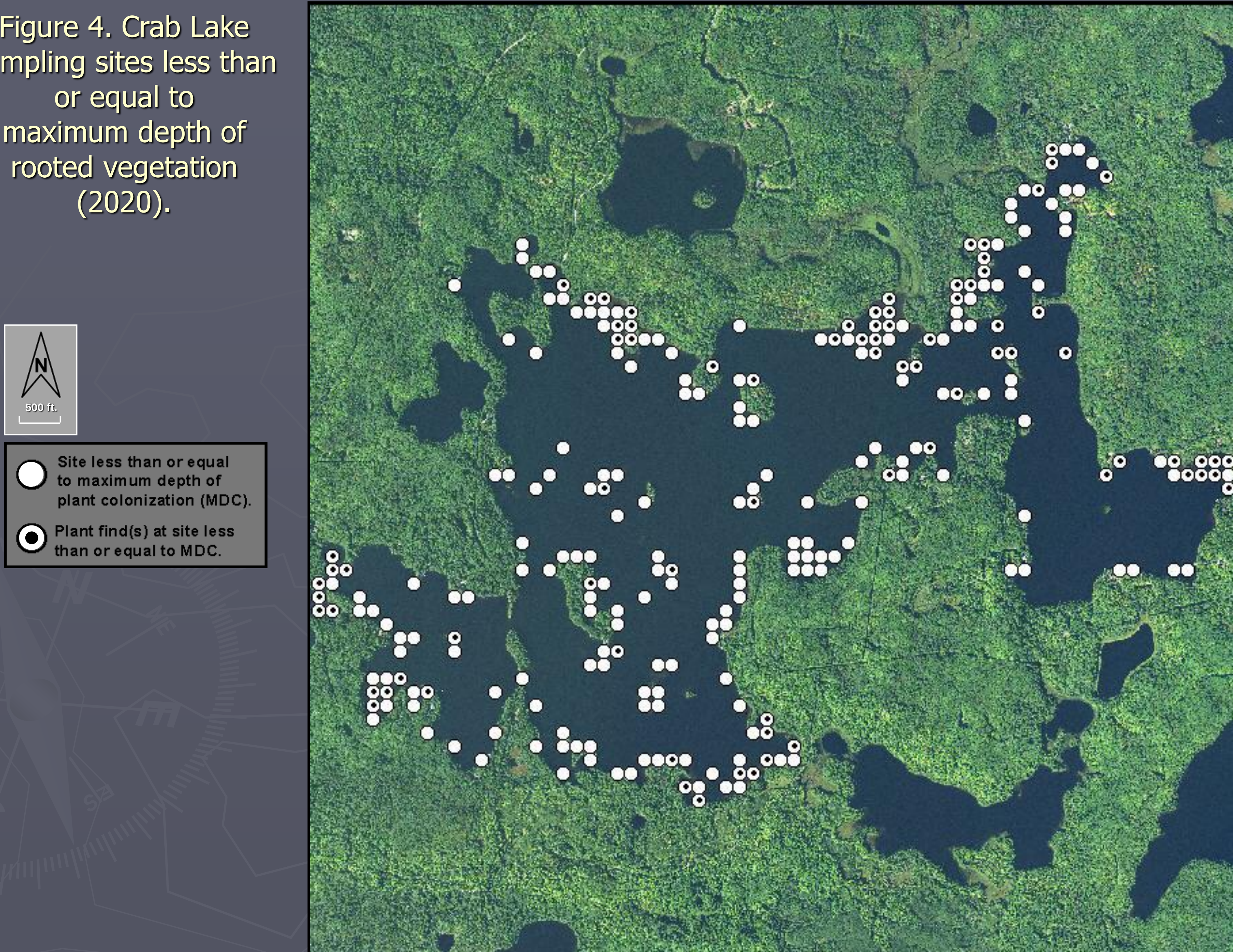
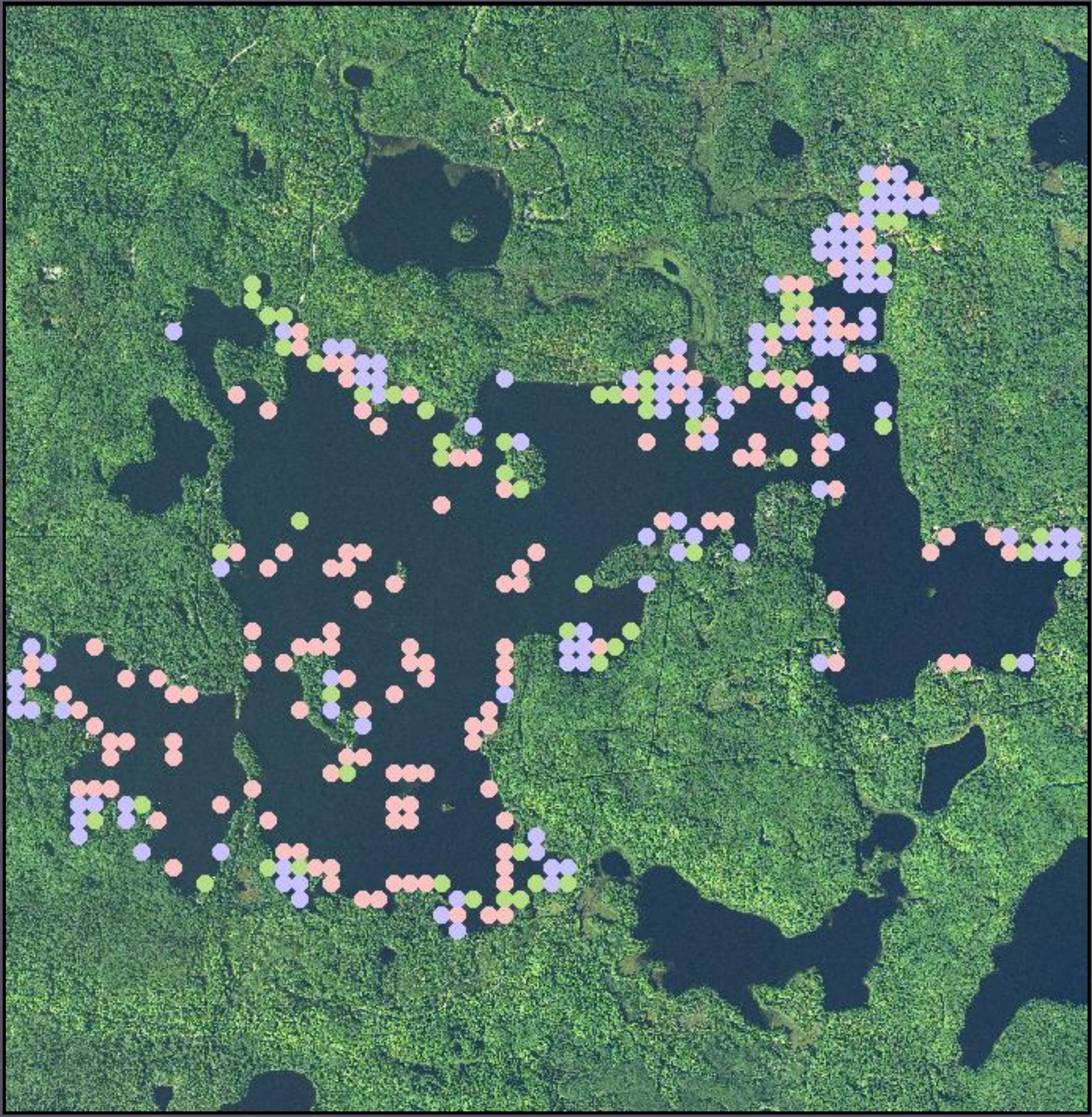


Figure 5. Crab Lake substrate encountered at point-intercept plant sampling sites (2020).



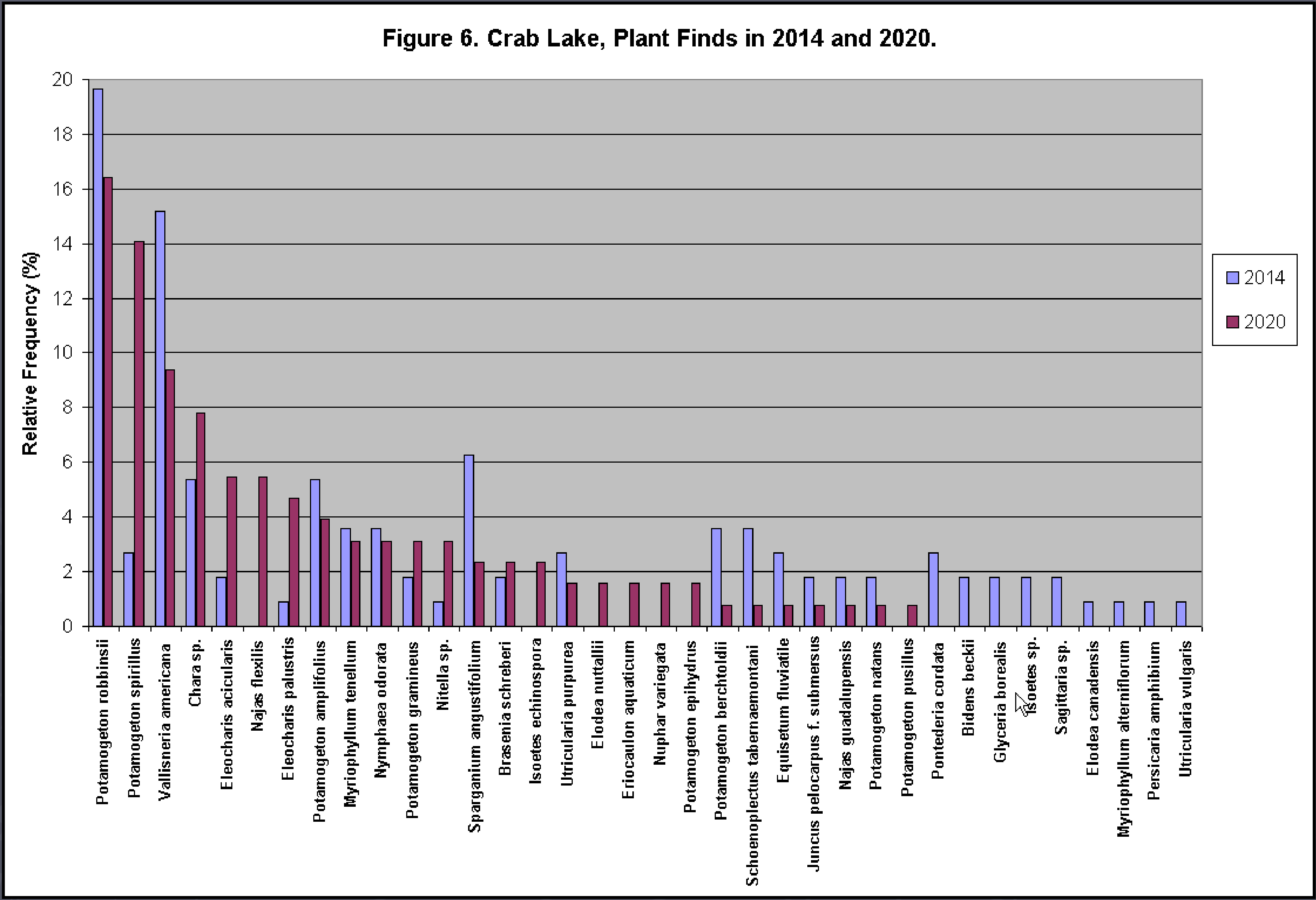


Figure 6. Crab Lake, Plant Finds in 2014 and 2020.
Relative Frequency (%)
20
18
16
14
12
10
8
6
4
2
0
2014
2020
Potamogeton robbinsii
Potamogeton spirillus
Vallisneria americana
Chara sp.
Eleocharis acicularis
Najas flexilis
Eleocharis palustris
Potamogeton amplifolius
Myriophyllum tenellum
Nymphaea odorata
Potamogeton gramineus
Nitella sp.
Sparganium angustifolium
Brasenia schreberi
Isoetes echinospora
Utricularia purpurea
Elodea nuttallii
Eriocaulon aquaticum
Nuphar variegata
Potamogeton epihydrus
Potamogeton berchtoldii
Schoenoplectus tabernaemontani
Equisetum fluviatile
Juncus pelocarpus f. submersus
Najas guadalupensis
Potamogeton natans
Potamogeton pusillus
Pontederia cordata
Bidens beckii
Glyceria borealis
Isoetes sp.
Sagittaria sp.
Elodea canadensis
Myriophyllum alterniflorum
Persicaria amphibium
Utricularia vulgaris

Figure 7. Crab Lake point-intercept plant sampling sites with emergent and floating aquatic plants (2020).

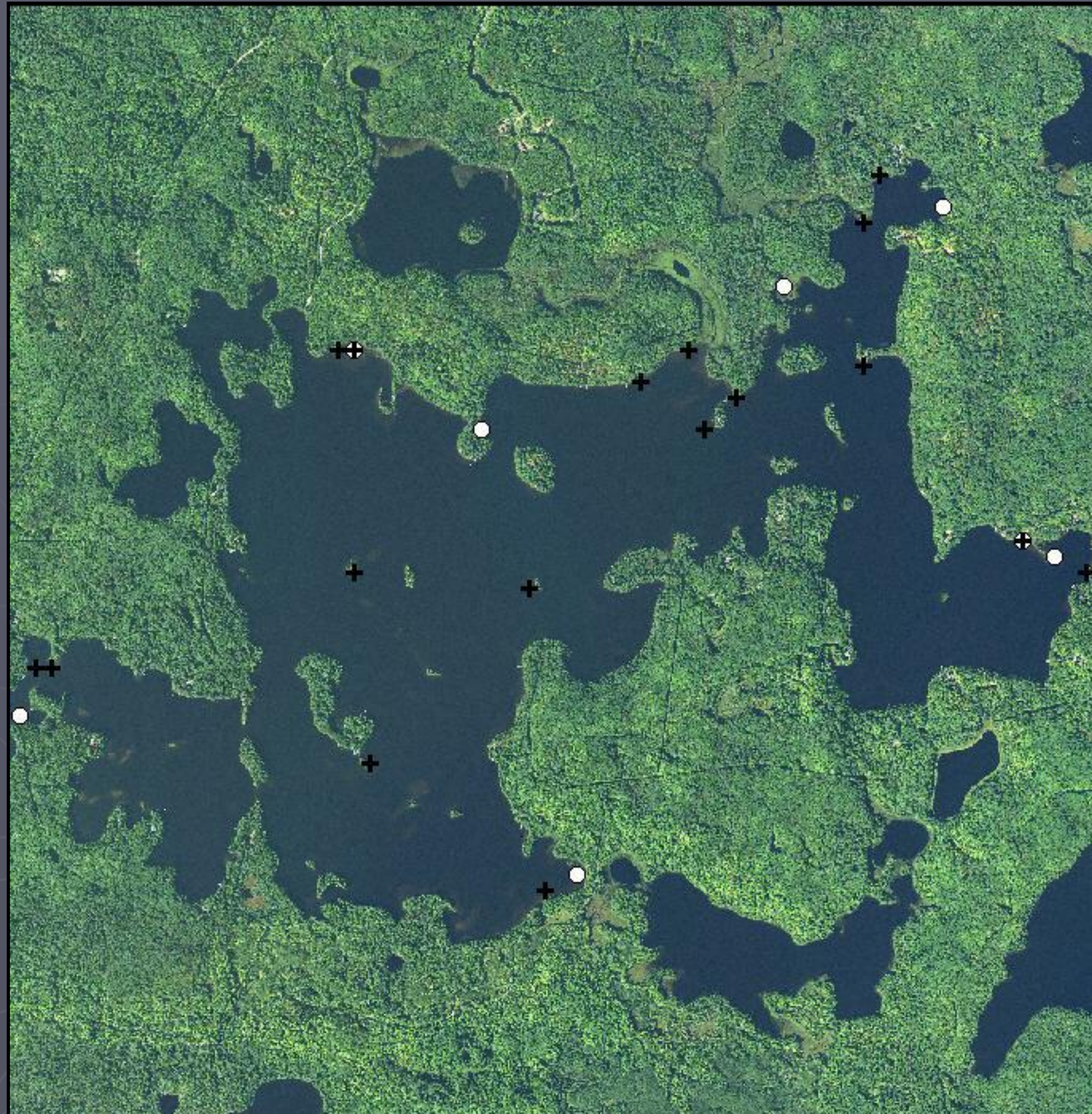


Figure 8. Distribution of plant species, Crab Lake (2020).

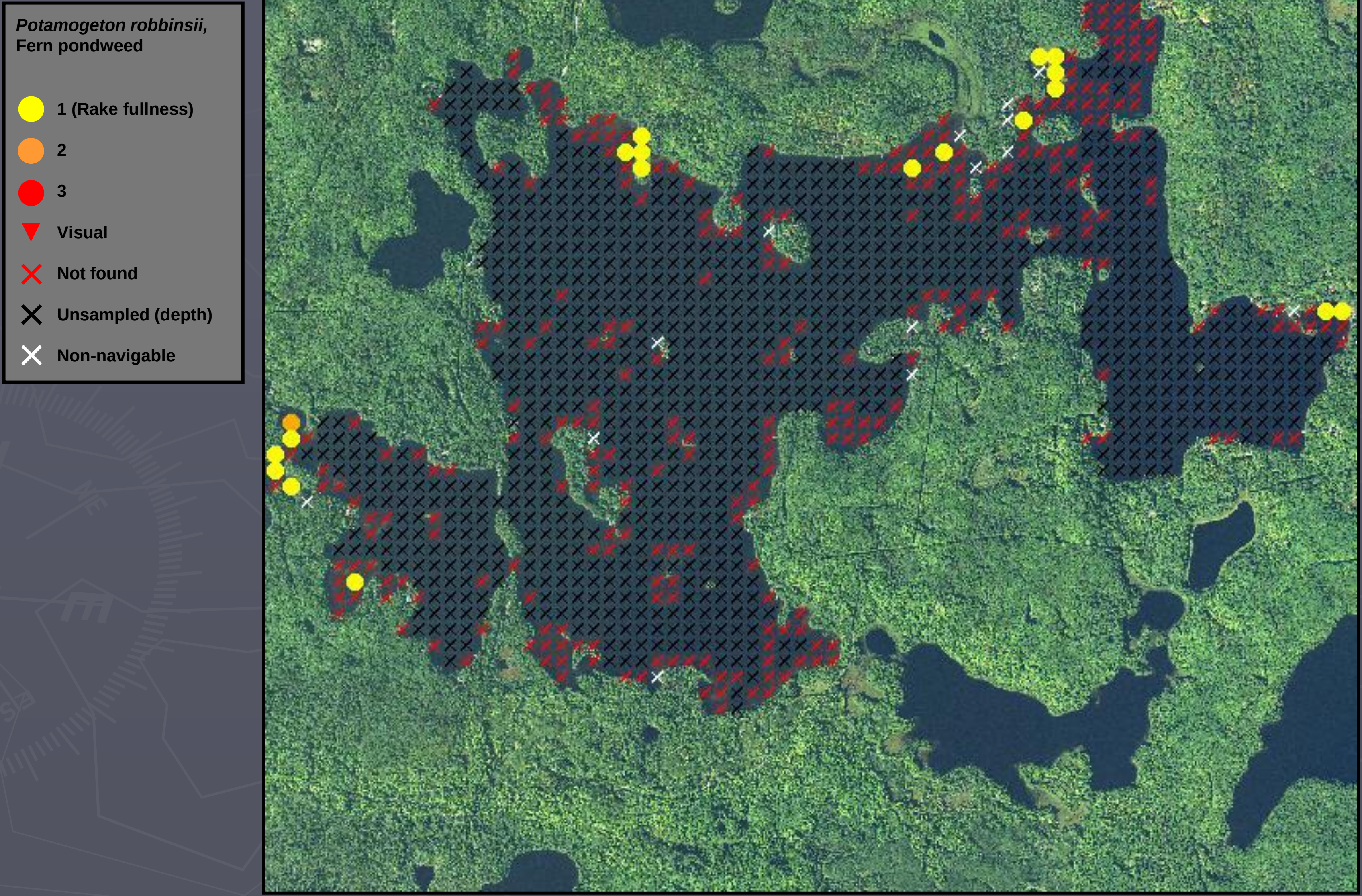


Figure 9. Distribution of plant species, Crab Lake (2020).

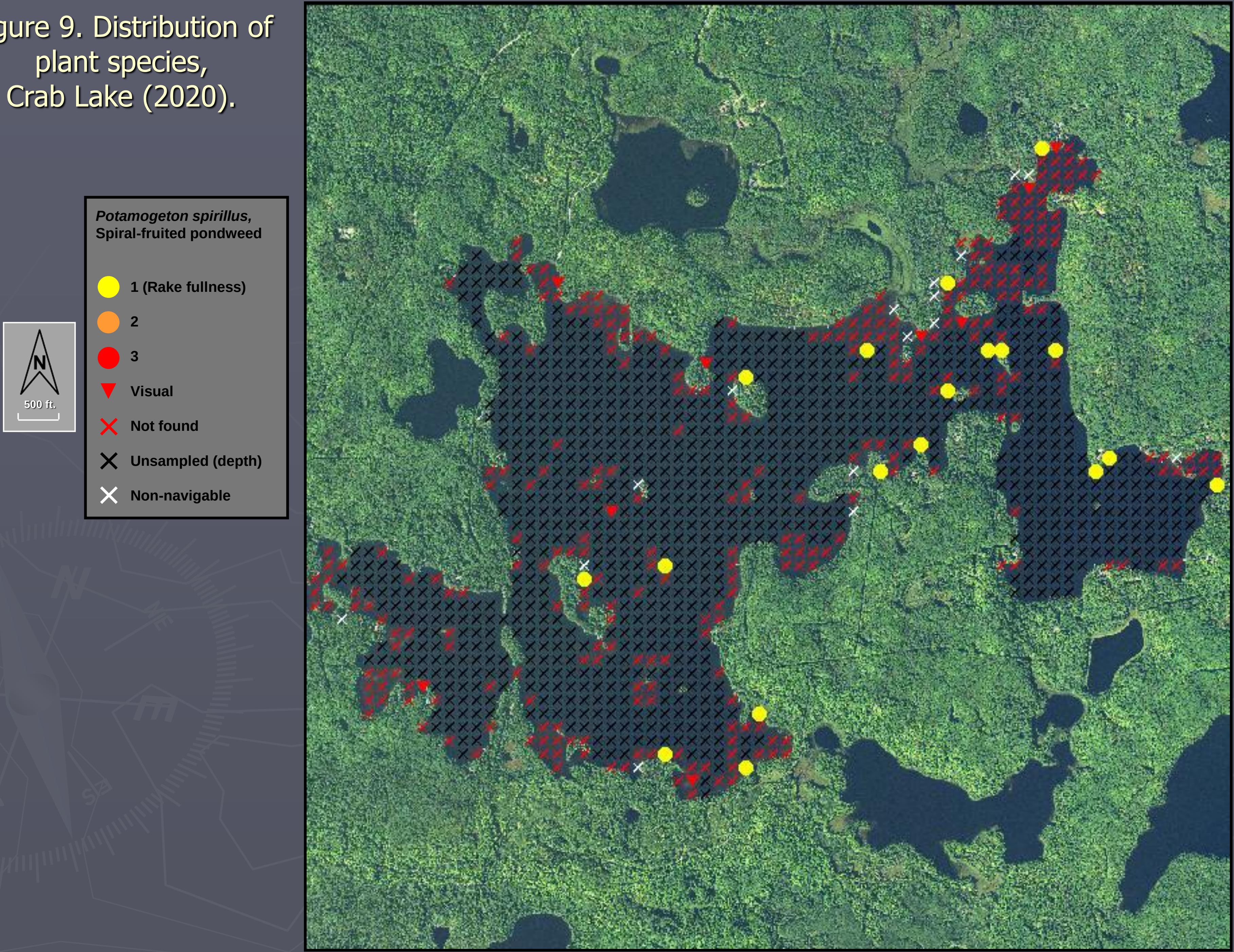


Figure 10. Distribution of plant species, Crab Lake (2020).

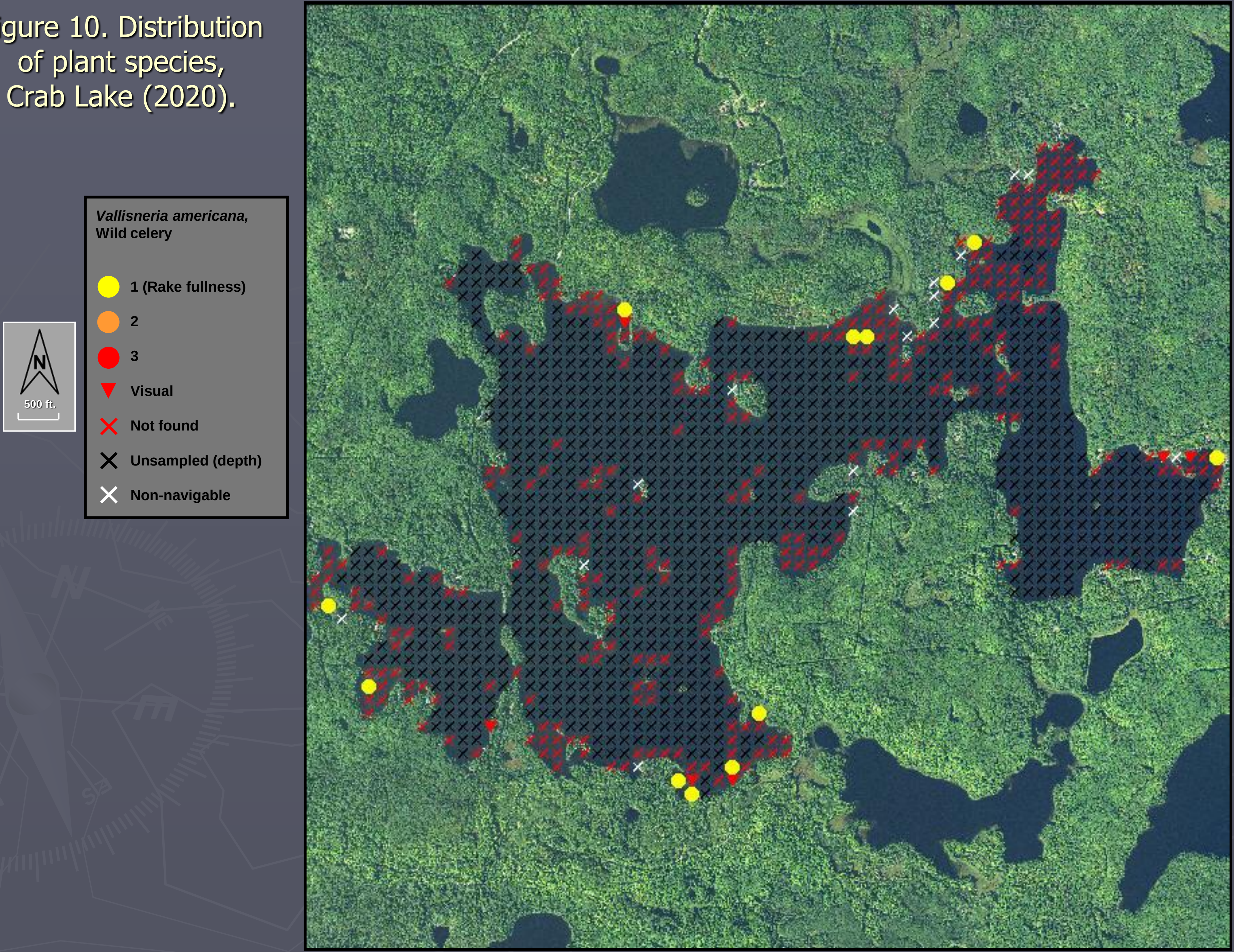


Figure 11. Distribution of plant species, Crab Lake (2020).

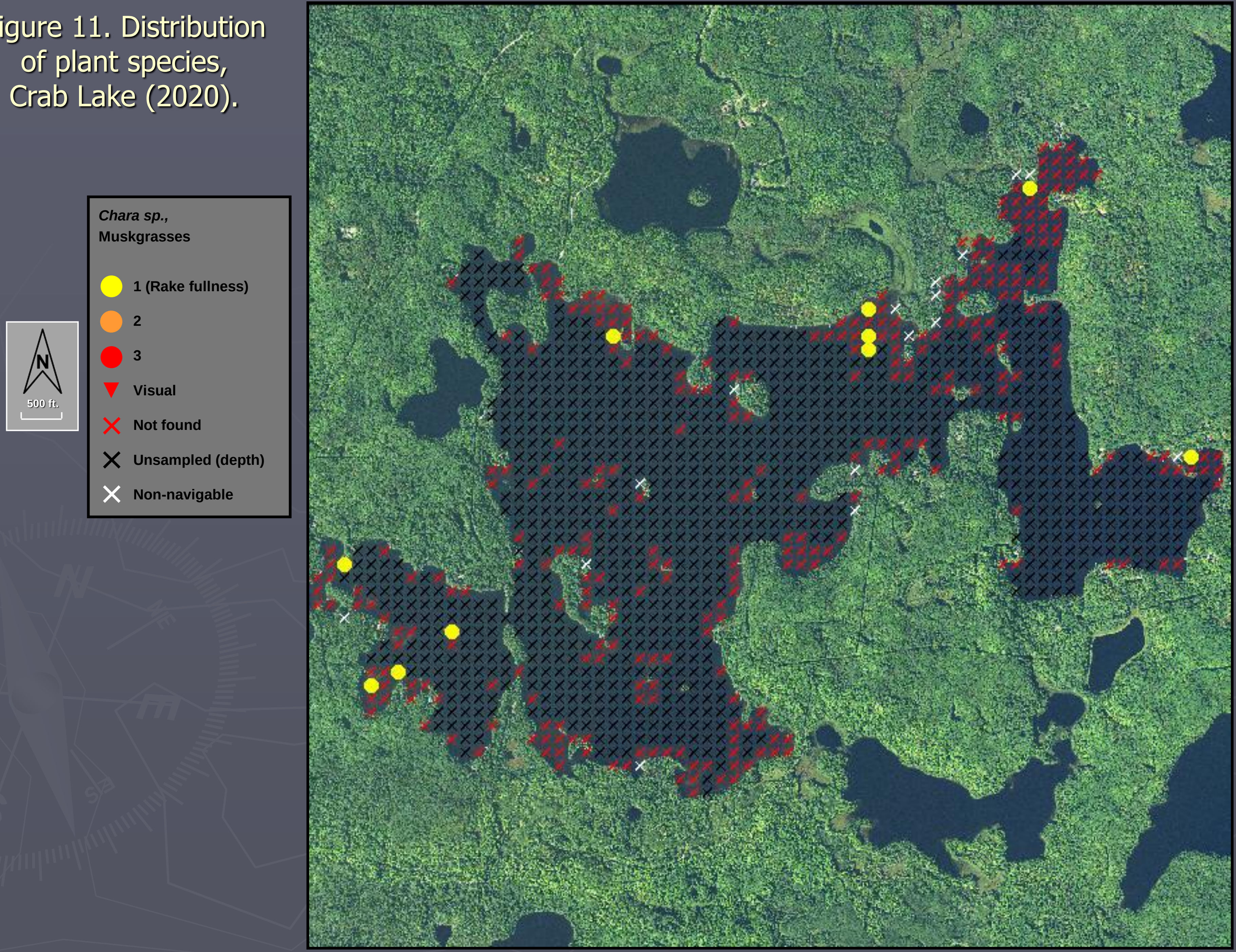


Figure 12. Distribution of plant species, Crab Lake (2020).

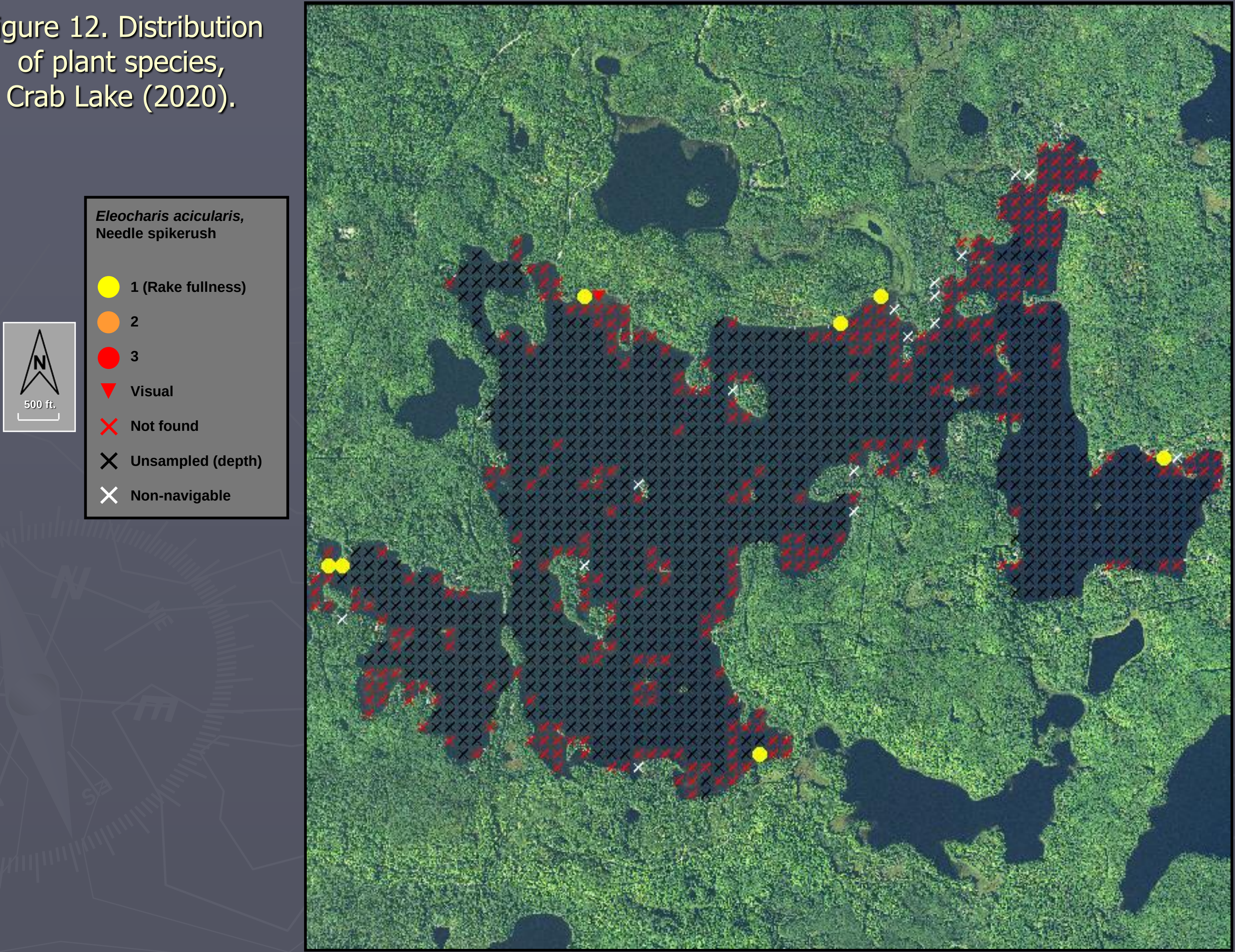


Figure 13. Distribution of plant species, Crab Lake (2020).

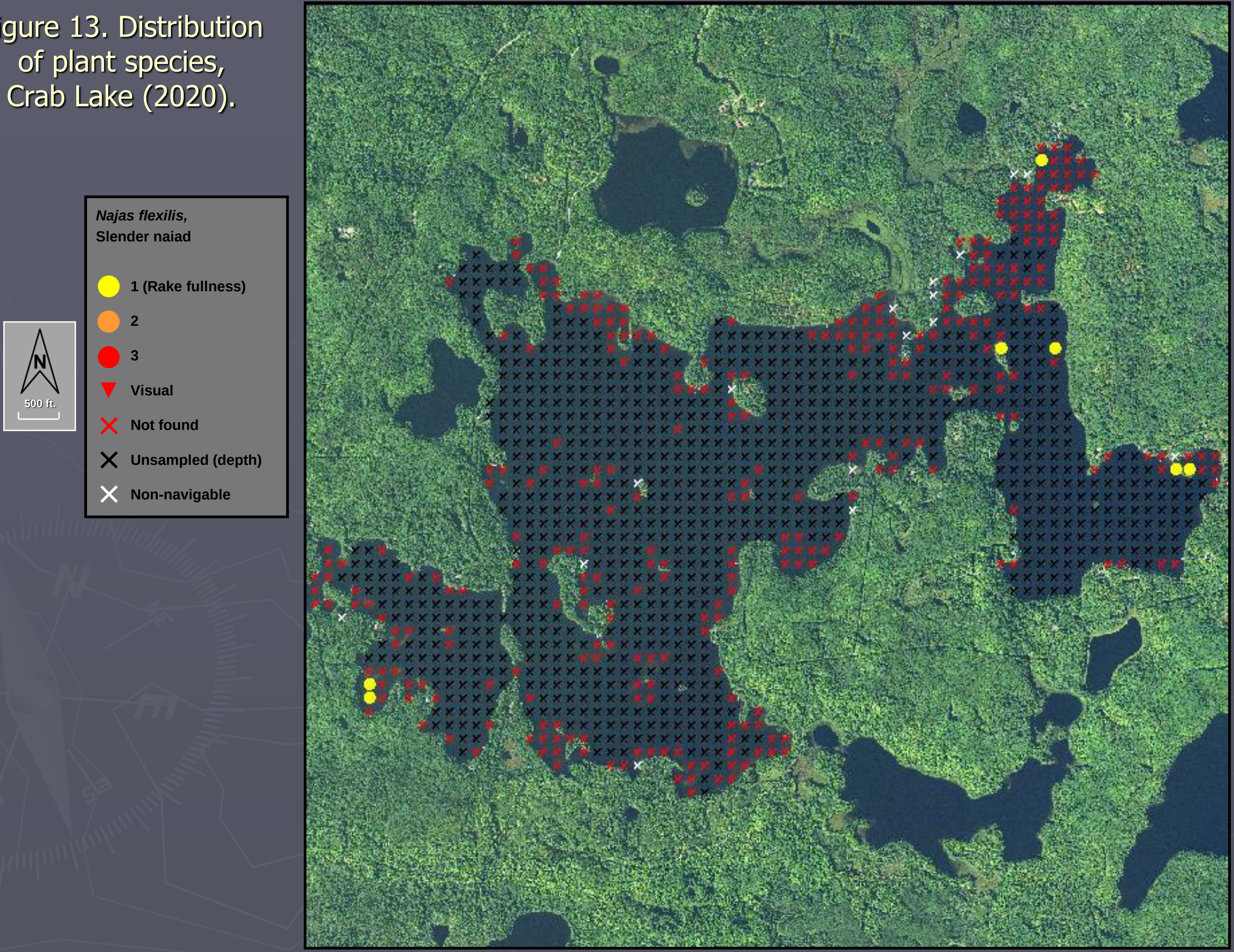


Figure 14. Distribution of plant species, Crab Lake (2020).

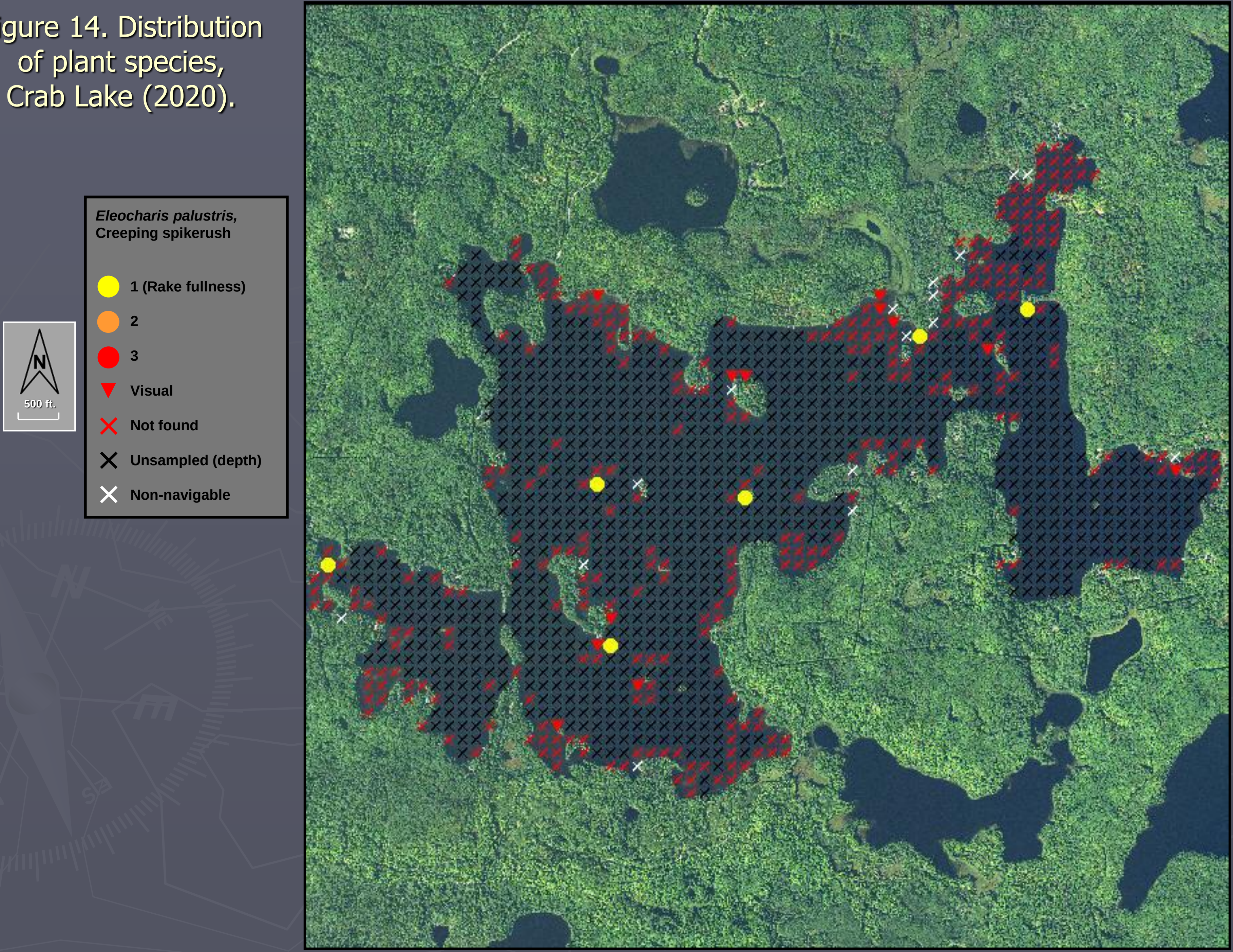
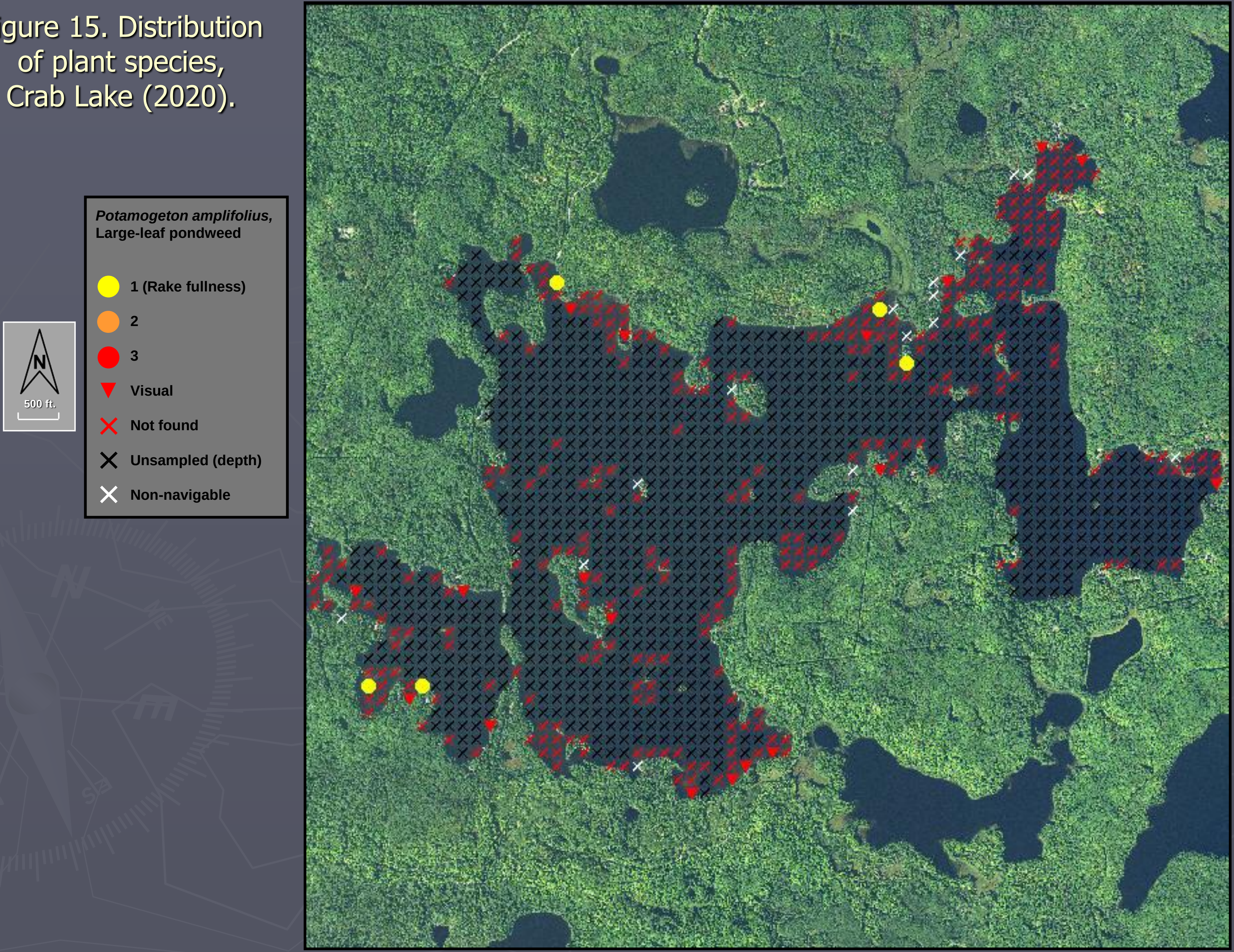


Figure 15. Distribution of plant species, Crab Lake (2020).



Appendix C

Crab Lake Water Quality Report

Appendix C

Review of Lake Water Quality

Table of Contents

Review of Crab Lake Water Quality

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

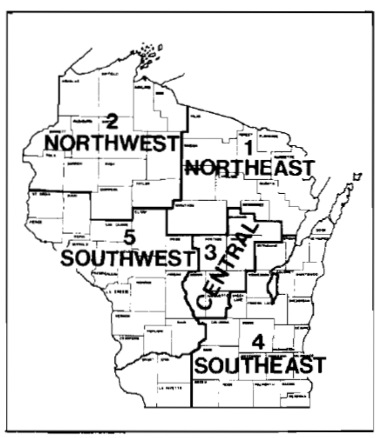
Introduction

Crab Lake is located in Vilas County, Wisconsin. It is a 909 acre drainage lake with a maximum depth of 60 feet. The Waterbody Identification Code (WBIC) is 2953500. The purpose of this study was to review and report existing baseline water quality data found in the Wisconsin DNR SWIMS database. Future water quality monitoring data can be compared to this baseline dataset in order to detect and understand long-term changes in water quality. Water quality data was retrieved from the Wisconsin DNR SWIMS database between 1992 and 2020. On November 13, 2012 UW Stevens Point monitored various water quality parameters on Crab Lake. Secchi disk measurements were collected by Citizen Lake Monitoring Network (CLMN) volunteers from 1992 to 2020. Chlorophyll *a* and total phosphorus were also collected by CLMN volunteers from 1993 to 2020.

Comparison of Crab Lake with other datasets

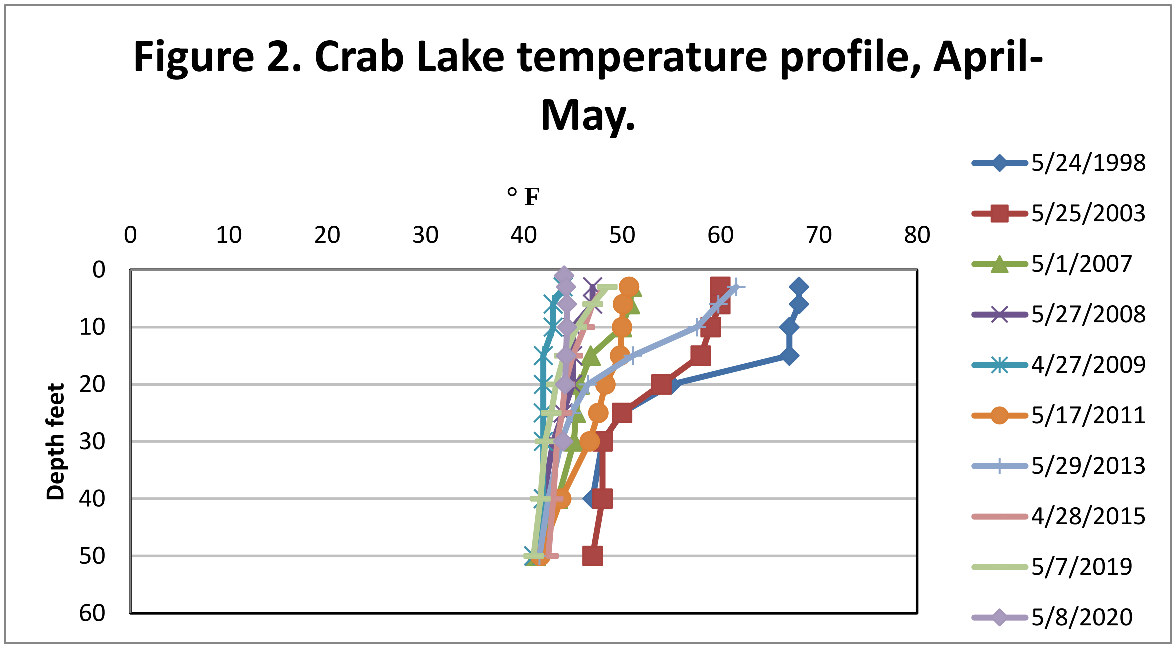
Lillie and Mason's *Limnological Characteristics of Wisconsin Lakes* (1983) is a great source to compare lakes within our region to a subset of lakes that have been sampled in Wisconsin. Wisconsin is divided into five regions of sampling lakes. Vilas County lakes are in the Northeast Region (Figure 1) and were among 243 lakes randomly selected and analyzed for water quality.

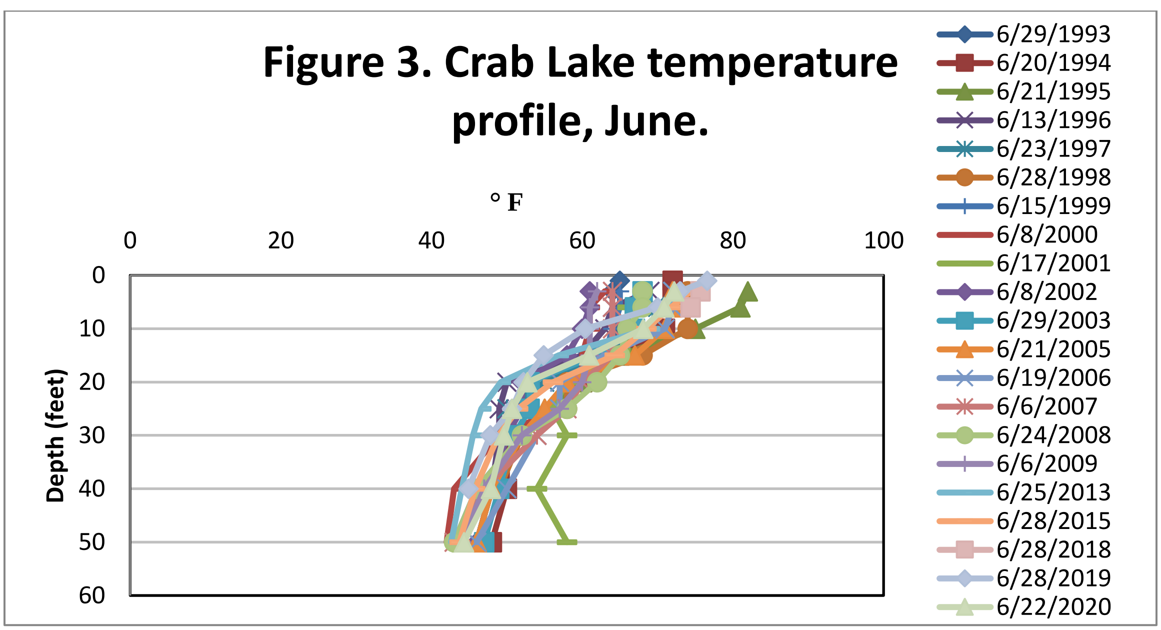
Figure 1. Wisconsin regions in terms of water quality.



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 2 displays the water temperatures from April to May. In May, 1998, 2003, 2013, and 2020 the temperatures began to stratify from surface to bottom. In June, Crab Lake began to stratify at 18 to 20 feet (Figure 3). In July, Crab Lake stratified between 18 and 25 feet (Figure 4). In August, Crab Lake stratified between 20 and 30 feet (Figure 5). Crab Lake water temperatures started mixing in September, and by October the temperature was consistent from surface to bottom (Figure 6).





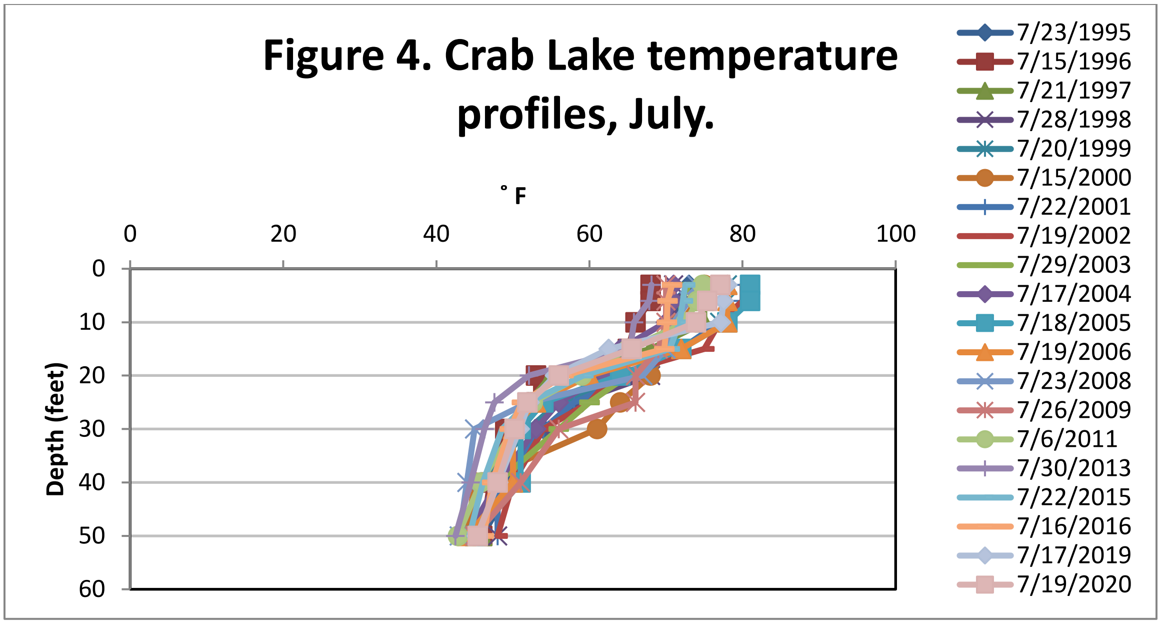


Figure 4. Crab Lake temperature profiles, July.
° F
0
20
40
60
80
100
Depth (feet)
0
10
20
30
40
50
60
7/23/1995
7/15/1996
7/21/1997
7/28/1998
7/20/1999
7/15/2000
7/22/2001
7/19/2002
7/29/2003
7/17/2004
7/18/2005
7/19/2006
7/23/2008
7/26/2009
7/6/2011
7/30/2013
7/22/2015
7/16/2016
7/17/2019
7/19/2020

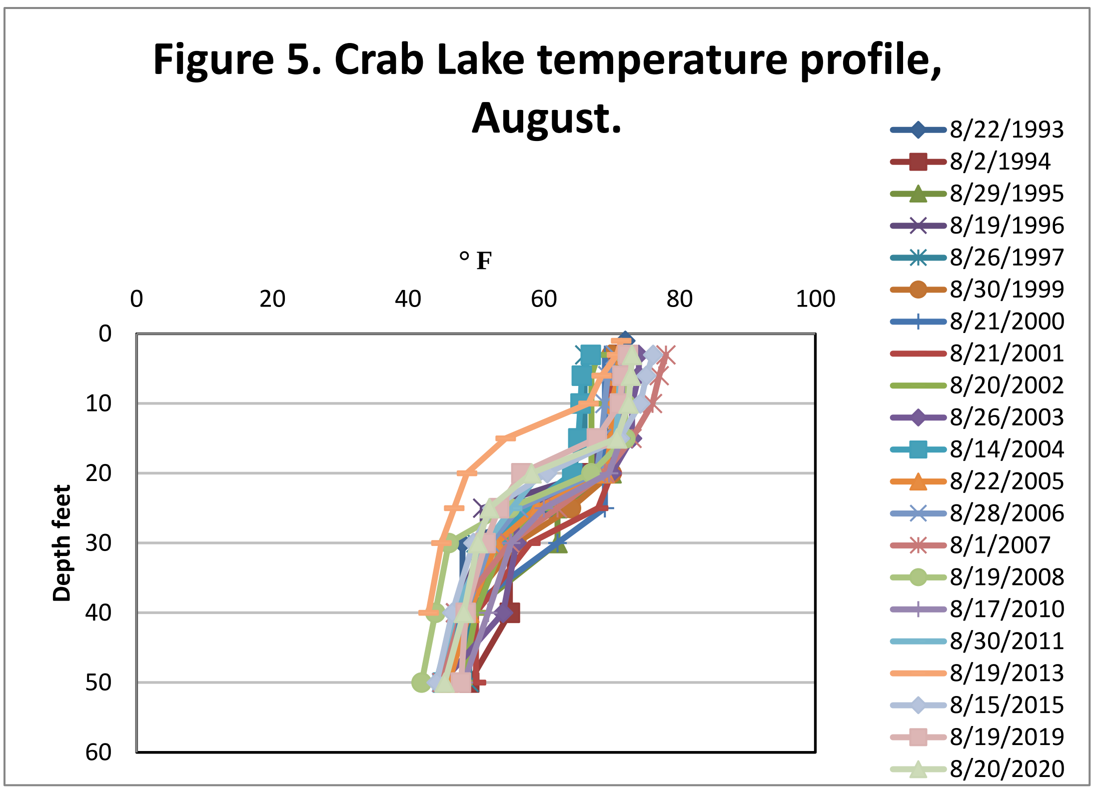


Figure 5. Crab Lake temperature profile, August.
° F
0
20
40
60
80
100
Depth feet
0
10
20
30
40
50
60
8/22/1993
8/2/1994
8/29/1995
8/19/1996
8/26/1997
8/30/1999
8/21/2000
8/21/2001
8/20/2002
8/26/2003
8/14/2004
8/22/2005
8/28/2006
8/1/2007
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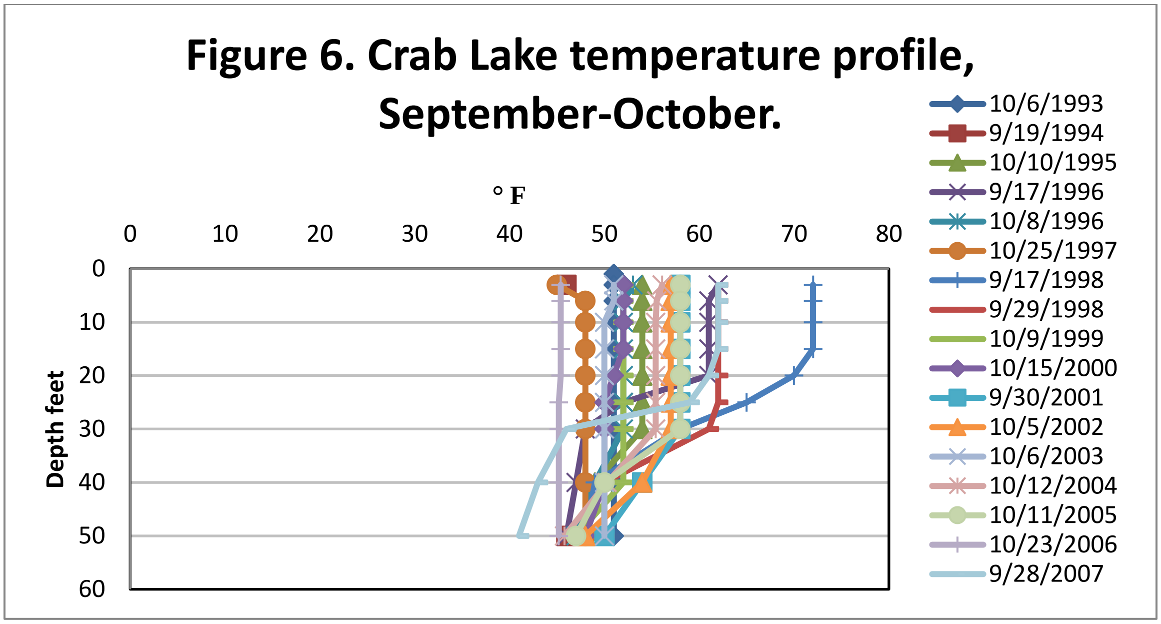
8/19/2013
8/15/2015
8/19/2019
8/20/2020



Dissolved Oxygen

The dissolved oxygen (D.O.) 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 April and May, dissolved oxygen levels were high from surface water to bottom (Figure 7). In June, there was a notable variation of dissolved oxygen content (Figure 8). The June, 1995 and 1996 D.O. levels were lower than usual. In July, D.O. levels dropped between 20 and 30 feet (Figure 9). In August, D.O. levels decreased around 20 feet (Figure 10). In September and October, mixing occurred in the lake (Figure 11).

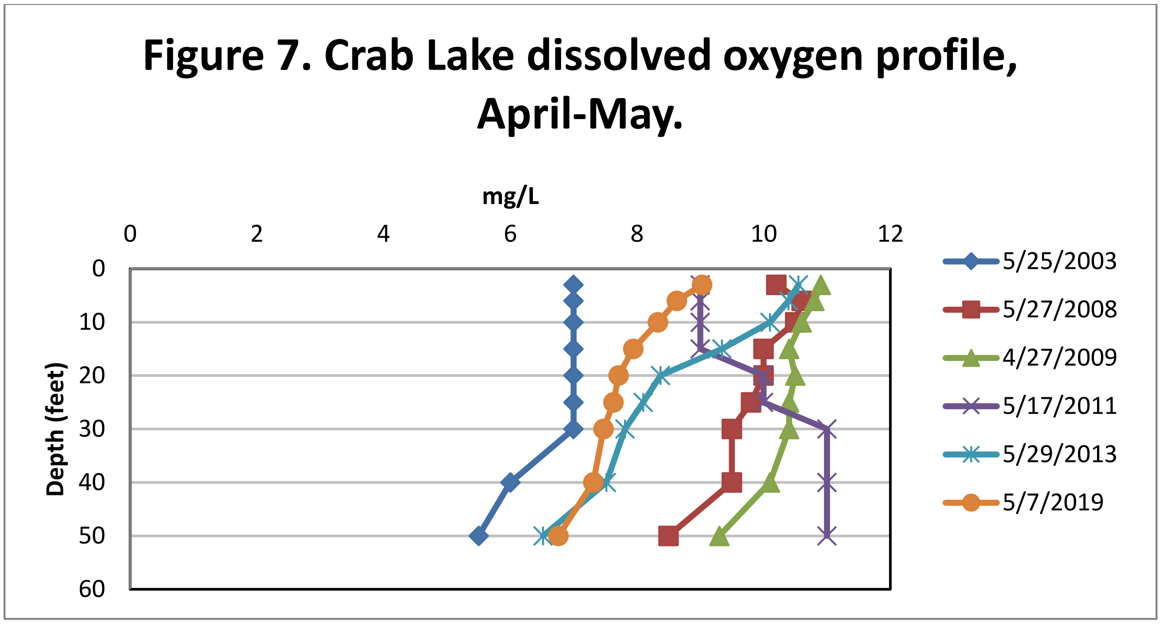


Figure 7. Crab Lake dissolved oxygen profile, April-May.
mg/L
0
2
4
6
8
10
12
Depth (feet)
0
10
20
30
40
50
60
5/25/2003
5/27/2008
4/27/2009
5/17/2011
5/29/2013
5/7/2019

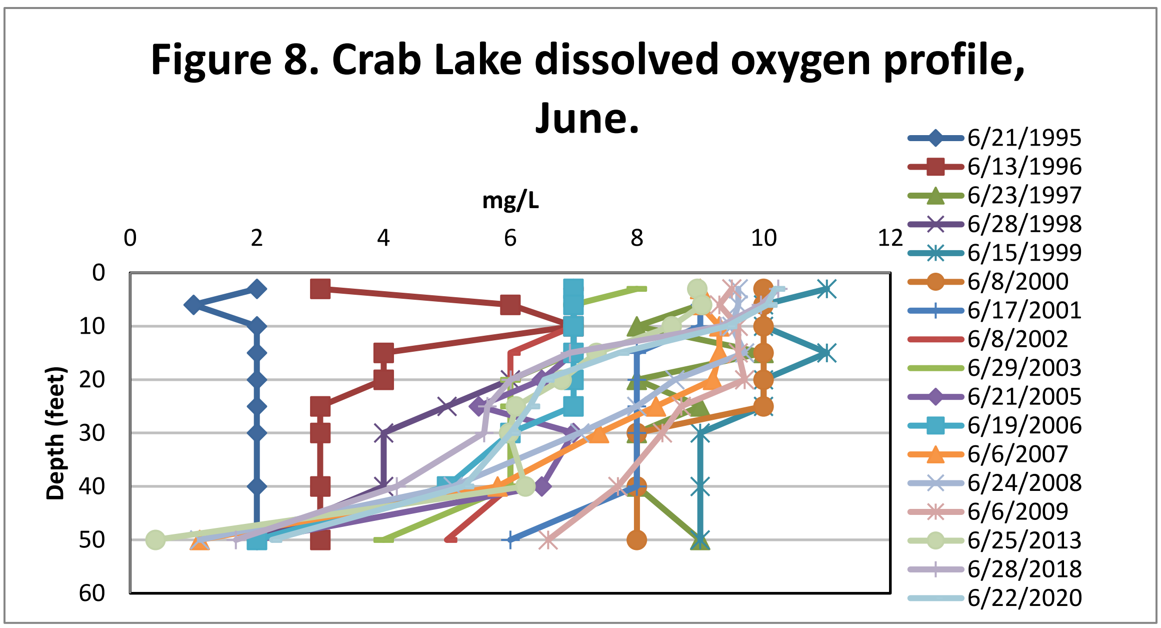


Figure 8. Crab Lake dissolved oxygen profile, June.
mg/L
0
2
4
6
8
10
12
Depth (feet)
0
10
20
30
40
50
60
6/21/1995
6/13/1996
6/23/1997
6/28/1998
6/15/1999
6/8/2000
6/17/2001
6/8/2002
6/29/2003
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6/6/2009
6/25/2013
6/28/2018
6/22/2020

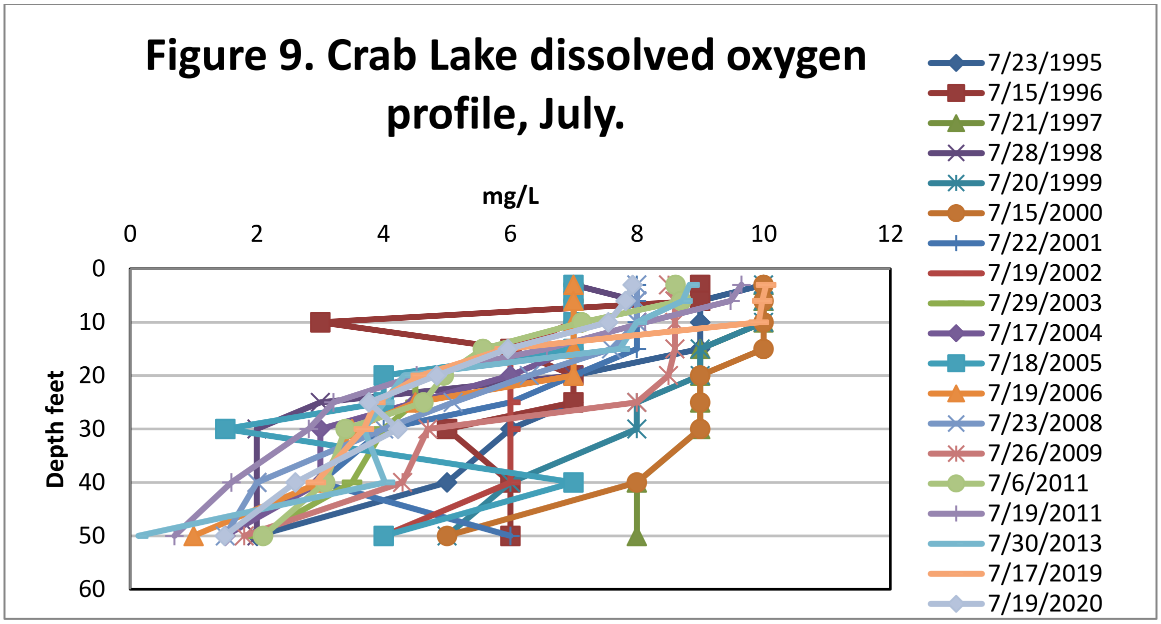
Figure 9. Crab Lake dissolved oxygen profile, July.
mg/L
0
2
4
6
8
10
12
0
10
20
30
40
50
60
Depth feet
7/23/1995
7/15/1996
7/21/1997
7/28/1998
7/20/1999
7/15/2000
7/22/2001
7/19/2002
7/29/2003
7/17/2004
7/18/2005
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7/6/2011
7/19/2011
7/30/2013
7/17/2019
7/19/2020

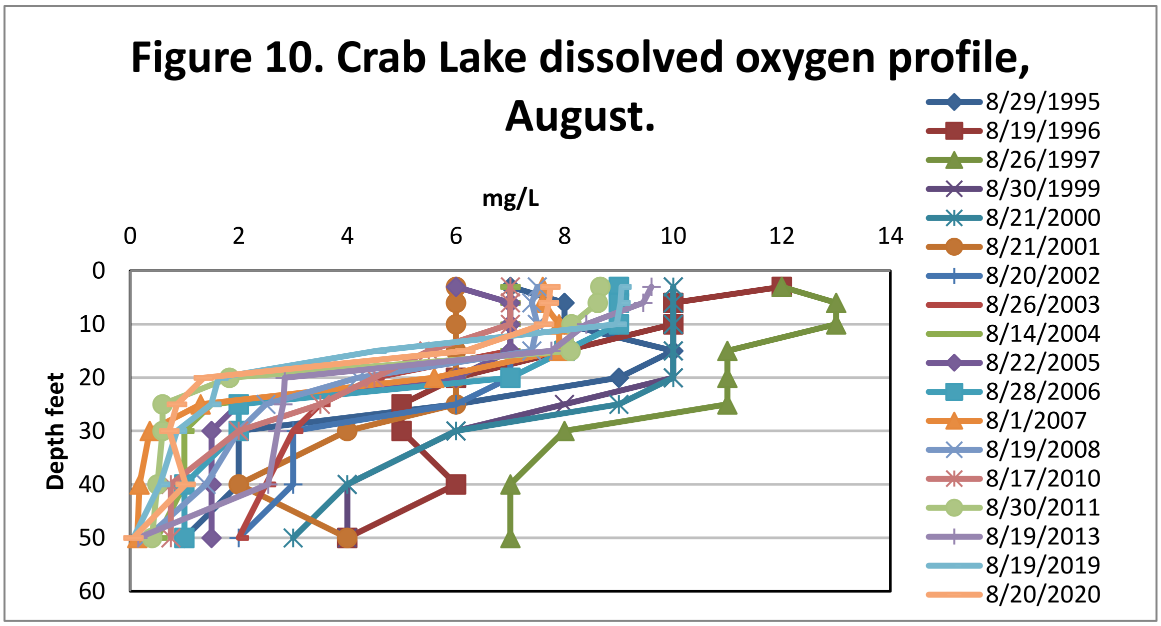
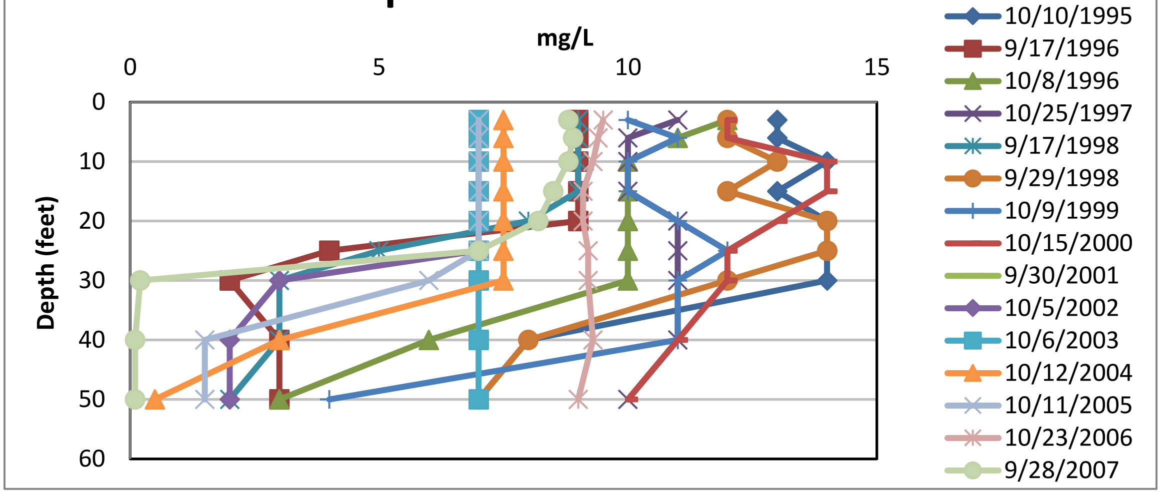


Figure 10. Crab Lake dissolved oxygen profile, August.
mg/L
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
Depth feet
8/29/1995
8/19/1996
8/26/1997
8/30/1999
8/21/2000
8/21/2001
8/20/2002
8/26/2003
8/14/2004
8/22/2005
8/28/2006
8/1/2007
8/19/2008
8/17/2010
8/30/2011
8/19/2013
8/19/2019
8/20/2020

Figure 11. Crab Lake dissolved oxygen profile, September and October.

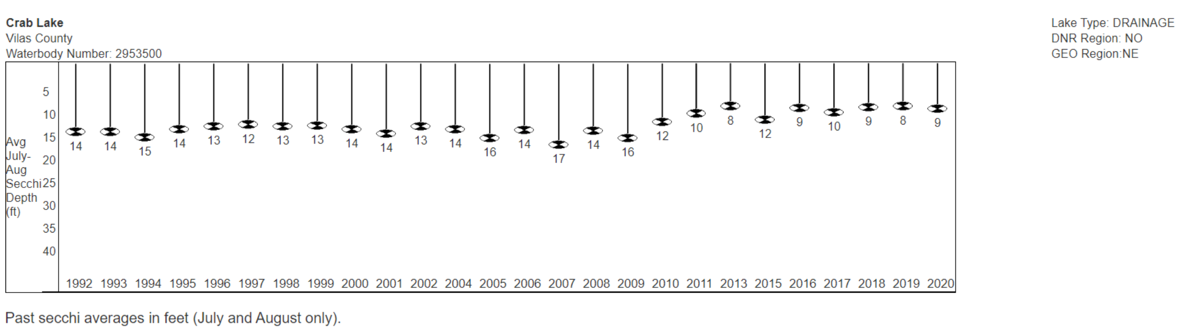


Water Clarity

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 12 shows the July and August mean Secchi depths from 1992 to 2020. The shallowest mean Secchi depth was 8.5 feet in 2013 and 2020, and the deepest reading was at 17 feet in 2007 (Figure 13). According to Table 1, Crab Lake's 2020 mean Secchi depth is considered "fair to good," with respect to water clarity.

Figure 12. Crab Lake Secchi depth averages (July and August only).



(WDNR, 2021)

Figure 13. Crab Lake's July and August Secchi Data: Mean, Min, Max, and Secchi Count (1992-2020).

Year	Secchi Mean	Secchi Min	Secchi Max	Secchi Count
1992	14.1	14	14.5	5
1993	14.25	14	15	4
1994	15.38	14.5	17	4
1995	13.5	13	14	2
1996	13	13	13	2
1997	12.5	11	14	2
1998	13	13	13	1
1999	12.83	11	14	3
2000	13.5	13	14	2
2001	14.5	14	15	2
2002	13	12	14	3
2004	13.5	13	14	2
2005	15.5	15	16	2
2006	13.75	13	14.5	2
2007	17	17	17	1
2008	14	14	14	2
2009	15.5	15.5	15.5	1
2010	12	12	12	1
2011	10.13	9	12	4
2013	8.5	8	9	2
2015	11.5	11	12	2
2016	9	9	9	2
2017	10	10	10	1
2018	8.75	7.5	10	2
2019	8.5	7	10	2
2020	9.2	8	10	5

Report Generated: 03/23/2021

(WDNR, 2020)

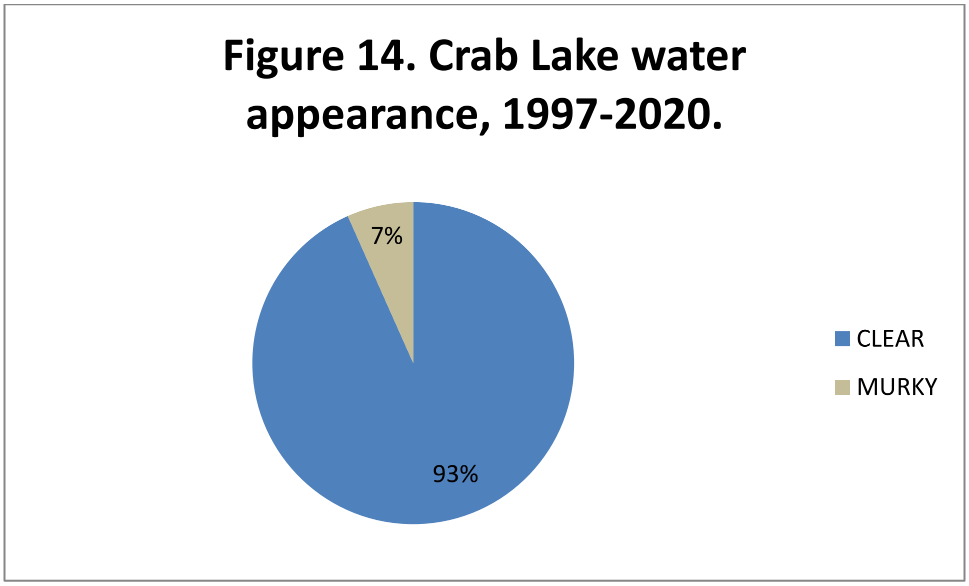
Table 1. Water clarity index (Shaw et al., 2004).

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

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. Crab Lake turbidity was analyzed in November, 2012 and had a value of 1 NTU.

While checking Secchi depth, the CLMN volunteers also rate water clarity and describe it as "clear" or "murky." From 1997 to 2020, 93% of volunteers rated the water in Crab Lake as "clear" (Figure 14).



Water Color

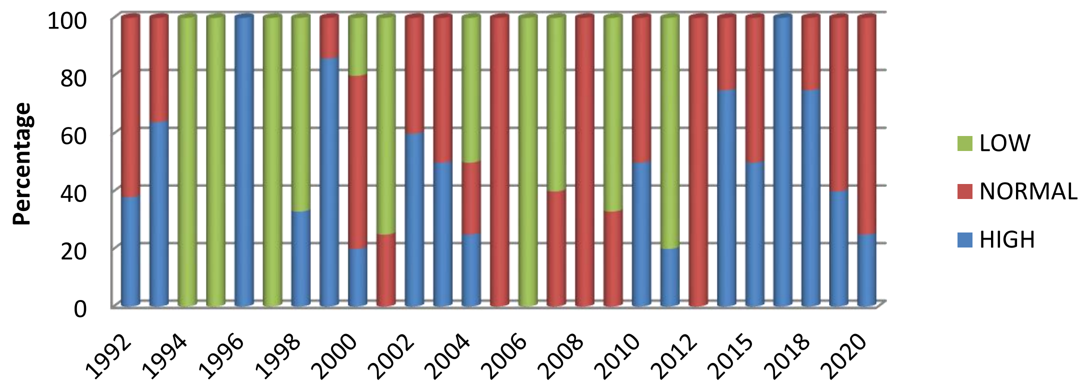
Color of lake water is related to the type and amount of dissolved organic chemicals. Its main significance is aesthetics, although it may also influence light penetration and in turn affect aquatic plant and algal growth. Many lakes have naturally occurring color compounds from decomposition of plant 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. Crab Lake water color was analyzed in November, 2012 (14.3 Pt-Co), November 2019 (54 Pt-Co), May 2020 (38 Pt-Co) and July 2020 (20 SU).

CLMN volunteers also recorded their perceptions of water color in Crab Lake. Since 1992 to 2020, 100% of volunteers indicated the water appeared "brown" in color.

Water Level

CLMN volunteers also recorded their opinion of the lake level as "high," "normal," or "low." Figure 15 displays the CLMN opinions of water level from 1992-2013. In 1994, 1995, 1997 and 2006, 100% of volunteers viewed the water level as "low." In 1996, 100% viewed the water level as "high." In 2012, 100% of volunteers viewed the water level as "normal."

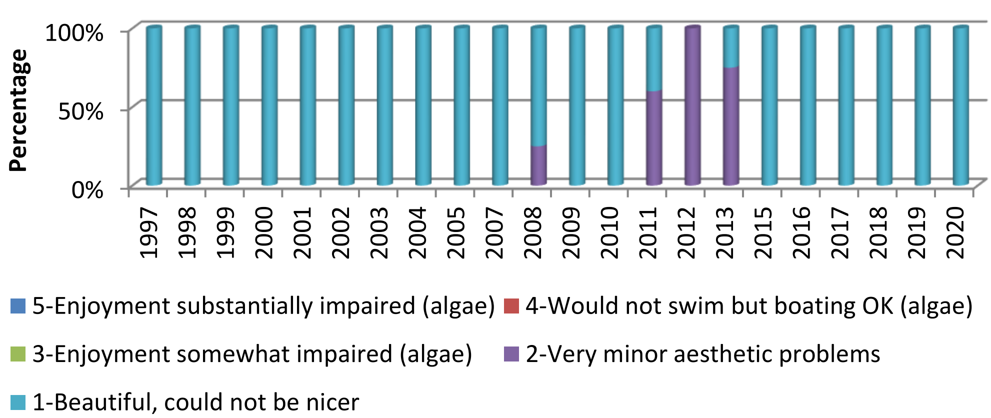
Figure 15. Crab Lake water level percentage viewed by CLMN, (1992-2020).



User Perceptions

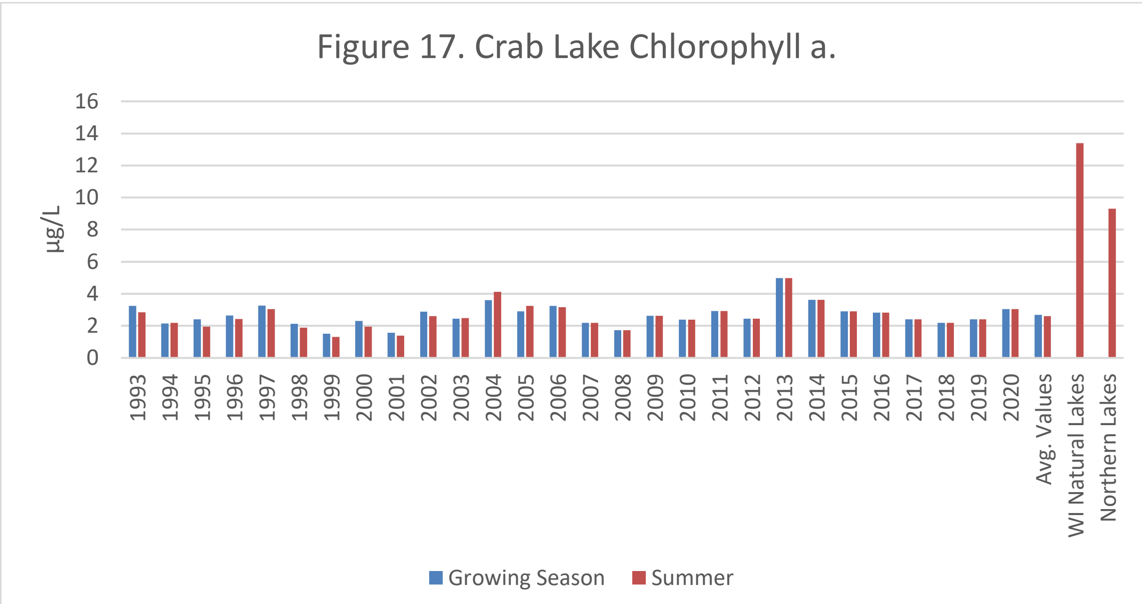
When Secchi depth readings are collected, the CLMN record their perceptions of the water, based on the physical appearance and the recreational suitability. These perceptions can be compared to water quality parameters to see how the lake user would experience the lake at that time. When interpreting 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 16. From 1992 to 2007, 2009 to 2010, and 2015 to 2020 100% of CLMN volunteers recorded Crab Lake to be "beautiful, could not be nicer." From 2011 to 2013, the majority of volunteers said Crab Lake had "very minor aesthetic problems."

Figure 16. Crab Lake aesthetic value, (1992-2020).



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* was analyzed on a routine basis in Crab Lake. Figure 17 displays the chlorophyll *a* values from 1993 to 2020 during the growing season (April-May) and summer season (June-August). As we can see, chlorophyll *a* values were well below nuisance levels and well below the average levels for Wisconsin natural lakes.

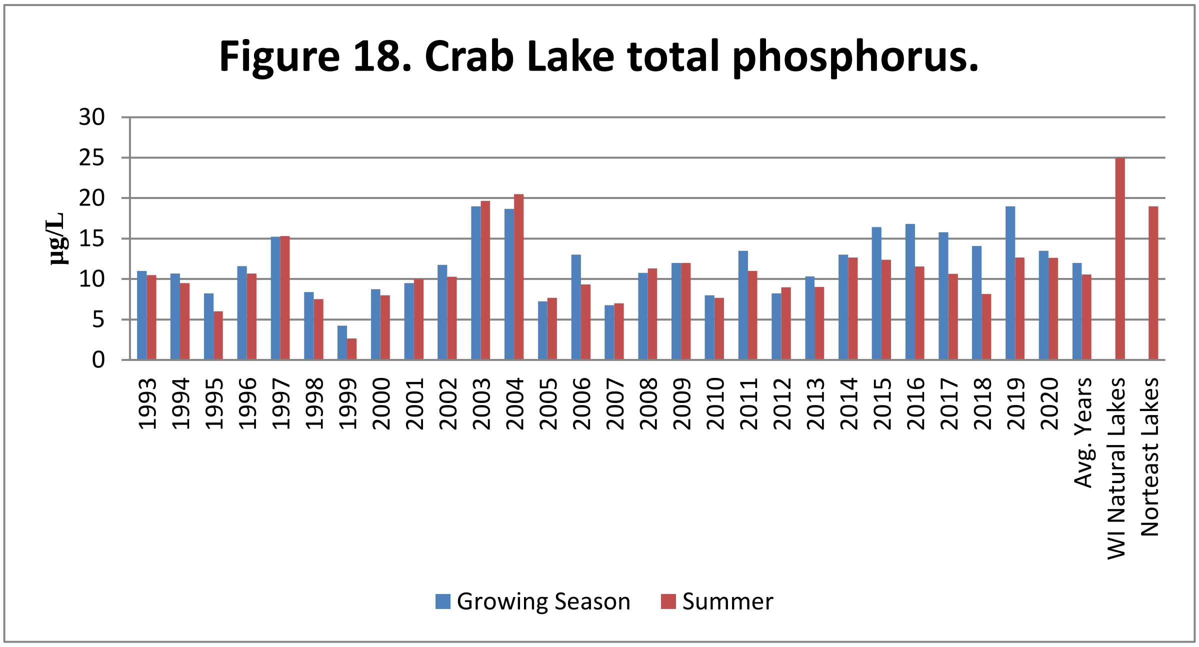


Phosphorus

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). Crab Lake total phosphorus values were collected from 1993 to 2020 during the growing and summer seasons (Figure 18). Total phosphorus levels remained at or below the nuisance threshold. According to Figure 20, the average total phosphorus for

Crab Lake (11.98) can be categorized as “very good.” Ortho phosphate was analyzed November 4, 2019 (0.009 mg/L) and on May 8, 2020 (0.003 mg/L).



Total phosphorus was also analyzed at 45 feet (considered the hypolimnion) (Figure 19). In the hypolimnion, total phosphorus values were above the threshold value.

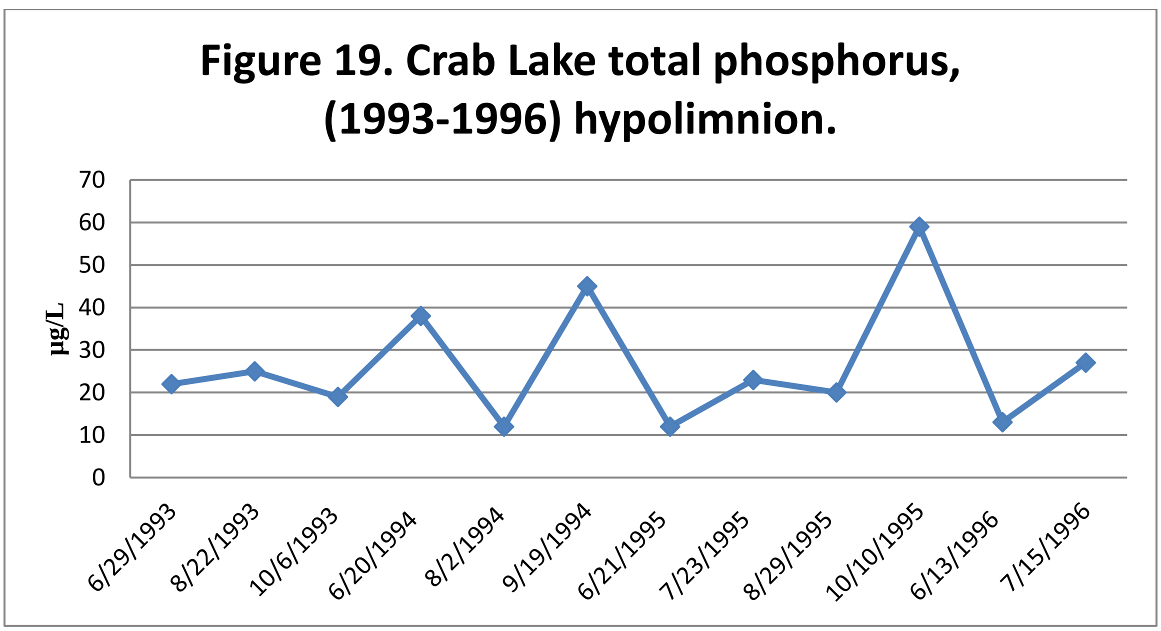
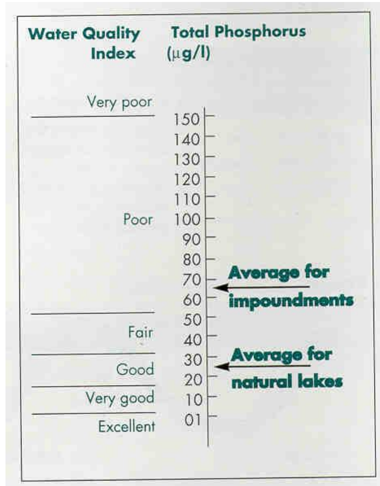


Figure 20. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments (Shaw et al., 2004).

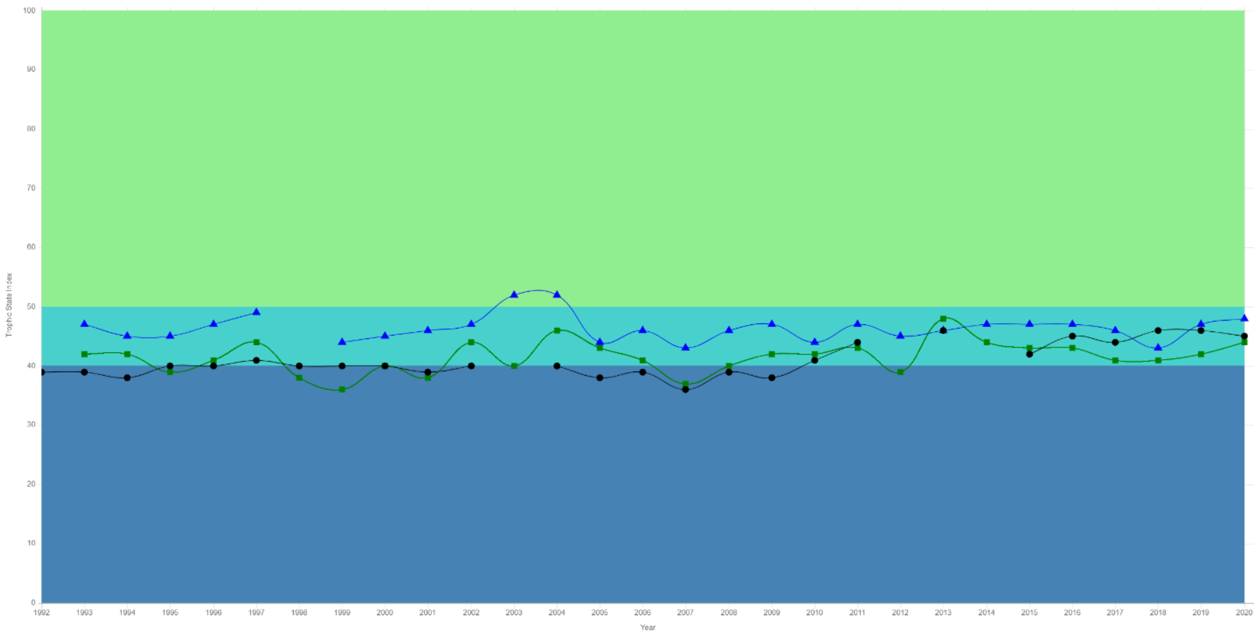


Trophic State

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 Secchi measurements in various years between 1992 and 2020, chlorophyll *a* (1993-2020), and total phosphorus (1993-2020) collected by the CLMN (Figure 21). The 2020 average Secchi TSI (45), chlorophyll *a* TSI (44) and total phosphorus TSI (48) classifies Crab Lake as "mesotrophic" (Table 2).

Figure 21. Crab Lake Trophic State Index (1992-2020).



(WDNR, 2021)

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, 2014)

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).

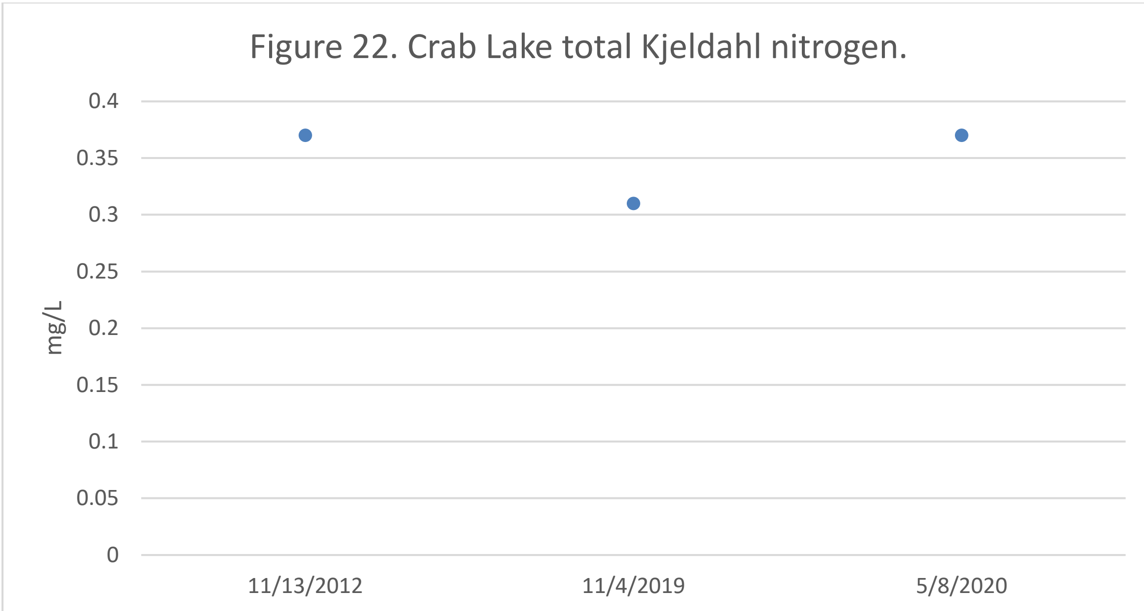
Table 3. Trophic classification of Wisconsin Lakes based on chlorophyll *a*, water clarity measurements, and total phosphorus values (Shaw et al., 2004).

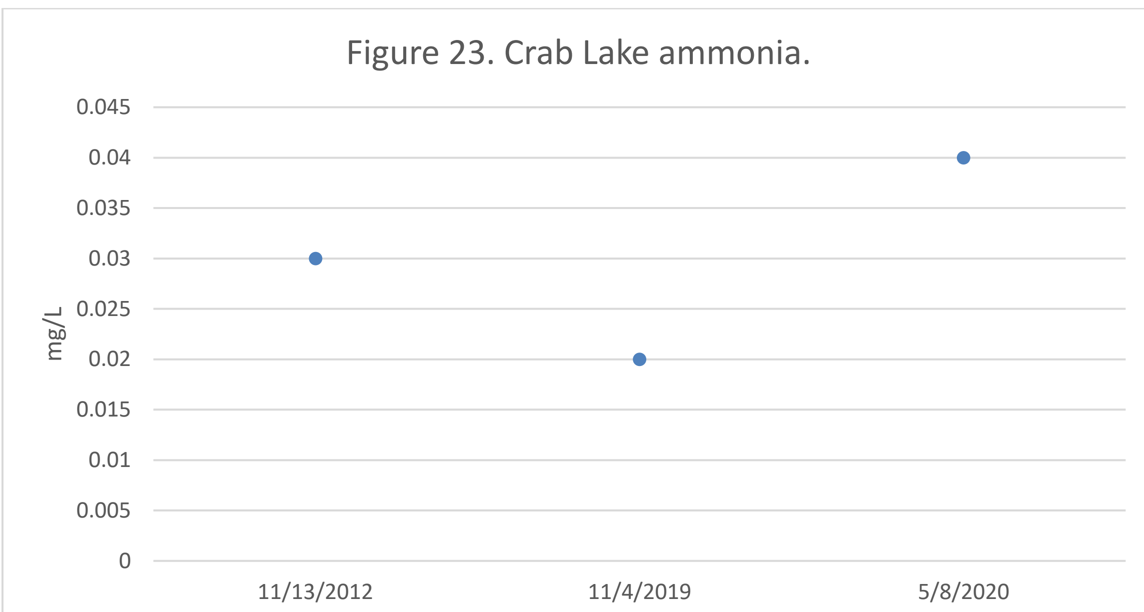
Trophic class	Total phosphorus µg/L	Chlorophyll *a* µg/L	Secchi Disk (ft.)
Oligotrophic	3	2	12
	10	5	8
Mesotrophic	18	8	6
	27	10	6
Eutrophic	30	11	5
	50	15	4

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. Crab Lake was analyzed for total Kjeldahl (Figure 22), ammonia (Figure 23), and nitrate-nitrite (0.04 mg/L in November, 2012, and no detection on November 4, 2019 and May 8, 2020). 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). Crab Lake chloride level was < 0.2 mg/L in November 13, 2012 and no detection November 4, 2019 and May 8, 2020. The chloride concentration was well below the generalized distribution gradient found in surface waters in Wisconsin.

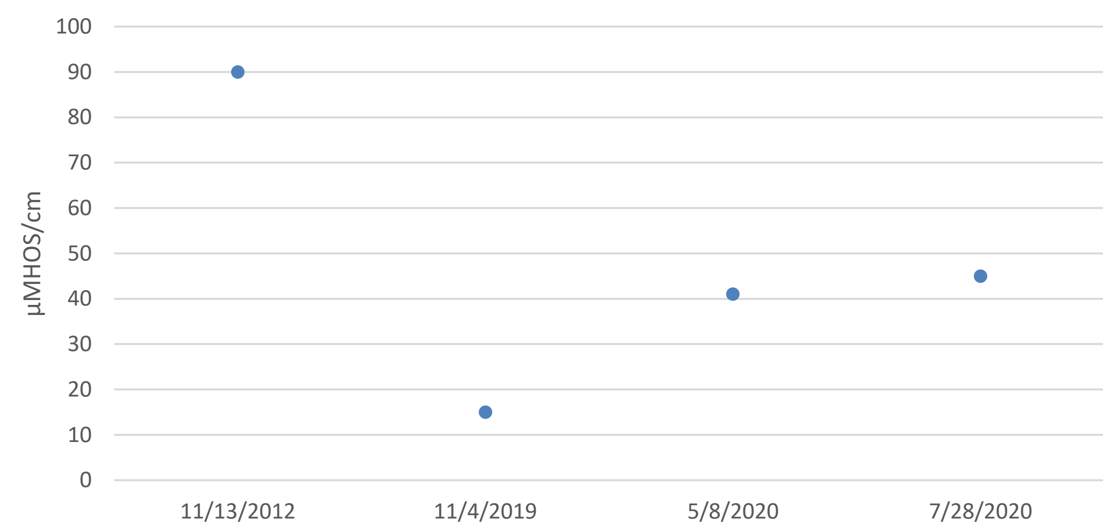
Sulfate

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). University of Wisconsin-Steven's Point laboratory sampled Crab Lake in November, 2012. They calculated a sulfur-ICP (inductively coupled plasma) value of 27.31 mg/L. Sulfate was at no detection July 28, 2020.

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). Crab Lake conductivity levels are displayed in Figure 24.

Figure 24. Crab Lake conductivity.



pH

The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is considered neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid, bog lakes to 8.4 in marl lakes (Shaw et al., 2004). Natural 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. Crab Lake pH is shown in Figure 25 and in the years sampled is close to a neutral pH.

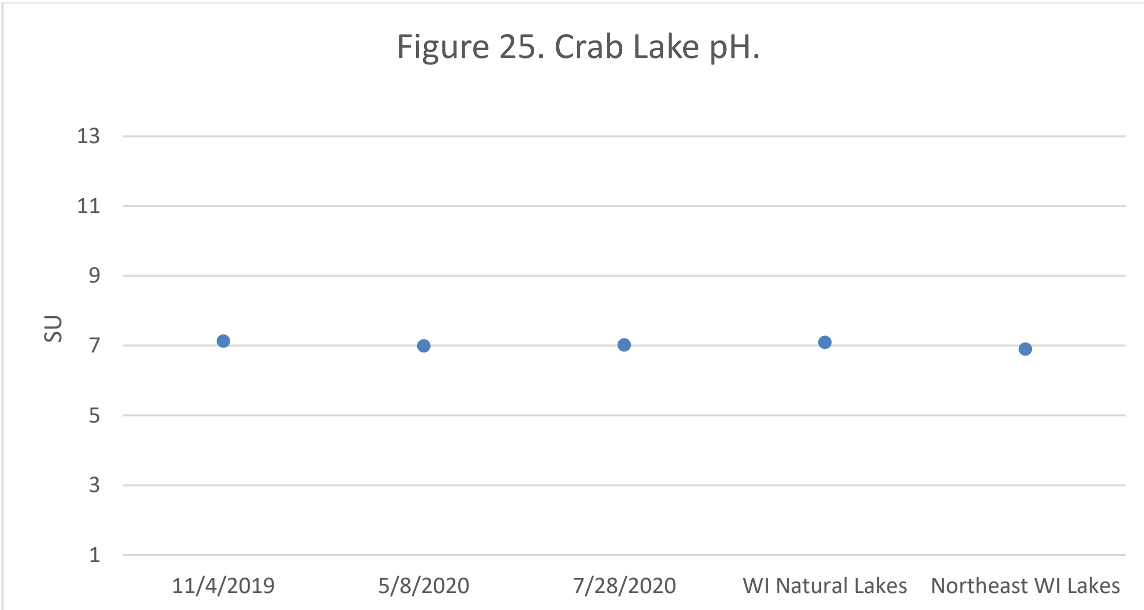


Table 4 indicates the effects pH levels less than 6.5 will have on fish. While moderately low pH does not usually harm fish, the metals that become soluble under low pH can be important. In low pH waters, aluminum, zinc, and mercury concentrations increase if they are present in lake sediment or watershed solids (Shaw et al., 2004).

Table 4. Effects of acidity on fish species (Olszyk, 1980).

Water pH	*Effects*
6.5	Walleye spawning inhibited
5.8	Lake trout spawning inhibited
5.5	Smallmouth bass disappear
5.2	Walleye & lake trout disappear
5	Spawning inhibited in most fish
4.7	Northern pike, sucker, bullhead, pumpkinseed, sunfish & rock bass disappear
4.5	Perch spawning inhibited
3.5	Perch disappear
3	Toxic to all fish

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. In November, 2012 alkalinity in Crab Lake was < 4 mg/L and had no detection on May 8, 2020 and July 28, 2020.

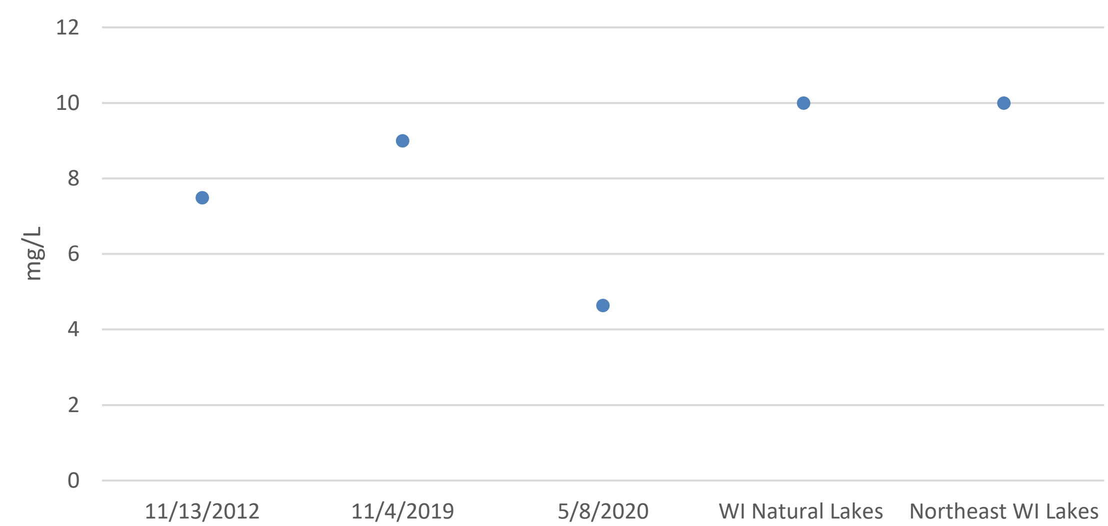
Hardness

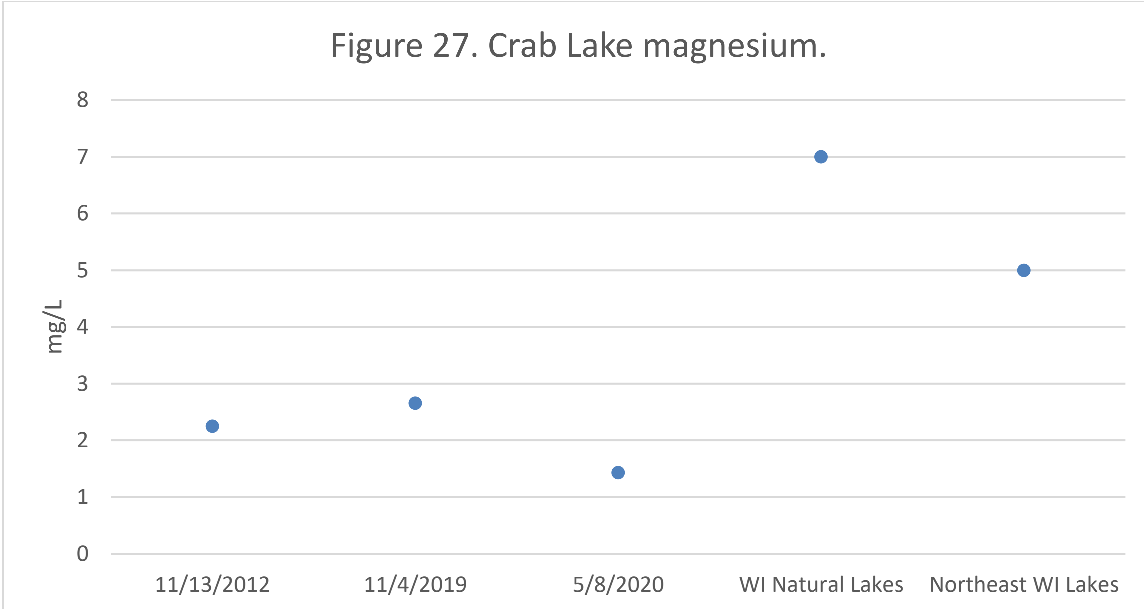
Hardness levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water and these materials (Shaw et al., 2004). One method of evaluating hardness is to test for calcium carbonate ($CaCO_3$). Crab Lake hardness was 33.41 mg/L on November 4, 2019.

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. Crab Lake has had calcium measured in 2012, 2019, and 2020 with values below 10 mg/L (Figure 26) which is an indication that zebra mussels could not flourish. Magnesium was also sampled on three occasions (Figure 27).

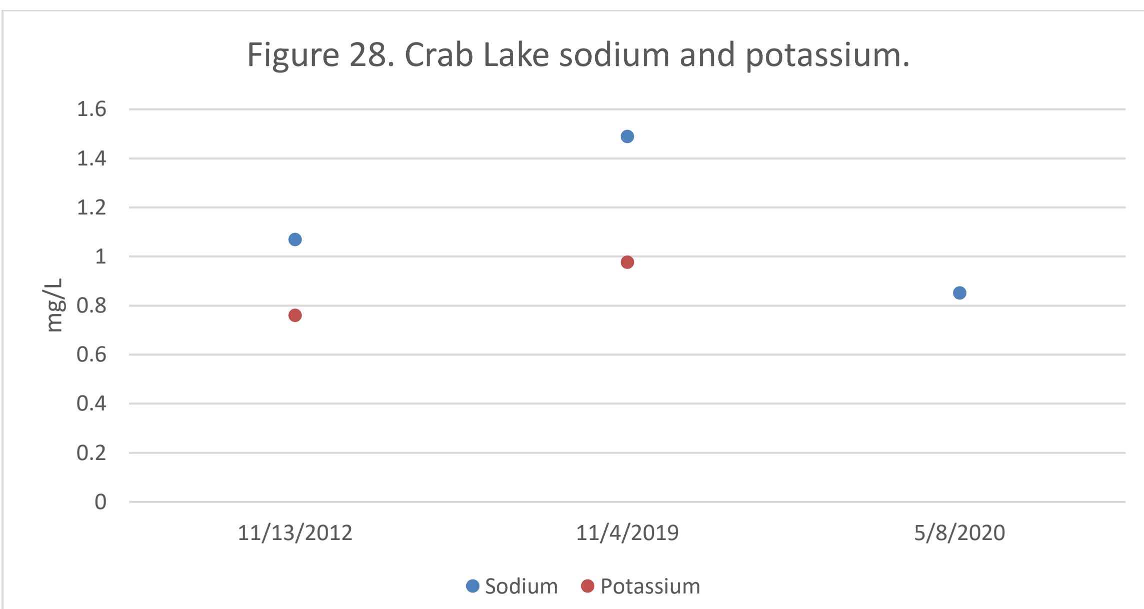
Figure 26. Crab Lake calcium.





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). Figure 28 has the Crab Lake sodium and potassium values for 2012, 2019 and 2020.



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. Crab Lake DOC was analyzed in August 2014 (8.06 mg/L), June 2014 (8.78 mg/L), and July 2015 (9.63 mg/L).

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. Crab Lake silica levels have not been tested, and should be included in future water quality sampling.

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. Crab Lake aluminum levels have not been tested, and should be included in future water quality sampling.

Iron

Iron also forms sediment particles that 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. Crab Lake iron levels have not been tested, and should be included in future water quality sampling.

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 data is unknown for Crab Lake, so future water quality sampling should include this parameter.

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 Crab Lake, and future sampling should include this parameter.

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 data is unknown for Crab Lake, so future water quality sampling should include this parameter.

Aquatic Invasive Species

There are two invasive species found in Crab Lake: common reed (2010) and rusty crayfish (2009).

The University of Wisconsin-Madison's Aquatic Invasive Species Smart Prevention program classifies Crab Lake as "Not Suitable" for zebra mussels, based on calcium and conductivity levels found in the lake (UW-Madison).

AIS monitoring has been conducted by a Citizen Aquatic Invasive volunteer in 2009 and 2010. In 2009, curly-leaf pondweed, Eurasian water-milfoil, zebra mussels, rusty crayfish and purple loosestrife were monitored. The volunteer said the rusty crayfish and purple loosestrife were present. No coordinates were recorded for the purple loosestrife observation, so future searches of purple loosestrife around Crab Lake would be beneficial. In 2010, the volunteer looked for some additional invasives such as the Chinese mystery snail, banded mystery snail, freshwater jellyfish, hydrilla, and the spiny waterflea. The only AIS found was the rusty crayfish.

Additional AIS monitoring was conducted in July and August, 2010 by the DNR using a zooplankton tow for zebra mussel veligers, with no finds. In September, 2012 an expansion for the AIS survey included a plankton tow for spiny and the fishhook water fleas, with no finds. The DNR also searched for purple loosestrife, *Phragmites*, flowering rush, hydrilla, Brazilian waterweed, Eurasian water-milfoil, curly-leaf pondweed, yellow floating heart, quagga mussels, zebra mussels, New Zealand mudsnail, faucet snail, red swamp crayfish, Chinese mystery snail, and banded mystery snail. Only *Phragmites* was present.

September 1, 2002 AIS baseline monitoring was conducted and Phragmites was noted. August 20, 2019 a volunteer noted the yellow iris. On June 11, 2020 White Water Associates biologist conducted a AIS

Survey and aquatic forget-me-not, hybrid cattail, rusty crayfish, and the yellow iris were noted. A full report can be found in Appendix E.

Clean Boats, Clean Waters (CBCW) is a program that inspects boats for aquatic invasive species and in the process educates the public on how to help stop the spread of these species. Clean Boats, Clean Waters inspected 392 boats on Crab Lake in 2019 with 591 people contacted and 539 boats with 683 people contacted in 2020 (Figure 29). Some boaters were contacted more than once by CBCW and 100% were willing to answer questions (Figure 30). Seventy-four percent of patrons asked said they were on a different waterbody in the last five days (Figure 31). This high percentage makes education on how to stop the spread of AIS an important part of the CBCW. Figure 31 indicates that the majority of people understood the information. It would be beneficial to continue with the CBCW boat inspections to educate boaters about aquatic invasive species and to minimize the transfer of aquatic invasive species to other water bodies.

Figure 29. Crab Lake Clean Boats Clean Waters data (WDNR, 2021).

Figure 30. Crab Lake Clean Boats Clean Waters data (WDNR, 2021).

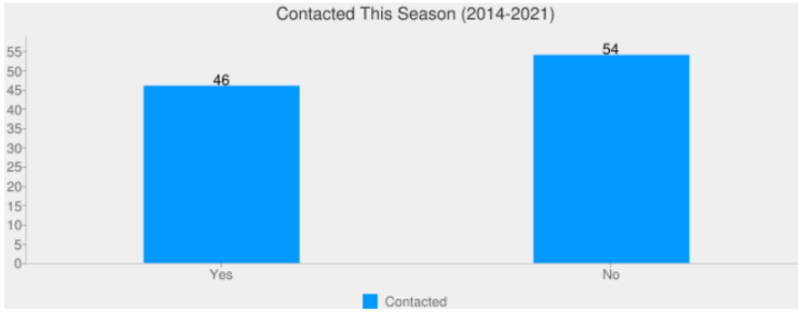
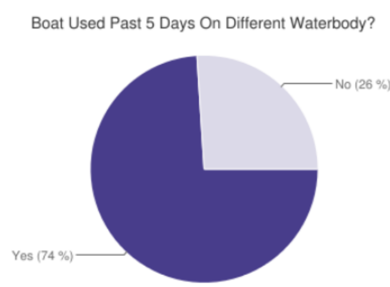
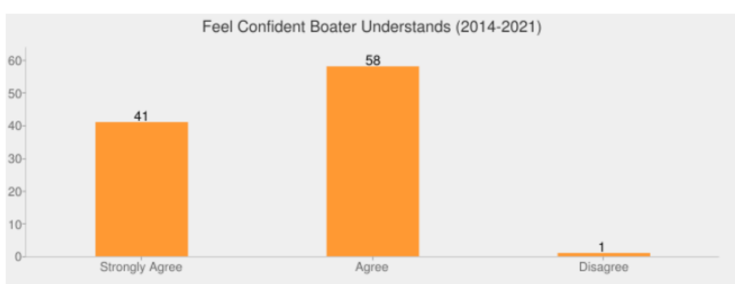


Figure 31. Crab Lake Clean Boats Clean Waters data (WDNR, 2021).





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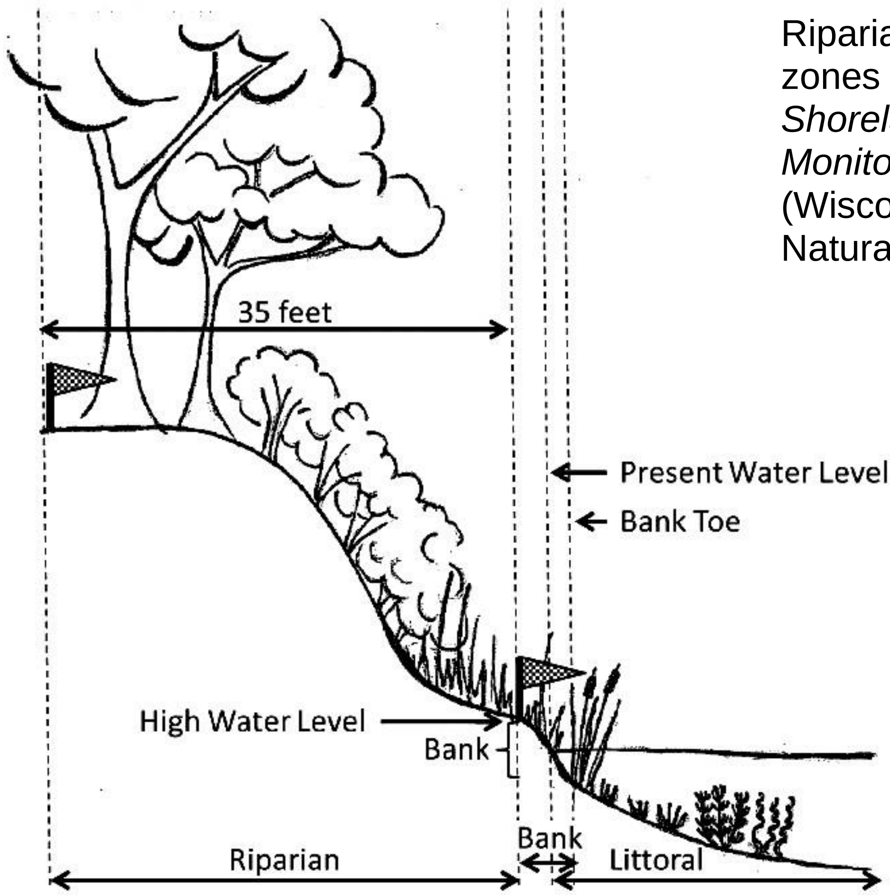
Appendix D

Crab Lake Shoreland and Shallows

Habitat Monitoring Report

Crab 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: 2020

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 Crab 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. An example shoreland photograph is shown on next page. 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.

Photo of the water's edge and understory vegetation on Crab Lake (White Water Associates, Inc., 2020)

The shoreline habitat assessment was conducted for every ownership parcel on the lake. To facilitate this effort, parcel data was obtained March 2019 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. The map is provided as Exhibit 1. 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 Crab 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 June 8 and 9, 2020. At the time of the survey there were 118 ownership parcels on Crab Lake. The shoreline perimeter of Crab Lake is 15.113 miles. Exhibit 4 summarizes some of the Crab Lake data. Exhibits 5 through 13 provide maps of findings on Crab 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. Exhibit 14 provides instructions for navigating the WDNR AIS Mapping Tool.

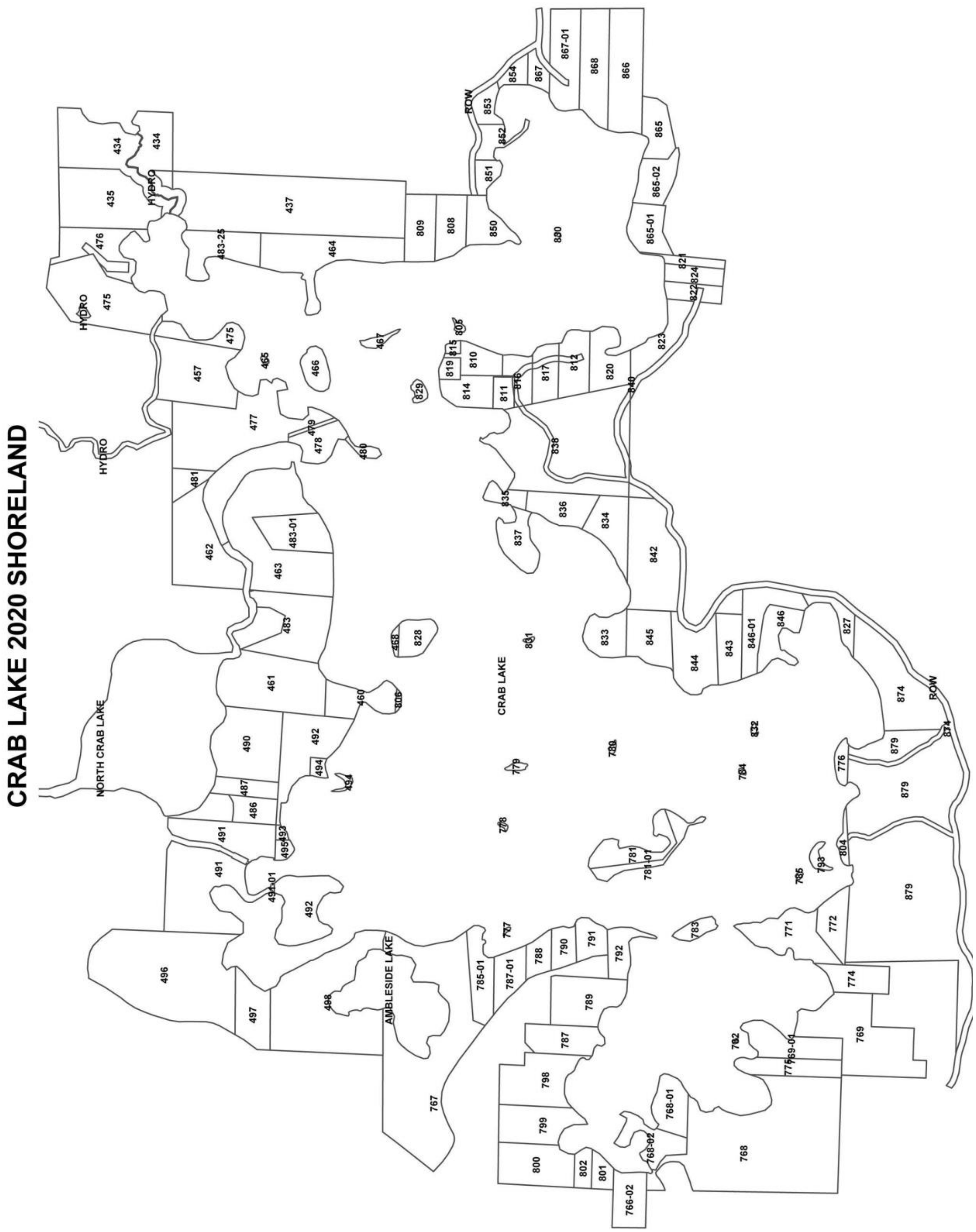
In general, the assessment shows the shoreland and shallow water habitat of Crab Lake to be of high quality. There is excellent tree canopy coverage as well as shrub and herbaceous coverage. That being said, there is evidence of human influence in the riparian buffer zone and bank zone. The number of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

It should be noted that this report has summarized only some of the data collected during the assessment in order to exemplify how the data might be investigated. This only hints at the possibilities and interested stakeholders can sort through more shoreland data on the WDNR data base (see Exhibit 14 for instructions).

LAKE STRATEGY

Crab 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 Crab 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 2020 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). Crab Lake large woody habitat is average but in areas that are sparse the habitat could be augmented with the “fish sticks” best practice.

Exhibit 1. Shoreland Parcels.



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			

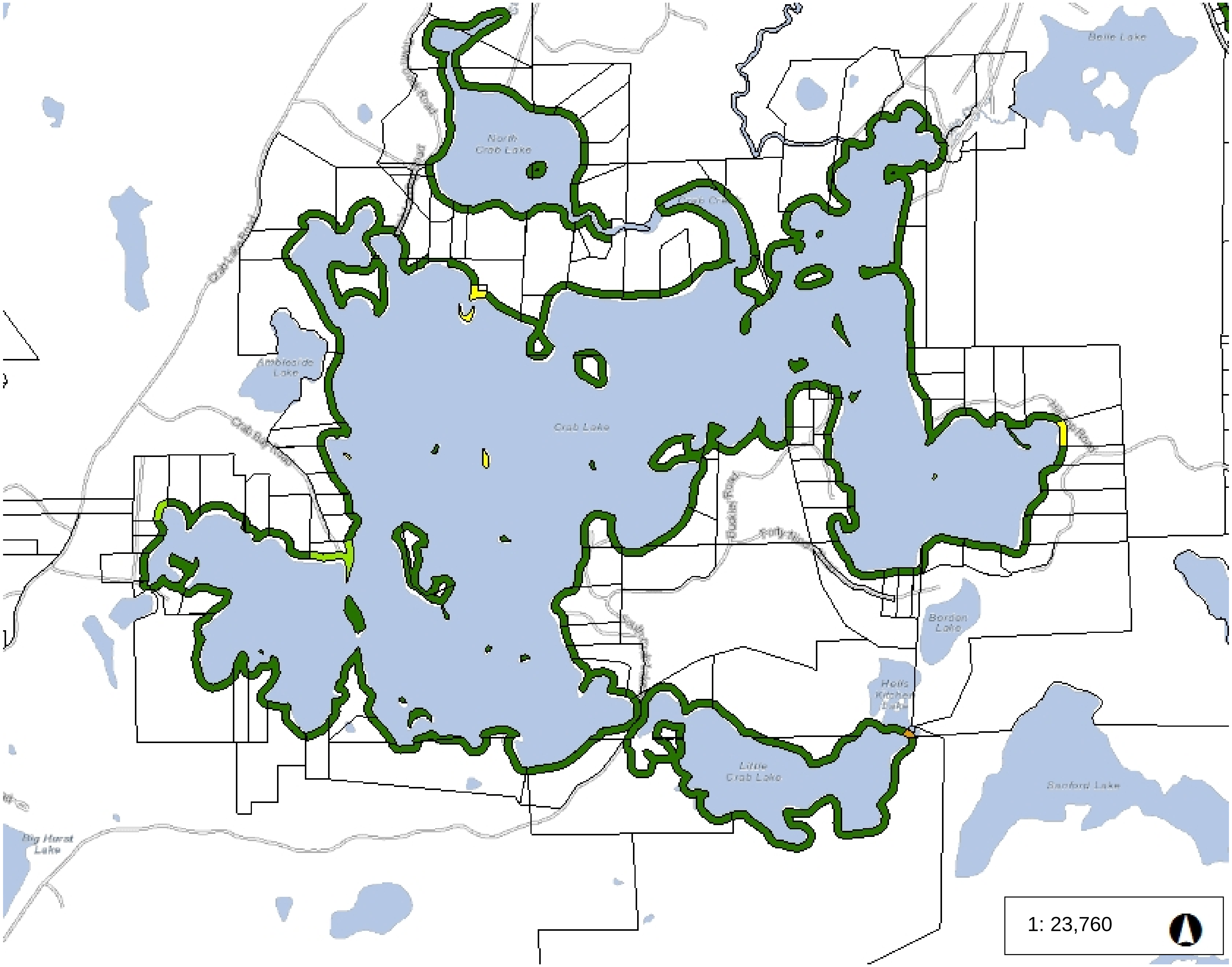
Branch: 0 = no branches, 1 = a few branches, 2 = full tree crown

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 Crab Lake.		
Date of Survey: June 8 and 9, 2020	Miles of shoreline: 15.113	
Number of ownership parcels: 118	Mean parcel frontage feet: 806	
Riparian Buffer Zone	# of parcels	% of parcels
Impervious surfaces	78	64
Manicured lawn	34	29
Agriculture	0	0
Other (duff, soil, mulch)	39	33
Human structures (buildings, boats on shore, fire pit, other)	78	66
Broad runoff concerns (incl. point source; channelized water flow; straight stair, trail, or road to lake; lawn or soil sloping; bare soil; sand/silt deposits; other erosion). Note: Exhibit 10 is less inclusive	71	60
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)	5	4
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)	67	57
Emergent and/or floating aquatic plants	104	88
Evidence of aquatic plant removal	0	0
Large Wood Habitat		
Total Number of large wood pieces	1094	
Number of large wood pieces per mile of shoreline	60.7	

Exhibit 5. Crab Lake Riparian Coverage - % Canopy - 2020



1: 23,760

Legend

Percent Canopy
- 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

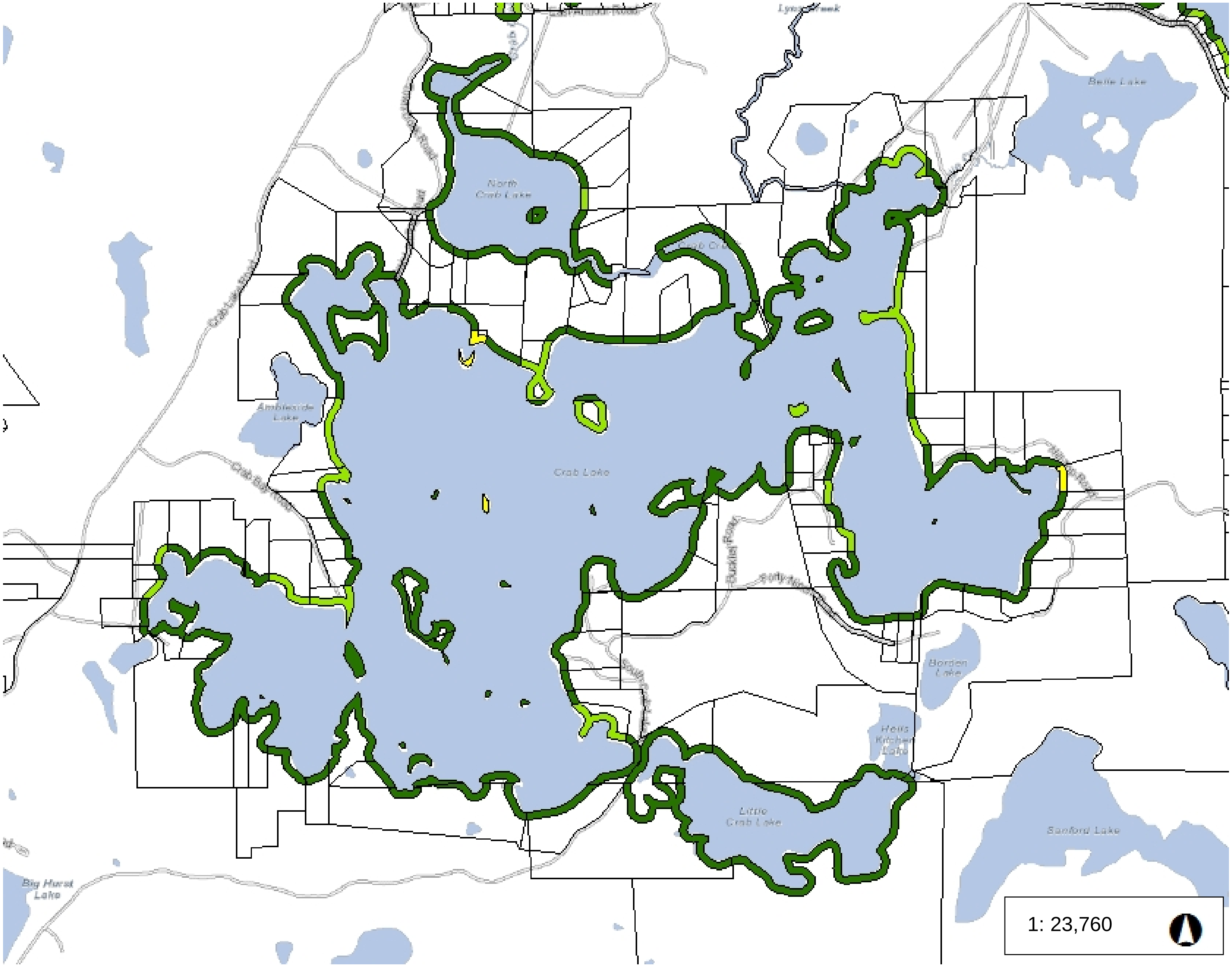
Railroads
Tribal Lands
Rivers and Streams
Intermittent Streams
Open Water
Great Lakes

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 6. Crab Lake Riparian Coverage - % Shrub Herbaceous - 2020



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

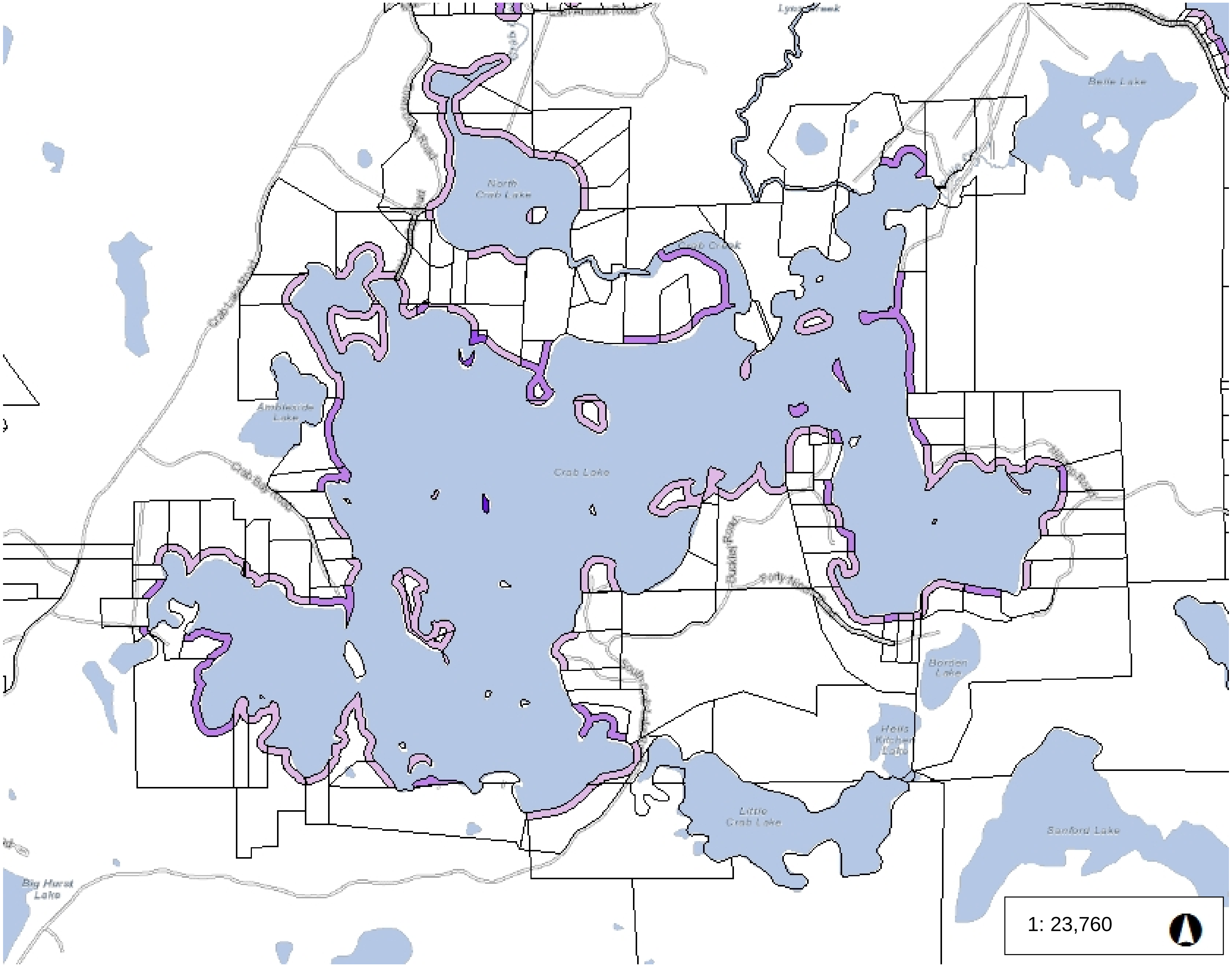
Railroads
Tribal Lands
Rivers and Streams
Intermittent Streams
Open Water
Great Lakes

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 7. Crab Lake Riparian Coverage - % Impervious - 2020



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

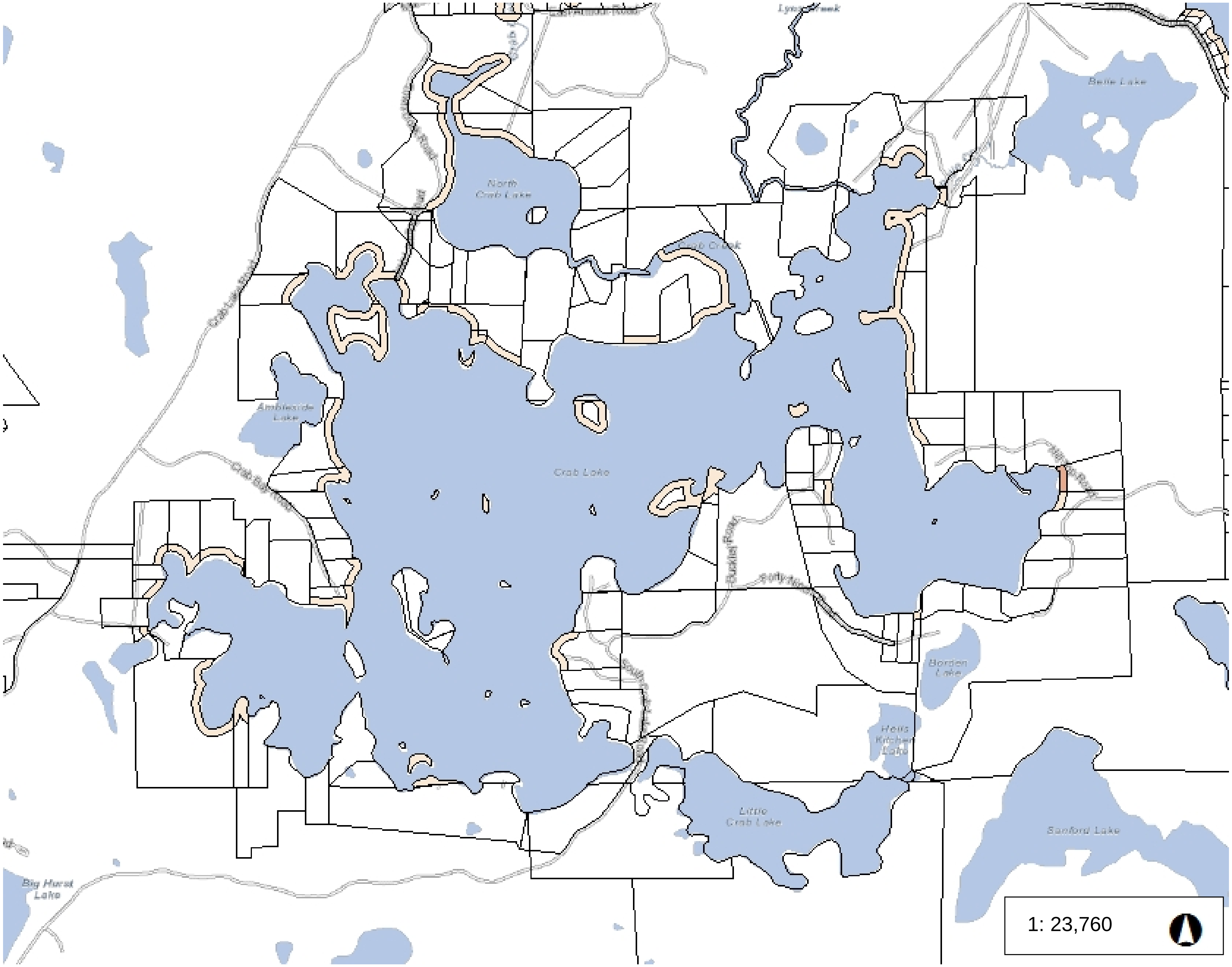
1: 23,760

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 8. Crab Lake Riparian Coverage - % Manicured Lawn - 2020



Legend

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

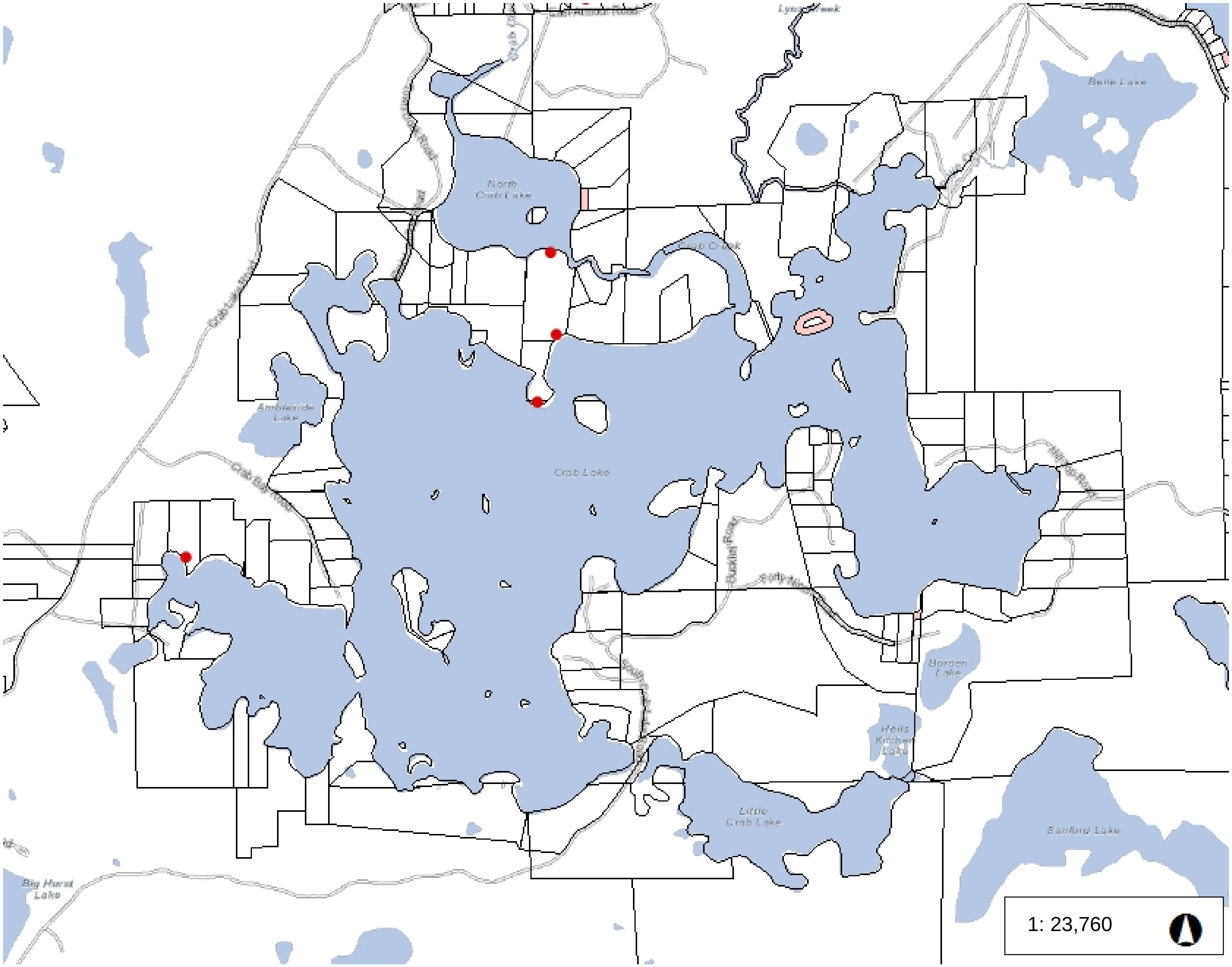
1: 23,760

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 9. Crab Lake Bank Erosion and Modifications - 2020



1: 23,760

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

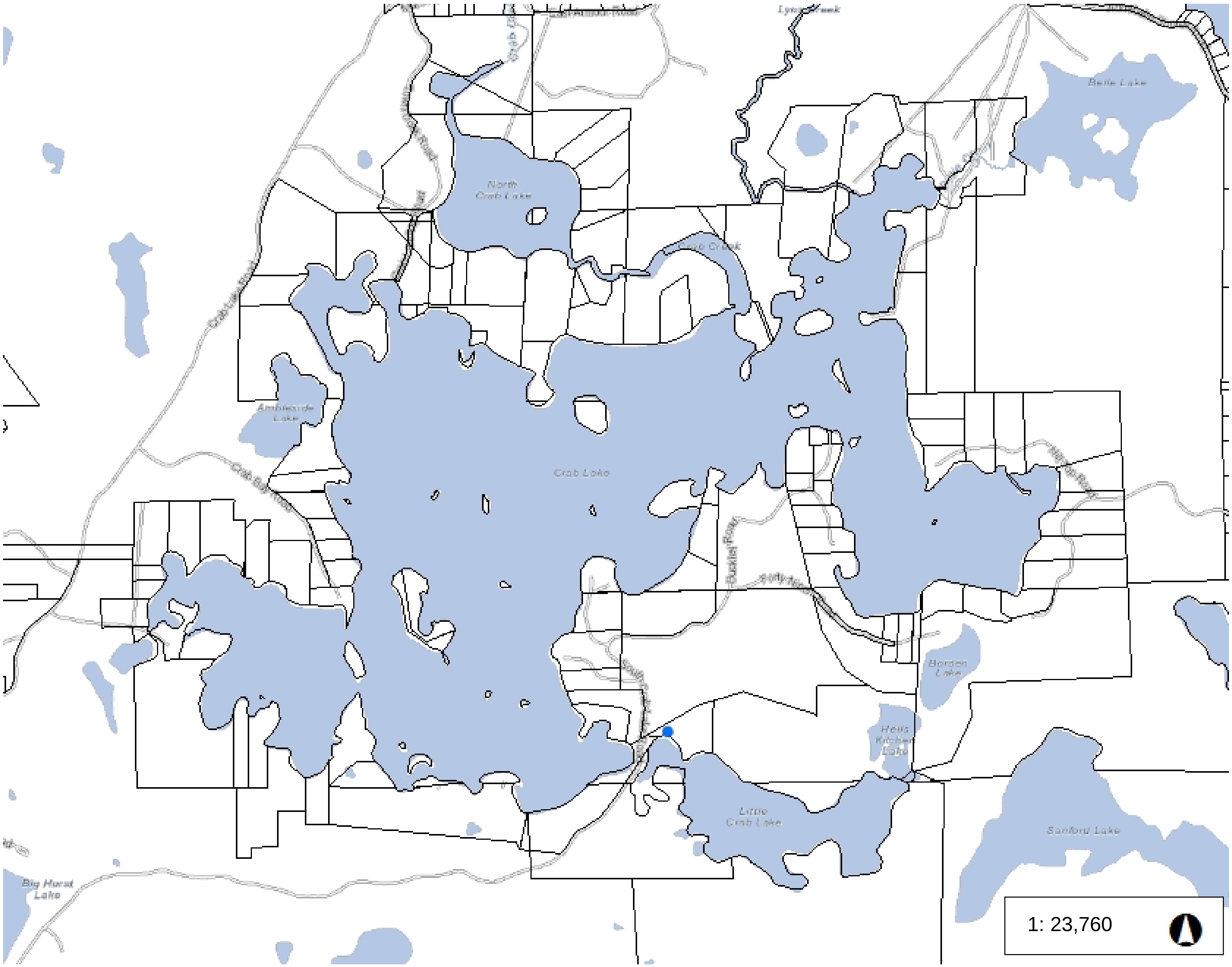
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 10. Crab Lake Runoff Concerns - 2020



Legend

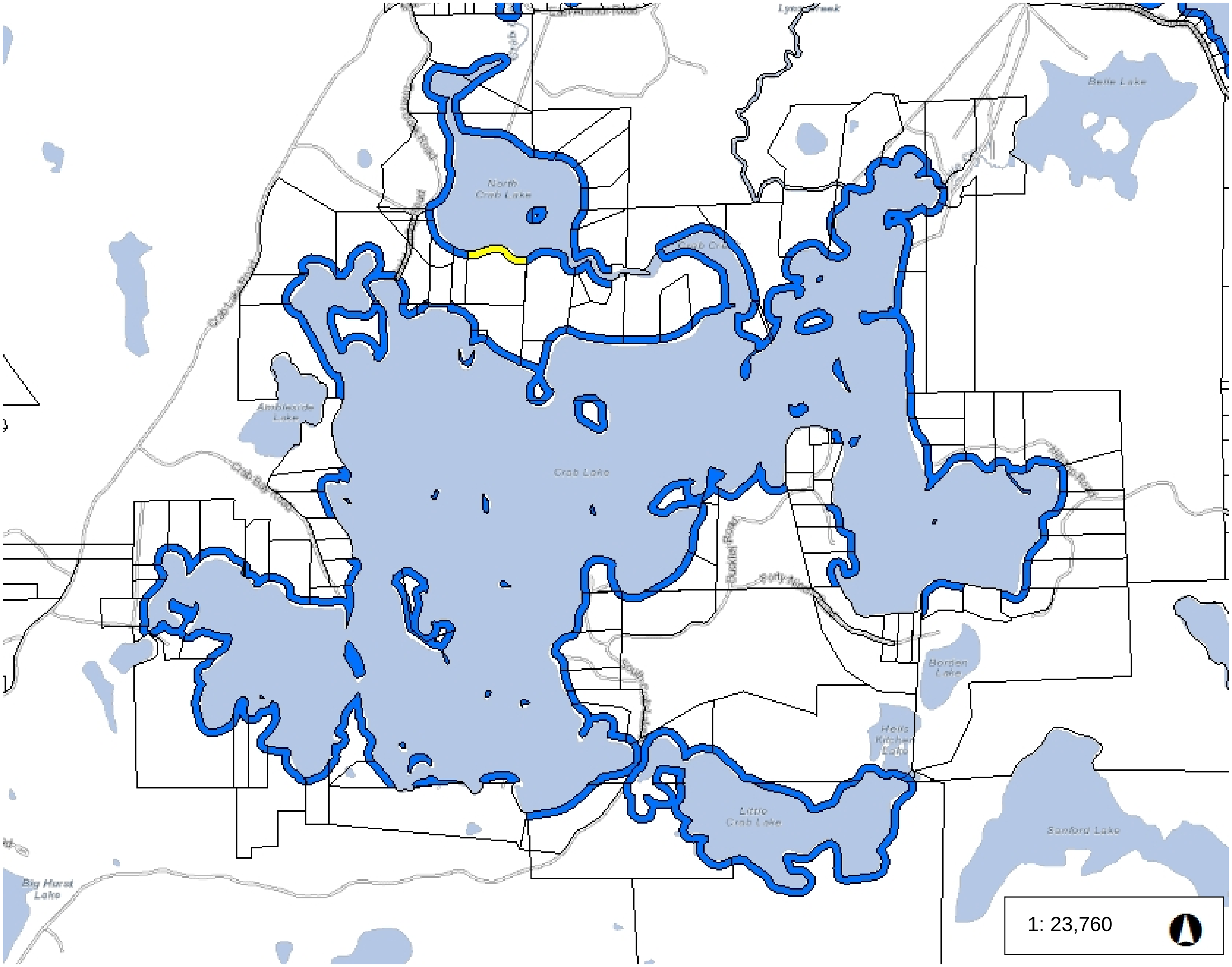
- Channelized Flow
- Point Source
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local Road
- Railroads
- Tribal Lands
- Rivers and Streams
-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

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 11. Crab Lake Littoral Zone - Aquatic Plants - 2020



1: 23,760

Legend

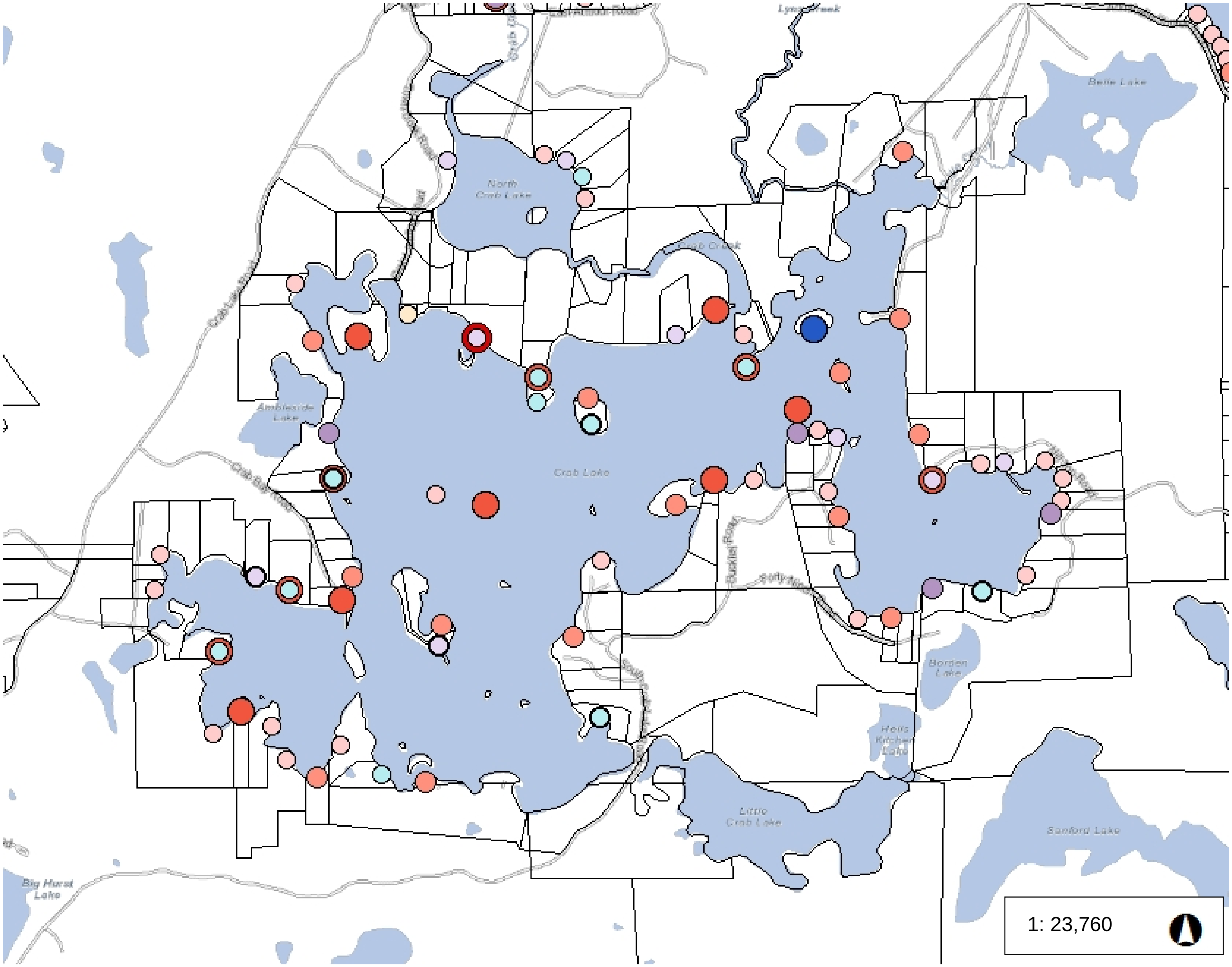
- Aquatic Plant Removal
- Floating & Emergent Plants
- Emergent Plants
- Floating Plants
- Shoreland Parcels
- County Boundary
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local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

Notes

0.8 | 0 | 0.38 | 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 12. Crab Lake Human Structures - 2020



1: 23,760

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+

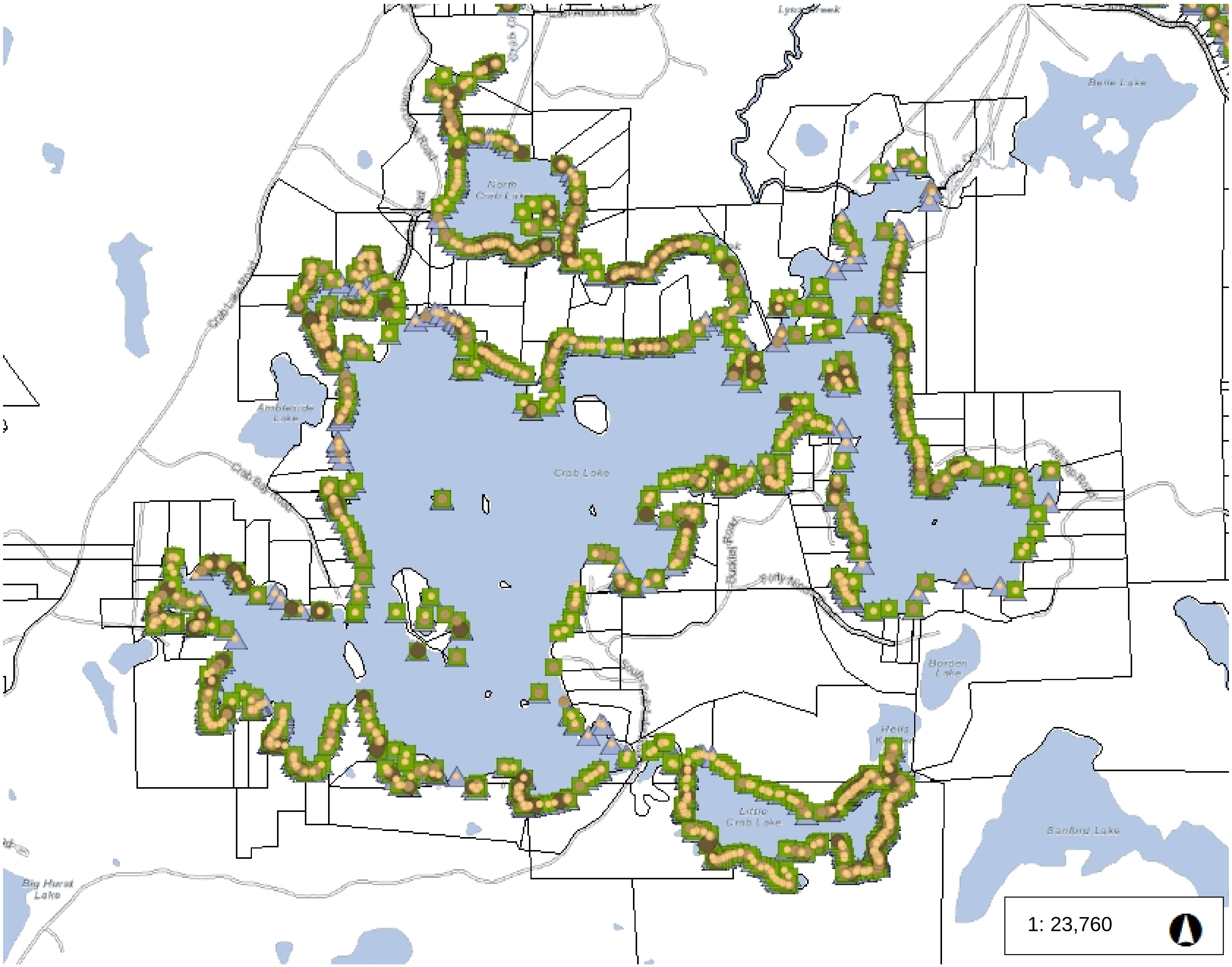
Shoreland Parcels

Notes

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Exhibit 13. Crab Lake Woody Habitat - 2020



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: 23,760

0.8 0 0.38 0.8 Miles

NAD_1983_HARN_Wisconsin_TM

Notes

Exhibit 14. Exploring the Wisconsin DNR AIS Mapping Tool for shoreland and shallow water habitat data for specific lakes.

For stakeholders interested in mining the trove of shoreland and shallow water habitat data that has been collected for specific lakes, the Wisconsin DNR AIS Mapping Tool is the portal for entry. The following steps have been outlined to facilitate your experience.

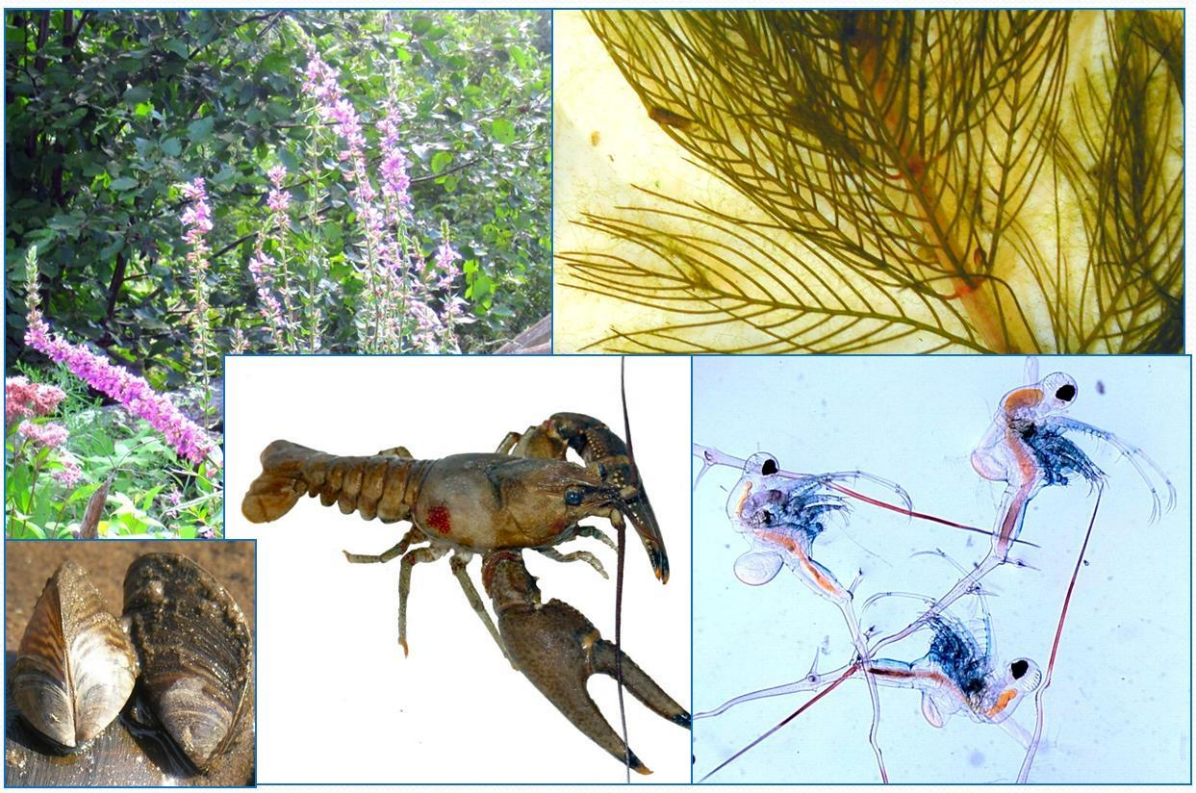
1. https://dnr.wi.gov/lakes/viewer/
2. Click on ***Proceed*** – it will take a while to load.
3. Click on ***I Accept***
4. On top grey menu go to ***Find Location***
5. Right below grey menu ***Find Locations*** click on ***Find Locations***
6. Bottom Left – Click on ***Lakes and Open Waters*** then scroll down click on ***Find***
7. Search Type – you can put ***Name of Lake*** or ***WBIC*** (Water Body Identification Code)
8. ***Value*** – put ***Lake Name*** or ***WBIC*** then click on ***Find***
9. If using ***Lake Name*** then also select the ***County***
10. If you know where your lake is you do not need to use the tool above; you can just go on the map and find your location by holding the left button on your mouse and scrolling to the location you want to view. You can use the Zoom In and Zoom Out on the menu bar or use your mouse.
11. The lake should show up – Then on the white menu bar click on ***Show Layers***
12. Under Layers - Uncheck all boxes that have a black check mark except ***surface waters*** and ***basemap***
13. Check (click on) the ***Shoreland Habitat Monitoring*** box
14. Click on the grey **+** symbol next to it
15. All of the categories that were mapped show up here.
16. Check (click on) the box you want to view. For example, check the box in front of the category ***Riparian Coverage***
17. Then check (click on) the sub category ***Percent Canopy***. The display will show up on the map to the right.
18. Each Heading there is a + sign on you need to click on the + sign to make it a – sign to see the categories underneath. The Main Sub Heading needs to be checked to see the sub categories. To go onto the next category, you need to uncheck the one you were just on. If there are no colors that show up on the map that would indicate it wasn't indicated on the data sheet and entered. So, if you click on Rip Rap and the map is clear then there is no rip rap by definition of the protocol.
19. If you want to find more info on a certain section on the top menu under basic tools click on ***Get Info***. Then go to the parcel you want information on and click once- to the left you will see information on this parcel. You then have to click on the > to find the info and you may have to > again. To close out of the info use the < back arrow. To close out of that click on the X to right of ***Identify Results***.
20. You can use your mouse to hold and move the ***Lake Map*** or use it to scroll in or out to make the map smaller or larger.

Appendix E

Crab Lake Aquatic Invasive Species Report

Crab Lake (Vilas County, Wisconsin)

Aquatic Invasive Species Report



WHITE WATER ASSOCIATES, INC.

Date: 2020

INTRODUCTION

White Water Associates, Inc. has been retained by Wilderness Waters: through a Lake Planning Grant on Crab 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 Crab Lake. This work prepares Crab Lake stakeholders to conduct actions that serve lake health. A portion of this project monitored Crab Lake for AIS using Wisconsin Department of Natural Resources (WDNR) protocol. This approach assesses the lake as to its vulnerability to AIS and documents any AIS detected. Findings from the survey were entered into the SWIMS database. A *floating workshop* on lake health, riparian ecology, and AIS was not offered due to Covid-19 concerns in 2020 and 2021.

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 Crab Lake Survey took place June 11, 2020.

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 15 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 Exhibit 2. Snorkeling was not used to search for AIS due to the temperature of the air and water. 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 aquatic invasive zooplankton found in several nearby 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 Crab Lake, a zooplankton net was used at three locations (Exhibit 1 and Exhibit 3). The sample was brought back to the lab and filtered to look for spiny water fleas under magnification. No AIS were found.

There are two known AIS that are established in Crab Lake prior to this survey (rusty crayfish and narrow-leaf cattail). During the survey there were four new invasive plants that were documented including Aquatic Forget-Me-Not (*Myosotis scorpioides*), Yellow Iris (*Iris pseudacoris*), Reed Canary Grass (*Phalaris arundinacea*), and hybrid cattail (*Tyhpa angustifolia* x *glauca*) (Exhibit 4). The locations of the plants can be found in Exhibit 1 and 2. Voucher specimens for the aquatic forget-me-not, reed canary grass, and hybrid cattail were collected during the aquatic plant survey and sent to Dr. Freckmann (U.W. Steven's Point) and were confirmed November 2020. Site 1, 4, and the boat landing had no AIS present. At MS5 the land owner was digging out the yellow iris at the location noted.

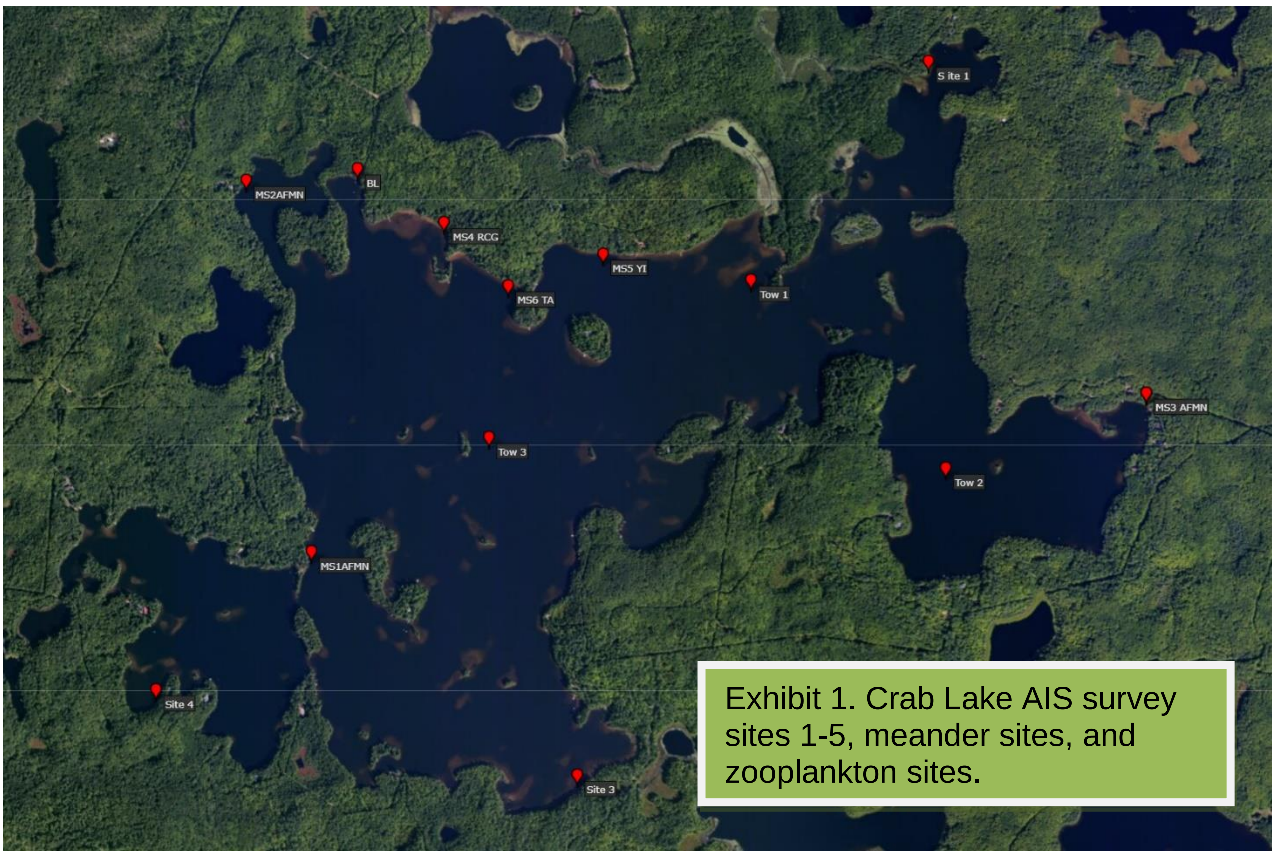


Exhibit 1. Crab Lake AIS survey sites 1-5, meander sites, and zooplankton sites.

Exhibit 2. AIS Survey on Crab Lake 6/11/2020. Density (1-5), and live (L) or dead (D).			
Site	**Latitude**	**Longitude**	**Species found**
1	46.20653	-89.70374	No AIS
2	46.19627	-89.69401	Aquatic forget-me-not 1 (L), Yellow iris 3 (L)
3	46.18444	-89.71947	Rusty crayfish 1 (D)
4	46.18707	-89.73830	No AIS
BL	46.20321	-89.72929	No AIS
MS1	46.19135	-89.73135	Aquatic forget-me-not 3 (L)
MS2	46.20286	-89.73426	Aquatic forget-me-not 1 (L)
MS3	46.19627	-89.69401	Aquatic forget-me-not 1 (L)
MS4	46.201560	-89.72541	Reed canary grass 1 (L)
MS5	46.200553	-89.718289	Yellow iris 2 (L) (land owner mentioned)
MS6	46.199573	-89.722571	Narrow-leaf cattail x broadleaf cattail (hybrid)

Exhibit 3. Spiny Water Flea Zooplankton Tows from Crab Lake			
Date: 6/11/2020	**GPS Coordinates**		**Depth of sample (feet)**
Site 1	46.19978	-89.71169	15
Site 2	46.19395	-89.70298	27
Site 3	46.19488	-89.72342	15

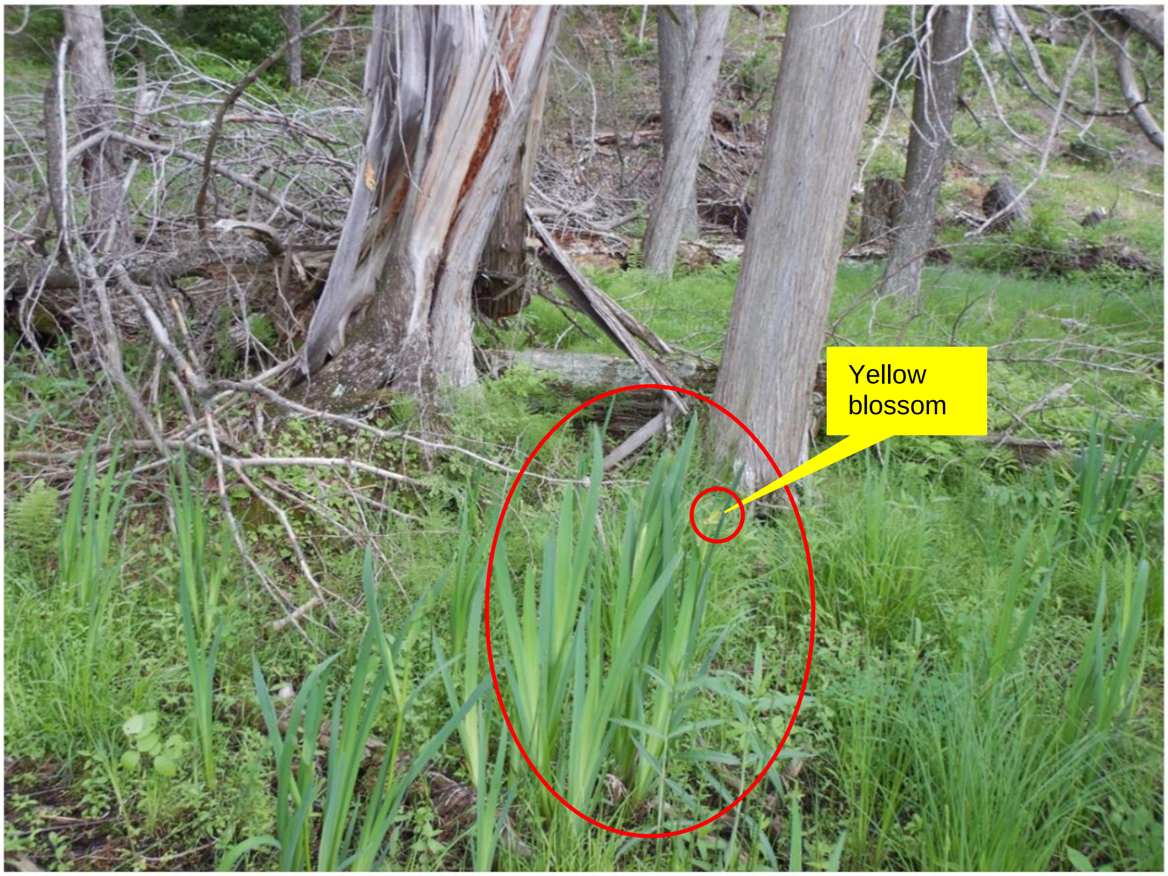


Exhibit 4. Yellow Flag Iris 2020 (White Water Associates photo).

Exhibit 5. Aquatic forget-me-not 2020 (White Water Associates photo).

Aquatic Forget-me-not (*Myosotis scorpioides*) grows in shallow water along the shoreline. It is an aggressively growing plant that can crowd out native plant species. It can form large monocultures, especially in situations where it is in or near a stream (WDNR, 2019). This plant is restricted in Wisconsin.

The yellow iris (*Iris pseudacoris*) is a perennial aquatic plant native to Europe, western Asia and North Africa. It was first introduced to North America in the 1800s as an ornamental plant. Over time, the plant has spread too many wetlands and proliferated to the detriment of native plants and animals. Yellow iris is present on numerous Wisconsin lake margins and the Wisconsin Department of Natural Resources has listed this species as “Restricted” which prevents its sale, transfer, transportation and intentional cultivation. Yellow iris can reduce habitat needed by fish and waterfowl (Thomas, 1980).

Rusty crayfish are native to 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).

Narrow-leaved cattail (*Typha angustifolia*) is another perennial wetland plant that can grow very tall. It has a flowering spike of male flowers with another section of female flowers just below it (Czarapata, 2005). It grows along shorelines, roadsides, marshes, and wet meadows. Narrow-leaved cattails form monocultures that push out native plant species and can alter the hydrology and wildlife habitat (Czarapata, 2005). The hybrid was also found in Crab Lake during the aquatic plant survey.

Reed canary grass (*Phalaris arundinacea*) grass has been found in nearly every county in Wisconsin. It is on the *Restricted* species list. It forms dense, monocultured stands in wetland and riparian areas (Czarapata, 2005). It reproduces by spreading rhizomes, and seeds (Czarapata, 2005). It is one of the first grasses to sprout in the spring, increasing its chances of out-competing other plants.

The Wisconsin DNR has a very informative website that educates on invasive species. The Crab Lake stakeholders are the ones that frequent the lake and play a big role in protecting the lake. Stopping the spread of AIS and early detection is important when it comes to invasives. Please feel free to take the time to browse through the many links provided: https://dnr.wi.gov/topic/Invasives/.

Yellow iris abatement efforts started in 2019 on Crab Lake. Volunteers are leading this effort. The volunteer hours were noted for yellow iris control efforts for 2019 (26.75), 2020 (52), and 2021 (106.75). Crab Lake volunteers plan to continue these efforts for 2022 through possibly 2024. Expenses, such as dumpster fees, trash can liners, cable ties, tags, margining paint, and printing are noted for each year's efforts. The 2019, 2020, and 2021 Yellow Iris Reports along the 2021 Yellow Iris Survey can be found on the Crab Lake Conservation foundation website: https://www.crablakeconservationfoundation.org/reports/ .

Since 2005, Crab Lake annually implements an Adopt-A-Shoreline program. The lake littoral zone is divided into segments with each segment monitored by a lake volunteer (typically a riparian owner that lives in the vicinity of the segment). The volunteer inspects the littoral zone about once per month from May through September looking for unusual plants or dramatic plant growth. They use a variety of watercraft and occasionally snorkel gear to conduct the monitoring. Any unusual findings are addressed by a collected plant to verify species.

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Wisconsin Department of Natural Resources. 2019. *Aquatic Forget-me-not*. Retrieved 2019. < https://dnr.wi.gov/topic/Invasives/fact/AquaticForgetMeNot.htm>