Finger Lake Stewardship Program

Aquatic Plant Management Plan – Finger Lake

Prepared for:
Friends of Finger Lake
Contact: William Abba
E9434 Justin Trail
Freemont, WI 54940

Prepared by:
White Water Associates, Inc.
Contact: Dean Premo, Ph.D.
429 River Lane, P.O. Box 27
Amasa, Michigan 49903

Finger Lake (photo by Angie Stine, White Water Associates)

Date: May 2019

Finger Lake Stewardship Program

Aquatic Plant Management Plan – Finger Lake

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

Friends of Finger Lake
Contact: William Abba
E9434 Justin Trail
Freemont, WI 54940
Phone: (920) 667-4953; Email: billabba@centurytel.com

Submitted to:
Wisconsin Department of Natural Resources
Attention: Kevin Gauthier, Sr., Water Resource Management Specialist
8770 Hwy J
Woodruff, WI 54568
Phone: (715) 365-5211 ext. 214; Email: Kevin.GauthierSr@wisconsin.gov

Prepared by:
White Water Associates, Inc.
Dean Premo, Ph.D., Angie Stine, B.S., and Kent Premo, M.S.
429 River Lane, P.O. Box 27
Amasa, Michigan 49903
Phone: (906) 822-7889; E-mail: dean.premo@white-water-associates.com

Cite as: *Premo, Dean, Angie Stine, and Kent Premo. 2019. Finger Lake Stewardship Program: Finger Lake Aquatic Plant Management Plan. White Water Associates, Inc.*

TABLE OF CONTENTS

CHAPTER 1

Introduction

The ***Finger Lake Stewardship Program*** results from the efforts of The Friends of Finger Lake Association, Inc. (FOFL). The Finger Lake Stewardship Program views stewardship of the lake as an ongoing endeavor that is integrated, coordinated, and administered by the FOFL. This perspective reflects the appropriate range of geographic scales from which to approach lake stewardship: a "lake specific" focus that goes hand-in-hand with waterscape-wide awareness. Although this aquatic plant management plan (APMP) addresses Finger Lake in Vilas County, Wisconsin, it maintains the waterscape perspective crucial to effective lake stewardship. This is especially important when it comes to addressing of aquatic invasive species (AIS).

Three aquatic plant surveys conducted by the Wisconsin Department of Natural Resources (WDNR) form an important technical foundation for this APMP. In fact, Dr. Susan Knight (Interim Director, Trout Lake Station, UW-Madison Center for Limnology, WDNR) was the lead field botanist for the three aquatic plant surveys conducted using the "point-intercept" method in 2009, 2013, and 2018. An important motive for the initiation of these aquatic plant investigations was the presence and proliferation of *Najas guadalupensis* (southern naiad) in Finger Lake. Although a plant that is native to Wisconsin, it sometimes achieves high population numbers and can influence overall plant species diversity. 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. Some folks still refer to an aquatic plant bed as 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 excess nutrients (for example, from lawn 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 and other organisms. Algae can respond rapidly to nutrient influxes and create nuisance conditions. These phenomena can cause people 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 aquatic invasive plant species capable of this kind of population boom. In some cases, even a native plant species can exhibit rampant growth and results in a population that is viewed by some as a recreational nuisance.

For most lakes, native aquatic plants are an overwhelmingly positive attribute and critical to the lake ecosystem. They greatly enhance the aesthetics of the lake and provide good opportunities for fishing, boating, swimming, snorkeling, sight-seeing, hunting, and more.

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 principal motivation for this plan lies in the first three 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, the FOFL 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. Chapter 4 presents an inventory and analysis of information that support the plan including results of aquatic plant surveys. Chapter 5 provides recommendations, actions, and objectives that support the goals and establish the stewardship component of plan. Finally, Chapter 6 discusses aquatic invasive species and outlines a contingency plan for AIS in Finger Lake. Eight appendices complete this document. Appendix 1 contains literature cited, Appendix 2 presents *WiLMS modeling*, Appendix 3 contains tables and figures for the aquatic plant surveys, Appendix 4 contains *The 2013 Finger Lake Aquatic Plant Survey* (a report by Susan Knight), Appendix 5 reviews *Finger Lake Water Quality*, Appendix 6 contains results from the Littoral Zone and Shoreline Survey, Appendix 7 outlines threats to the lake, and Appendix 8 contains the *Finger Lake AIS Report* from 2018.

CHAPTER 2

Study Area

Finger Lake is located in Vilas County about five miles northeast of Eagle River, Wisconsin. The water body identification code (WBIC) is 984700. Exhibit 1 is an aerial view of the Finger Lake landscape showing many other water features. This interconnected water landscape is a target for migrating and breeding waterfowl and other birds. Finger Lake has value and function in this larger landscape as well as its own watershed.

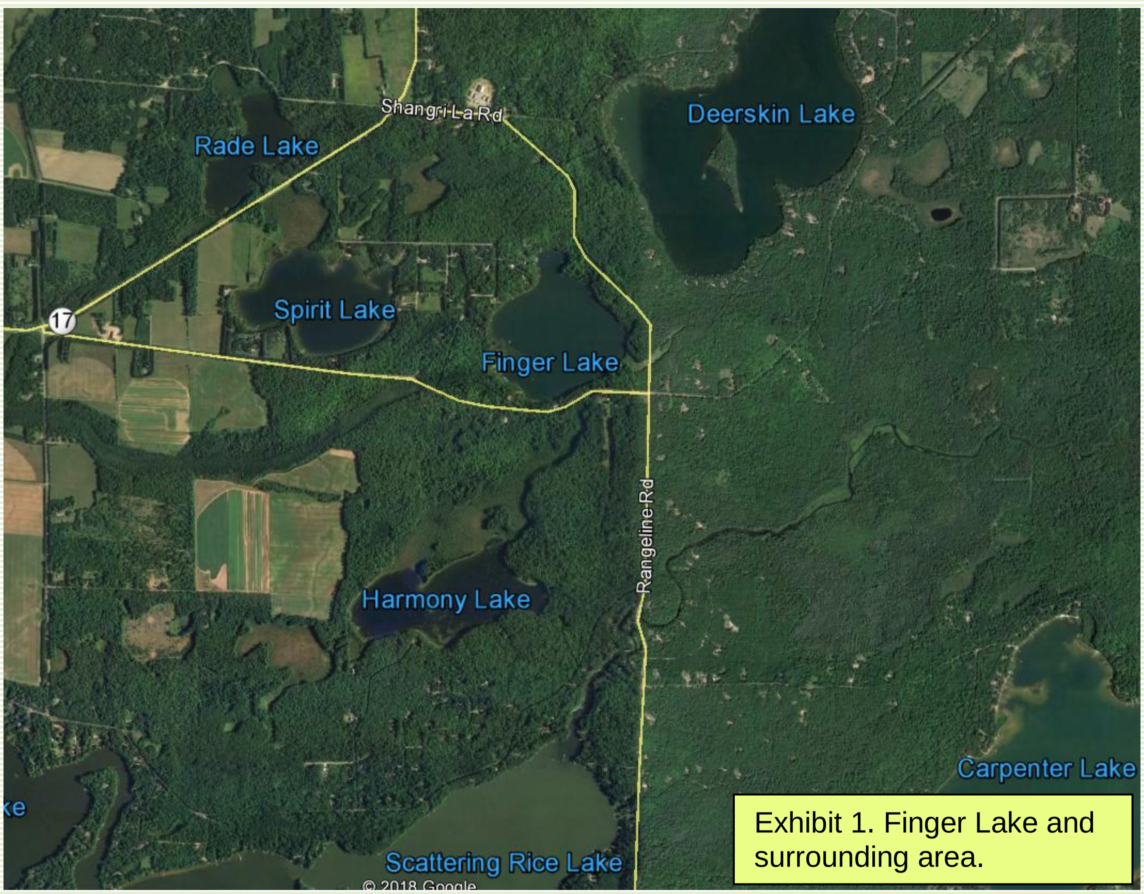


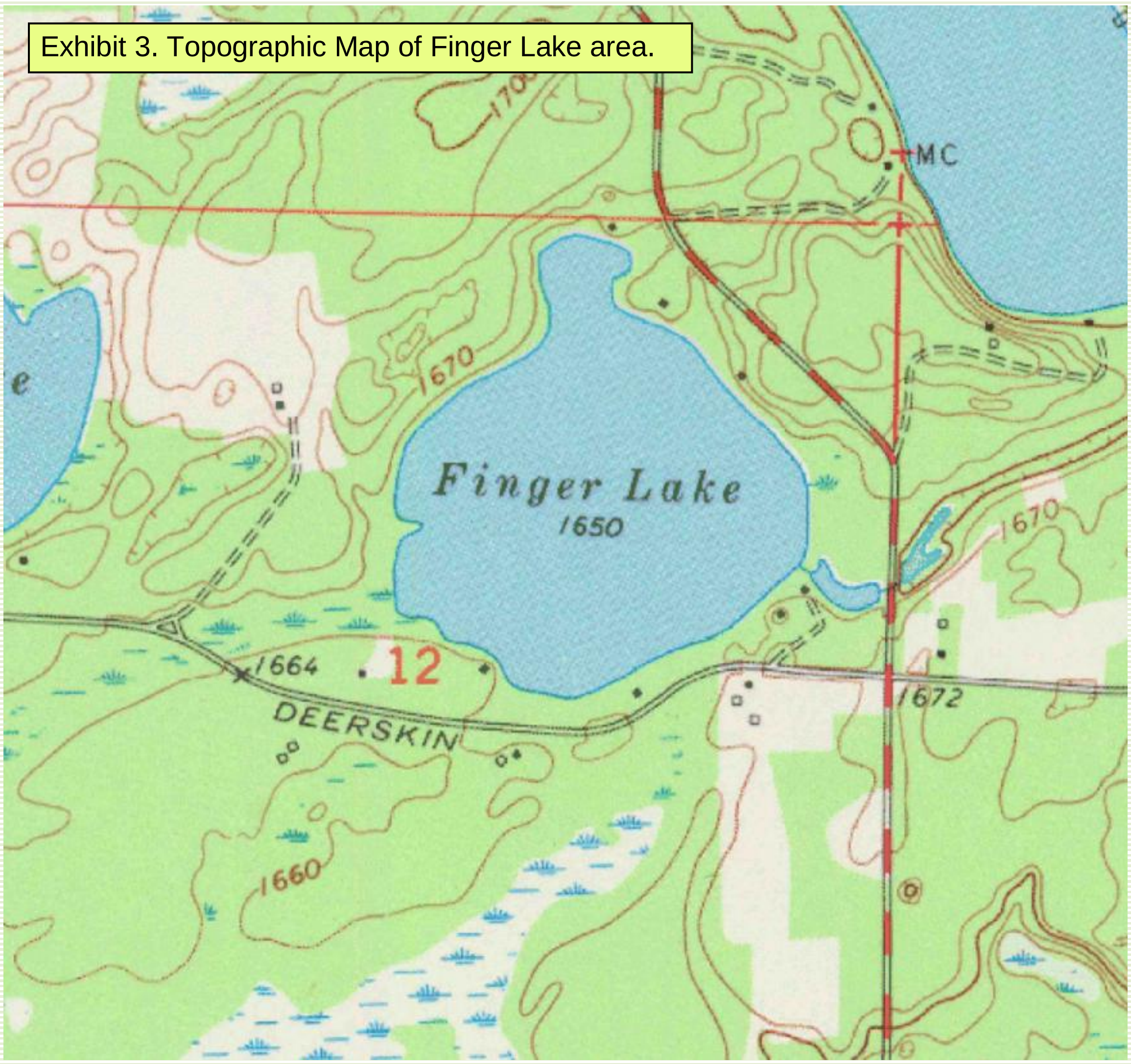
Exhibit 1. Finger Lake and surrounding area.

Descriptive parameters for Finger Lake are in Exhibit 2. It is a seepage lake of about 87 acres and has a maximum depth of 30 feet. It has a shoreline development index of 1.2. 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 2. Water Body Parameters.	
Water Body Name	Finger Lake
County	Vilas
Township/Range/Section	T40N-R10E-S12
Water Body Identification Code	984700
Lake Type	Seepage
Surface Area (acres)	87
Maximum Depth (feet)	30
Maximum Length (miles)	0.85
Maximum Width (miles)	0.46
Shoreline Length (miles)	1.6
Shoreline Development Index	1.2
Total Number of Piers (EPA study)	31
Number of Piers / Mile of Shoreline	19.4
Total Number of Homes (2018 aerial)	26
Number of Homes / Mile of Shoreline	16.25

Finger Lake has no public access site. We observed a total of 31 piers on the shoreline of Finger Lake (from 2016 EPA shoreline survey) or about 19.4 piers per mile of shoreline. The riparian area consists of both upland and wetland areas (Exhibit 3).

Exhibit 3. Topographic Map of Finger 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 for this plan:

> ***Comprehensive aquatic plant surveys in 2009, 2013, and 2018 establish that Finger Lake has a healthy and diverse aquatic plant community. The 2013 and 2018 surveys document that the native plant Najas guadalupensis (southern naiad) has greatly increased in the lake and possibly diminished overall plant diversity. Casual observations by lake users cite southern naiad as a cause of decreased recreational enjoyment of the lake. Nevertheless, the entire Finger Lake plant community is essential to, and part of, a high quality aquatic ecosystem that benefits the human community. The purpose of this aquatic plant management plan is to maintain a balanced, high quality, and diverse native aquatic plant community in Finger Lake.***

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 aquatic invasive species;

(3) Ecologically evaluate plant management options (including no action); and

(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that potentially alter the plant community, minimizing physical removal of native riparian and littoral zone plants, and recreating in a lake whose natural state includes an abundance of native aquatic plants.

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

CHAPTER 4 Information and Analysis

Our efforts in the Finger Lake Stewardship Program have compiled information about historical and current conditions of the Finger Lake ecosystem and its surrounding watershed. Of particular importance to this aquatic plant management plan are the aquatic plant surveys that were conducted in 2009, 2013, and 2018 using the ***WDNR Protocol for Aquatic Plant Survey, Collecting, Mapping, Preserving, and Data Entry*** (Hauxwell et al. 2010). The results of these comprehensive "point-intercept" aquatic plant surveys are presented and discussed in this chapter. The aquatic plant data as well as other relevant Finger Lake information is 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

Finger Lake can be classified as a "seepage lake" in that it has no inlet or outlet streams. Finger Lake and its watershed are very small components of a large-scale watershed landscape. The size of a lake's watershed (drainage basin) relative to the lake's surface area is important in determining the amount of nutrients and other materials that come into the lake (Shaw et al. 2004). The Finger Lake watershed can be viewed in Exhibit 4. Lakes with small watersheds, such as Finger Lake, tend to receive fewer nutrients from runoff than drainage lakes with larger watersheds and tend to have higher water quality.

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 Finger Lake watershed is about 318.5 acres. The cover types in the watershed are presented in Exhibit 5. Forest and woody wetland comprise the largest components. Soil groups A, B and D are present in the watershed. Soil group B makes up the majority of the watershed. Soil group D has the lowest infiltration capacity, and the highest runoff potential. Conversely, soil group A has the highest infiltration capacity, and the lowest runoff potential. The ratio of Finger Lake watershed area to lake area is 3.7:1. This is a relatively small ratio. 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.

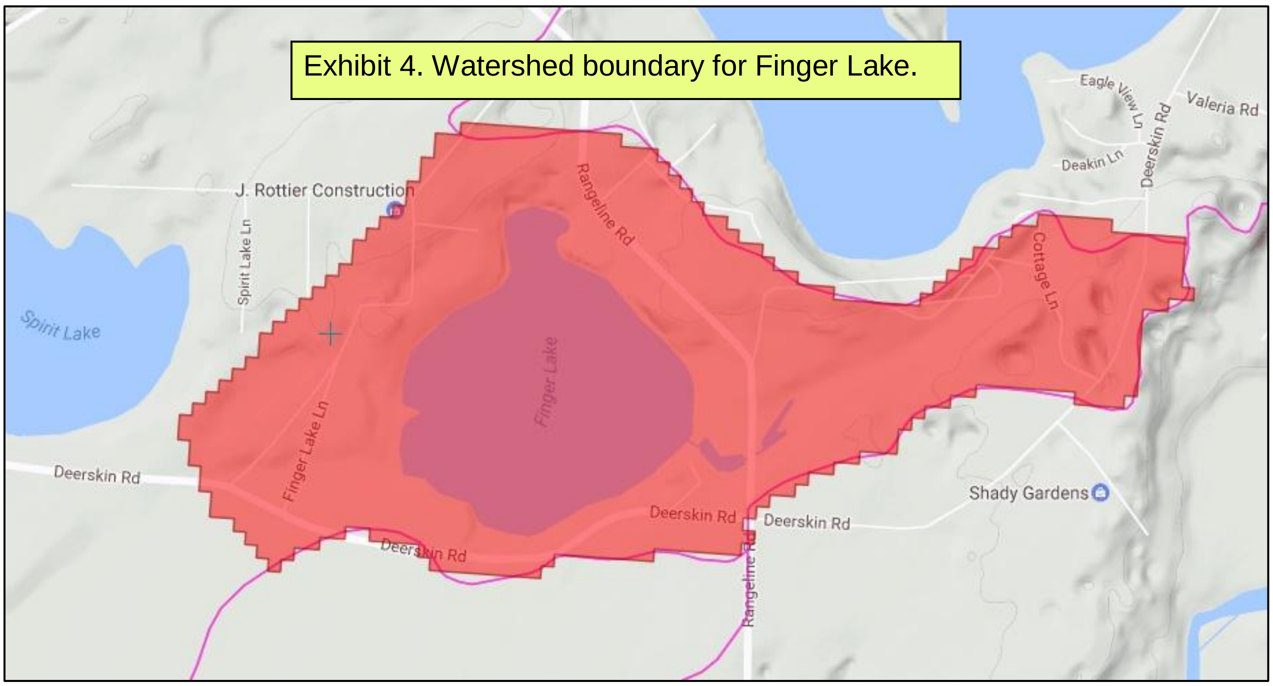


Exhibit 4. Watershed boundary for Finger Lake.

The Wisconsin Lake Modeling Suite (WiLMS) model is a lake water quality-planning tool. The WiLMS model incorporates consideration of nutrients available to the lake from the watershed and other factors to predict the trophic conditions. The WiLMS model output and additional description is provided in Appendix 2.

Exhibit 5. Cover Types and Soil Groups of the Finger Lake Watershed.

Cover Type	Acres	Percent
Agriculture	4.9	1.2
Open Space/Park	32.7	8.0
Deciduous Forest	98.5	24.0
Evergreen Forest	4.2	1.0
Mixed Forest	51.4	12.5
High-density Residential	0	0
Low-density Residential	0	0
Woody Wetland	126.7	30.9
Emergent Wetland	0	0
Water	91.8	22.4
Total	410.25	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	76.5	24.0	**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	241.0	75.7	**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	0.0	0.0	**Group C** soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
D	0.9	0.3	**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 Finger Lake. The Finger Lake aquatic plant community has been carefully investigated with systematic plant surveys occurring in 2009 and 2013. This type of historical information on a lake is quite rare and it is important in understanding the dynamics of the plant community over time. Findings from the 2018 survey are presented and discussed in the next section (Part 3) and compared to findings from previous years.

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 in the form of 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 high population levels and interfere with certain kinds of human recreation. Cases such as these may warrant some kind of plant management. It should be noted, however, that altering aquatic plant communities through hand-pulling, mechanical harvest, herbicides, or other means is expensive (in time and/or money) and by no means permanent. Long-term outcomes of these manipulations are difficult to predict. In addition, permits are required in many cases of aquatic plant management.

Aquatic plant surveys have been conducted on Finger Lake in 2009, 2013, and 2018. In each year, the survey was conducted using the WDNR point-intercept protocol. The principal field botanist for each survey was Dr. Susan Knight (Trout Lake Station, UW-Madison Center for Limnology, WDNR) ensuring a high level of scientific accuracy and consistency among the three surveys. This formal survey assessed the plant species composition on a grid of 248 points distributed evenly over the lake. The same points were used in 2009, 2013, and 2018. Using latitude-longitude coordinates and a handheld GPS unit, the survey team navigated to the points and used a rake mounted on a pole or rope to sample plants. Plants were identified, recorded, and eventually all data was entered into a dedicated spreadsheet for storage and data analysis. These systematic surveys provided baseline data about the lake and allow some analysis of change in the plant community over the time period of nine years.

An examination of changes in the aquatic plant community over nearly a decade is robust because the plant surveys were conducted using the same protocol and botanist. Future aquatic plant monitoring will allow additional analysis. Changes in a lake environment might manifest as loss of species, change in species abundance or distribution, difference in the relative composition of various plant life forms (emergent, floating or submergent plants), and/or appearance of an aquatic invasive plant species. 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 three surveys in Finger Lake and compare the plant communities of 2009, 2013, and 2018. Supporting tables and figures for the aquatic plant surveys are provided in Appendix 3 and the 2013 Aquatic Plant Survey report is found in Appendix 4.

Species richness refers to the total number of species recorded. When considering the plant species recorded at sampling points only, species richness was quite similar among the three surveys (see Exhibit 6). During the surveys, additional plant species observed but not found at the sampling points are also documented. In 2018, a total of 30 species of aquatic plants were recorded in Finger Lake with, 18 species collected at sampling sites. Table 1 displays summary statistics for the 2018 survey. Table 2 provides a list of the species encountered, including common and scientific name along with summarizing statistics for the 2018 survey.[2] The number of species encountered at any given sample point ranged from 0 to 7 and 73 sample points were found to have aquatic vegetation present. The average number of species encountered at these vegetated sites was 1.8, a slight decrease from previous surveys. 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.

Exhibit 6. Comparison Finger Lake Plant Stats for 2009, 2013, and 2018 Aquatic Plant Surveys			
Year of Point-Intercept Survey	2009	2013	2018
Number of points on grid	248	248	248
Total number of sites visited	247	244	126
Total number of sites with vegetation	101	117	73
Total number of sites shallower than maximum depth of plants	144	153	101
Freq. of occurrence at sites shallower than max depth of plants (%)	70.1	76.5	72.3
Simpson Diversity Index	0.86	0.84	0.71
Maximum depth of plants (ft)**	17.0	19.6	14.0
Average number of native species per site (shallower than max depth)	2.3	2.0	1.3
Average number of native species per site (veg. sites only)	2.27	2.04	1.8
Species Richness	17	21	18
Species Richness (including visuals)	21	23	30
FQI	28.75	33.54	33.23

The maximum depth of plant colonization in 2018 was 14 feet (Table 1 and Figure 3). This value was somewhat less (shallower) than the 2009 and 2013 surveys. Rooted vegetation was found at 73 of the 101 sample sites with depth ≤ the maximum depth of plant colonization this means that rooted plants were encountered at 72.3% of the sites that had suitable depth. This

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

value is remarkably similar to the frequency of occurrence encountered in both 2009 (70.1%) and 2013 (76.5%). 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). Figure 5 presents the substrates encountered during the aquatic plant survey (mud, sand, or rock).

Table 2 provides information about the frequency of occurrence of plant species recorded in Finger Lake. 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 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 at sample points in all three surveys are graphically displayed on Figure 6. This display shows a dramatic shift in species composition of the plant community over the time period of 2009 to 2018. These changes are most evident with southern naiad. It was not recorded by the 2009 plant survey in the lake, but by 2013 it came to dominate the plant community (relative frequency of 47%). This trend continues with the 2018 plant survey showing a 65% relative frequency for southern naiad. Other noteworthy changes occurred in the plant community over this time span as well. *Najas flexilis* was the dominant member of the plant community in 2009 (over 50% relative frequency), but dropped to 6.5% in 2013 and 1% in 2018. *Chara*, *Vallisneria Americana*, *Potamogeton pusillus*, and *Nitella* have also dropped dramatically in their individual relative frequencies in the community. Figure 7 displays sampling sites with emergent and floating aquatic plants. As examples of individual species distributions, we show the occurrences of a few of the most frequently and least frequently encountered plants in Figures 8-16.

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, species 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. In the 2009 and 2013 aquatic plant surveys the Simpson Diversity Index for Finger Lake was reasonably high (0.86 and 0.84, respectively). The Simpson Diversity Index 2018 Finger Lake data was 0.71 (Table 1) which indicates a fairly large reduction in aquatic plant diversity. This reduction results from the preponderance of southern naiad in the plant community (in other words, the large relative frequency of the southern naiad has diminished the "evenness" of species populations).

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 Finger Lake FQI (33.23) compares to other lakes and regions. The statewide medians for number of species and FQI are 13 and 22.2, respectively. In all three aquatic plant surveys, Finger Lake values are high compared to 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. Finger 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. Finger Lake data shows a higher species richness that this median value. Finally, the Finger Lake FQI values in all three surveys (28.75, 33.54, and 33.23, respectively) were higher than the median value for the Northern Lakes and Forests lakes group (24.3). These findings support the contention that the Finger Lake plant community is healthy and diverse. It is noteworthy that although diversity of plants as measured by Simpson's Diversity Index has decreased over the years in Finger Lake, the FQI has remained high and stable.

The Aquatic Macrophyte Community Index (AMCI, Nichols et al. 2000) is a tool intended to assess biological quality of aquatic plant communities in lakes. The components of the index are maximum depth of plant growth; percentage of the littoral zone that is vegetated; Simpson's diversity index; the relative frequencies of submersed, sensitive, and exotic (non-native) species; and taxa number (species richness). Values for each of the seven parameters are scaled to a maximum value of 10. AMCI values have been calculated for each of the three Finger Lake aquatic plant surveys and presented in Exhibit 7. The AMCI for 2009 and 2013 was the same (56) and only slightly lower than the median value for the northern lakes and forests region (57). Even the individual values comprising the 2009 and 2013 indices were quite similar. The AMCI for 2018 has decreased to 53, principally because the Simpson's diversity index and the depth to rooted vegetation are also lower in 2018. Certainly, the lower Simpson's diversity index is a result of the proliferation of southern naiad in Finger Lake. On the positive side the proportion of sensitive species in Finger Lake remains high (actually greater in 2018 than in the previous surveys). The trajectory of this species population in the plant community of Finger Lake should be monitored in the years to come to evaluate its influence on biodiversity in the lake. Certainly, Finger Lake's plant community has been in a very dynamic phase over the past decade.

Exhibit 7. Aquatic Macrophyte Community Index Finger Lake (2009, 2013, 2018)

Parameter	Northern Lakes & Forests Region Med. Value	Finger Lake 2009		Finger Lake 2013		Finger Lake 2018		Maximum AMCI Value
		AMCI Raw Value	AMCI Scaled Value	AMCI Raw Value	AMCI Scaled Value	AMCI Raw Value	AMCI Scaled Value	
Max depth of plant growth (m)	3.5	5.18	10	5.97	10	4.27	8	10
% Littoral Zone Area Vegetated	75	70.14	10	76.47	10	72.3	10	10
Submersed Species (rel %)	80	95.63	6	97.5	6	93	7	10
Taxa Number (Richness)	18	17	8	21	9	18	8	10
Exotic (Non-Native) Species (relative %)	0	0	10	0	10	0	10	10
Simpson's Diversity Index	88	86	7	84	6	71	3	10
Sensitive Species (relative %)	20	6.99	5	6.8	5	13.19	7	10
TOTALS	**57**		**56**		**56**		**53**	**70**

In fact, lakes are dynamic. Changes occur from year to year and may influence many aspects of the lake ecosystem. In Finger Lake, water level fluctuations are a natural part of the picture. Higher water levels have prevailed in recent years resulting from increased precipitation. Associated with this water level increase is a reduction in water transparency. Increased precipitation and runoff from the watershed can reduce water clarity due to turbidity (particles suspended in the water), increased algal concentrations stemming from more nutrients in the water runoff to the lake, and increased dissolved organic carbon that has leached from nearby wetlands (this is the tea-colored staining of water). Lower transparency (frequently measured by the Secchi depth) means that sunlight cannot penetrate as deeply into the lake. Since rooted aquatic plants depend on this sunlight, their ability to persist in deep water is reduced. The lower 2018 value for "maximum depth of plants" (14 feet, see Exhibit 6) is the likely result. A few dry years may reverse the trend. It is not possible to say for sure how Najas guadalupensis is influenced by these factors. It can be stated, however, that a diverse aquatic plant community such as exists in Finger Lake functions to ameliorate water quality changes. Dominant species may change over time, but the many critical ecosystem functions provided by the plant community will continue.

The population growth surge of the native southern naiad in the Finger Lake plant community is noteworthy. In some ways, this species is exhibiting "invasive" and "weedy" characteristics and has had a measurable effect on the aquatic plant diversity of the lake. This phenomenon has been documented in other lakes within the region. Although some may view the southern naiad in Finger Lake as an outbreak that needs to be treated, we must keep in mind that plant community changes involving native plants do occur in nature. We do not fully understand these phenomena and, in fact, are just starting to document the dynamics of the aquatic plant communities in Wisconsin and what environmental factors (e.g., climate, nutrients, and human disturbance) might be involved.

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. This condition sometimes results in a call for plant management. It must be recognized, however, that manipulation of an aquatic plant community is not without unintended consequences and risk.

Finger Lake has a native aquatic plant community that has been documented by three point-intercept aquatic plant surveys. The formal plant surveys and casual observation document that the southern naiad in recent years has attained high population size that is detrimental to recreational and aesthetic enjoyment of the lake and perhaps to the overall native plant diversity of the lake. Nevertheless, the overall native plant community is essential to, and part of, a high quality aquatic ecosystem that benefits the human community. The purpose of this aquatic plant management plan is to maintain a balanced, high quality, native aquatic plant community in Finger Lake.

Part 4. Fish Community

Fisheries information was not in the scope of this grant for Finger Lake. The WDNR Lake Pages website (http://dnr.wi.gov/lakes/lakepages/) indicates that the bottom is comprised of 80% sand, 5% gravel, 5% rock, and 10% muck and that fish species present include panfish, largemouth bass, and walleye.

Part 5. Water Quality and Trophic Status

Finger Lake is an 87 acre seepage lake with a max depth of 30 feet. Existing water quality data was retrieved from the WDNR SWIMS database between 1995 and 2018. Water quality information is briefly summarized in this section, but more fully interpreted in Appendix 5. Temperature and dissolved oxygen samples showed stratification in Finger Lake. Water clarity was good, with a 2018 average Secchi reading of 9 ft. The trophic state is mesotrophic. Water quality would be classified as "good to very good" with respect to phosphorus concentrations.

Part 6. Water Use

Finger Lake has no public access site. There is no State of Wisconsin ownership surrounding the lake. There are two residents that have suitable access to launch boats.

Part 7. Riparian Area

Part 1 (Watershed) describes the larger riparian area context of Finger Lake. The Finger Lake riparian area can be appreciated by viewing the topographic map in Exhibit 3. The lake is generally surrounded by forested habitat. Despite being developed with human structures, Finger Lake has 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 recent aerial photography reveals 28 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.

As part of a previous WDNR grant, the riparian area and shallow water littoral zone was assessed using U.S. EPA and WDNR methodology by White Water Associates staff. This assessment is more fully described in the Appendix 6.

Part 8. Wildlife

Eagle and loon studies have been conducted by the Wisconsin Department of Natural Resources and by many volunteers as part of programs such as LoonWatch. Rare species and communities have also been identified by the WDNR. Finger Lake volunteers have not submitted observational data on Finger Lake wildlife for this current project.

In the future, it would be desirable to more formally monitor indicator species of wildlife such as common loons, bald eagles, and osprey. Also of special importance would be monitoring the population of aquatic invasive animal species that already exist in the lake (Chinese mystery snail is the only currently know animal AIS in Finger Lake). Finally, it is essential to monitor Finger Lake for the presence of new aquatic invasive animal species (for example, spiny water flea and zebra mussels).

Part 9. Stakeholders and Perceived Threats

At this juncture in the ongoing aquatic plant management planning process, the Friends of Finger Lake Association has represented the Finger 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 direct plant management actions (for example, mechanical harvesting or use of herbicides) are recommended by this current plan. Nevertheless, some Finger Lake users have expressed concerns regarding the southern naiad populations that potentially influence specific recreational activities. Plant management may be a future concern and warrants diligent and careful consideration. The FOFL solicited input from all Finger Lake residents to better understand perceived threats to Finger Lake. The results of these Threats to Finger Lake are presented in Appendix 7.

It should be stressed that ecosystems are dynamic. In other words, they change over time. There is a natural ebb and flow of species, plant and animal communities (including fish), water level, and even water chemistry. These changes might be influenced by conditions outside of the lake, for example increase or decrease in average annual temperature or rain fall. The dynamics may also result from internal factors such as several consecutive years of good spawning conditions for a fish species. Whatever the cause, and we may not even know the cause, components of the lake ecosystem change over time. This is natural even though it may be disconcerting to humans who tend to like things to stay the same. Often when humans try to intercede in an attempt to direct nature away from its natural course of change it is expensive, frustrating, and unsuccessful (or even counterproductive). This is not necessarily a recommendation to never intervene, but a suggestion to be patient and vigilant. Finger Lake is a healthy ecosystem and therefore, a changing ecosystem. The southern naiad is the most recent and obvious example of that change. This species has proliferated in other lakes in the region and over time has slowly reduced in its population size. It will likely not remain at its current population level. Nature is reliable in its ability to check imbalances that occur.

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 aquatic invasive species;
(3) Ecologically evaluate plant management options (including no action); and
(4) Educate riparian owners and lake users on preventing AIS introduction, reducing nutrient inputs that potentially alter the plant community, minimizing physical removal of native riparian and littoral zone plants, and recreating in a lake whose natural state includes an abundance of native aquatic plants.

Since Finger Lake is a healthy and diverse ecosystem, we could simply recommend an alternative of "no action." In other words, Finger Lake continues without any effort or intervention on part of the Friends of Finger Lake. This ignores the fact, however, that the Friends of Finger Lake exists to care for and protect this special place. They are aware that Finger Lake is vulnerable to forces that might diminish the quality of the lake ecosystem. The Finger Lake Stewardship Program exists to understand and 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 lake 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 aquatic plants in Finger Lake. We do, however, emphasize tracking the population dynamics of the southern naiad in Finger Lake to ascertain how it might further influence the lake and to judge whether population management is warranted and prudent. No aquatic invasive plant species are known to be present.

Recommended Actions for the Finger 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:*** FOFL oversees activity and maintains the plan. ***Status:*** Planned for 2019.
Action #2: Monitor water quality in the lake. ***Objective***: Continue with collection and analysis of water quality parameters to detect trends in parameters such as nutrients, chlorophyll *a*, and water clarity. ***Monitoring:*** FOFL oversees activity and maintains data. ***Status:*** Ongoing.
Action #3: Monitor Finger Lake shoreline for areas of erosion and excessive terrestrial/wetland vegetation clearing. ***Objective***: To inform riparian owners of improvements to shoreline stability and health. ***Monitoring:*** FOFL oversees activity and maintains data. ***Status:*** Begin in 2019.
Action #4: 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 FOFL AIS Team oversees activity and maintains data. ***Status:*** Ongoing.
Action #5: 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 FOFL AIS Team oversees activity and maintains data. ***Status:*** Ongoing.
Action #6: Form an Aquatic Invasive Species Rapid Response Team (see Chapter 6 of this APMP). ***Objective:*** To be prepared for AIS discovery and efficient response. ***Monitoring:*** The FOFL coordinates activity. ***Status:*** Planned for 2019.

Recommended Actions for the Finger Lake APM Plan
Action #7: Conduct quantitative plant survey every five years using WDNR Point-Intercept Methodology. ***Objective:*** To track 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:*** FOFL oversees and maintains data; copies to WDNR. ***Status:*** Anticipated in 2023.
Action #8: Monitor the lake watershed for purple loosestrife. ***Objective:*** Identify and manage purple loosestrife populations before they reach large size. ***Monitoring:*** FOFL oversees activity. ***Status:*** Anticipated in 2019 and annually.
Action #9: Verify and monitor the lake shorelines for yellow iris. If present, devise a plan with consultant and WDNR to manage the population. ***Objective:*** Identify and manage yellow iris populations if present before they reach large size. ***Monitoring:*** FOFL oversees activity. ***Status:*** Anticipated in 2019 and annually.
Action #10: 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:*** FOFL oversees and maintains data; copies to WDNR. ***Status:*** Ongoing; next time in 2023.
Action #11: Develop a Citizen Lake Monitoring Network to monitor for invasive species and develop strategies including education and monitoring activities (see http://www.uwsp.edu/cnr/uwexlakes/clmn for additional ideas). ***Objective:*** To create a trained volunteer corps to monitor aquatic invasive species and to educate recreational users regarding AIS. ***Monitoring:*** FOFL AIS Team oversees activity and reports instances of possible introductions of AIS. ***Status:*** Anticipated to begin in 2018.

Recommended Actions for the Finger Lake APM Plan
Action #12: Become familiar with and recognize the water quality and habitat values of ordinances and requirements on boating, septic, and property development. Implement best management practices on Finger Lake shorelines where needed. ***Objective:*** To protect native aquatic plants, water quality, and riparian habitat. ***Monitoring:*** Overseen by the FOFL. Conducted by lake residents and other stakeholders. ***Status:*** Ongoing.
Action #13: Promote adherence to, and enforcement of ordinances. ***Objective:*** To minimize recreational and development impacts on the aquatic plant community and shoreline habitats, and promote safe boating. ***Monitoring:*** FOFL oversees activity and assesses effectiveness. ***Status:*** Ongoing.
Action #14: Create an education plan for the property owners and other stakeholders that will address issues of healthy 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:*** FOFL oversees activity and assesses effectiveness. ***Status:*** Anticipated to begin in 2019.

CHAPTER 6

Aquatic Invasive Species and Contingency Plan for AIS

Unfortunately, sources of aquatic invasive plants and other AIS are numerous in Wisconsin. Some infested lakes are quite close to Finger Lake. This proximity increases the likelihood of accidental introduction of AIS through conveyance of life stages by boats, trailers, and other vectors. It is important for the FOFL and other lake stewards to be prepared for the contingency of aquatic invasive plant species colonization in Finger Lake. The most recent WDNR grant to FOFL was an AIS Invasive Species Grant for Education, Prevention, and Planning on Finger Lake. This grant focuses on aquatic invasive species, increasing the understanding of Finger Lake, and enables FOFL to improve stewardship actions that address the lake. The project monitored Finger Lake for AIS using WDNR protocol. Findings were entered into the SWIMS database. A core group of lake stewards were trained in recognition of AIS so that monitoring can continue in the future. A broader educational activity was delivered in the form of a floating workshop for Finger Lake enthusiasts and focused on lake and riparian ecology while emphasizing the impacts that invasive species can have on these important ecosystems. Further discussion is found in Appendix 8.

For riparian owners and users of a lake ecosystem, the discovery of AIS is an event 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 7 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 take digital photo(s) of the plant in the setting where it was found (if possible, try to capture details such as flowers, leaf shape, leaf and stem arrangement, and fruits and include a common object in the photo for scale).

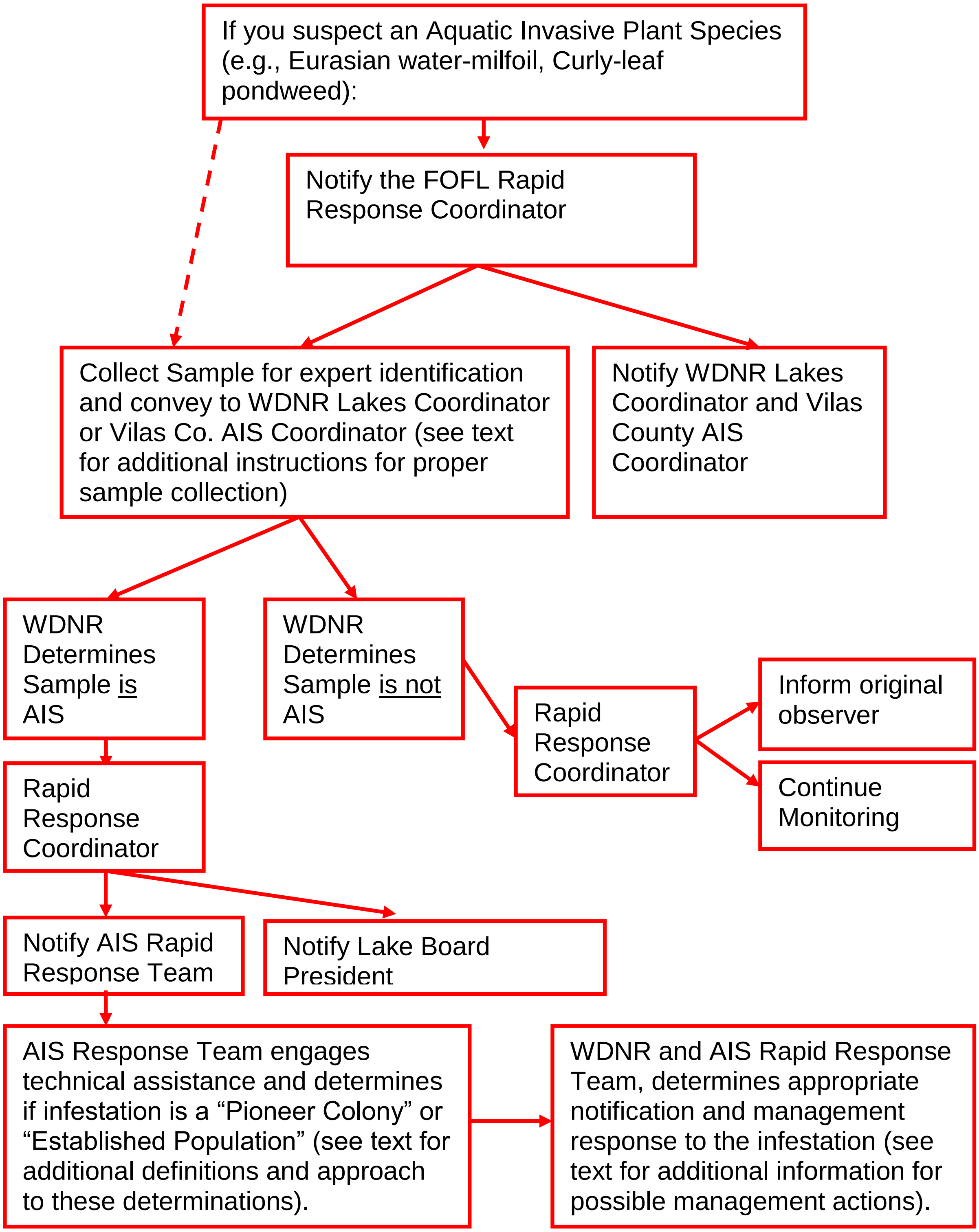
Next, the observer or team coordinator should collect an entire plant specimen including roots, stems, and flowers (if present). If plants are numerous, collect several. The sample should be placed in a sealable bag with a damp paper towel. Place a label in the bag written in pencil with date, time, 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 Lakes Management Coordinator (Kevin Gauthier in Woodruff) or the Vilas County AIS Coordinator (Catherine Higley) as soon as possible (at least within four 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 some other 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 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, FOFL President (or other points of contact), local WDNR warden, local government official(s), other experts, chemical treatment contractors, and consultant(s).

Exhibit 7. Aquatic Invasive Plant Species Rapid Response



Appendix 1
Literature Cited

Literature Cited

Czarapata, Elizabeth. 2005. *Invasive Plants of the Upper Midwest: An Illustrated Guide to Their Identification and Control*. University of Wisconsin Press. Retrieved 2017. <http://dnr.wi.gov/topic/Invasives/fact/.html>

Hauxwell, J., S. Knight, K. Wagner, A. Mikulyuk, M. Nault, M. Porzky and S. Chase. 2010. *Recommended baseline monitoring of aquatic plants in Wisconsin: sampling design, field and laboratory procedures, data entry and analysis, and applications.* Wisconsin Department of Natural Resources Bureau of Science Services. Madison, WI.

Nichols, Stanley A. 1999. *Floristic Quality Assessment of Wisconsin Lake Plant Communities with Example Applications.* Journal of Lake and Reservoir Management 15(2): 133-141.

Nichols, S., S. Weber and B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Journal of Lake and Reservoir management 15(2):133-141.

US Department of Agriculture, Natural Resources Conservation Service. June 1986. *Urban Hydrology for Small Watersheds.* Technical Release–55.

Walters, C. 1986. *Objectives, constraints, and problem bounding.* In W.M. Getz, ed., Adaptive Management of Renewable Resources. Macmillan Publishing Company. New York. p. 13+.

Appendix 2

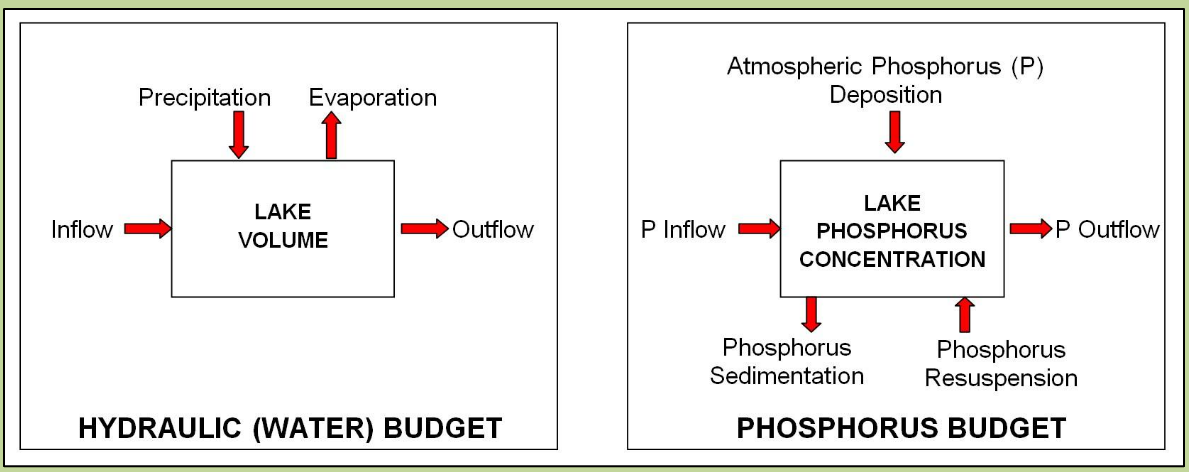
WiLMS Report

Finger Lake Watershed, Water Quality, and WiLMS Modeling

Freshwater algae and rooted aquatic plants (macrophytes) require a number of nutrients in order to grow. Two of these nutrients, phosphorus and nitrogen, are often present in small amounts and limit algae and macrophyte growth. In fact, phosphorus is the nutrient that most often limits the growth of aquatic plants in freshwater systems and, when present in high concentrations, is most often responsible for algal blooms, rampant growth of rooted plants, and lake eutrophication. This is the reason that phosphorus is such a focus when it comes to concerns of lake water quality.

The water (hydraulic) budget of a lake is closely associated with the phosphorus budget (both illustrated in Figure 1). The graphics show in general terms the overall movement of water and phosphorus into and out of a lake ecosystem.

Figure 1. Hydraulic (water) and phosphorus budgets in lakes.



Modified from Brylinsky (2004)

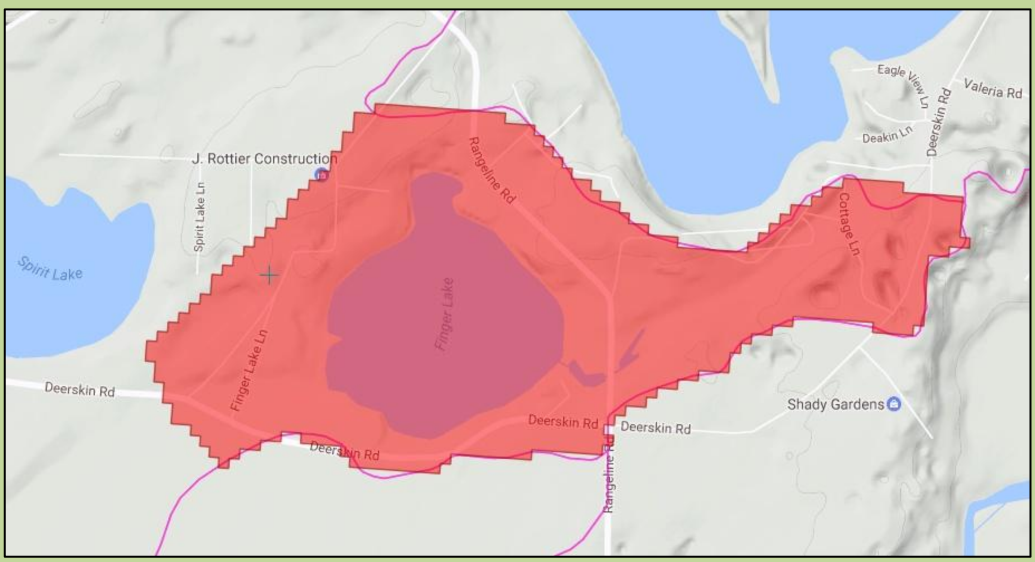
Several interrelated factors are at play when it comes to the water quality of a lake. These include water source, watershed size, retention time, watershed cover types, and internal loading. Because each lake and its watershed have unique characteristics and interactions, no two lakes behave in exactly the same way. Nevertheless, being familiar with these factors and how they interrelate is helpful for lake planning and stewardship.

The sources of water for a lake strongly influence the lake's water quality because the water carries with it nutrients such as phosphorus. The four water sources include precipitation, runoff from the surrounding land, upwelling groundwater, and inflow from a stream. The relative importance of each of these sources depends on several things. For example some lakes have no incoming stream, so these lakes depend on precipitation, runoff, and groundwater. A lake with a small drainage basin (watershed) receives relatively less water as runoff. Water can leave a lake through an outflow, evaporation, and groundwater seeping back into the aquifer (water table).

Water source is the factor that lake scientists use to classify lakes into four categories (Shaw et al., 2004). A “seepage lake” is fed by precipitation, limited runoff, and groundwater and has no inlet or outlet. A “groundwater drainage lake” is fed by groundwater, precipitation, and limited runoff and has a stream outlet. A “drainage lake” is fed by one or more streams, groundwater, precipitation, and runoff and has a stream outlet. Finally, an “impoundment” is a manmade lake formed by damming a stream and is also drained by a stream. When water comes into a lake from its various sources, it also carries other materials to the lake. Some of these are dissolved in the water (like phosphorus, nitrogen, and calcium). Some of the materials are suspended in the water (like silt and small bits of detritus). Precipitation (rain and snow) also carries with it dissolved and suspended materials to the lake (acid precipitation and dust are examples).

The size of a lake’s watershed (drainage basin) relative to the lake’s surface area is important in determining the amount of nutrients and other materials that come into the lake (Shaw et al., 2004). The Finger Lake watershed is depicted in Figure 2. This ratio of drainage basin area to lake area is a measure of how important the watershed is as the lake’s source of water, nutrients (like phosphorus), and other materials. A higher DB/LA ratio means the watershed is relatively more important and runoff contributes more water and nutrients to the lake. With their small watersheds, seepage lakes receive fewer nutrients from runoff than drainage lakes and tend to be higher in water quality.

Figure 2. Finger Lake watershed.



Another important concept in a lake’s water and nutrient “budget” (that is, inputs and outputs) is “retention time” (also called “water residence time”), the average length of time that water stays in the lake. This is determined by a lake’s size (volume), water sources, and watershed size. For some lakes and impoundments, retention time can be quite short (days or weeks). In other lakes, retention time can be as long as decades or centuries. Retention time also indicates how long nutrients stay in the lake. In short retention time lakes, nutrients are flushed through the system rather quickly. In long retention time lakes, nutrients stay around a longer time and can move into the sediments where they become a long-term part of the lake's chemistry.

The type of land cover (for example, forest, grassland, row crops, or human development) is also an important variable in determining amounts and kinds of materials (like nutrients and sediment) that are carried off the land and into the water. This is especially important close to the lake (the riparian area), but the entire watershed is a contributor and we often map the cover types and measure their acreages to give us some idea of how at risk the lake might be to receiving unwanted materials. Certain kinds of agriculture (tilled row crops) and urban areas (with their impervious surfaces) have a tendency to give up sediments and nutrients to runoff. In contrast, native vegetation (forests, wetlands, and grasslands), tend to slow runoff of water and nutrients, allowing the soil to absorb them. When excessive nutrients and sediment reach a lake they can cause increased growth of aquatic plants, algal blooms, and reduced water clarity.

The DB/LA (drainage basin/lake area) ratio interacts in an interesting way with drainage basin cover type when it comes to nutrient runoff to a lake. For lakes where the ratio is relatively high (greater than 15:1), the role of drainage basin size in delivering water and nutrients to the lake tends to dominate the role of cover type. In small ratio lakes, the kind of cover type on the watershed has the greater influence than the absolute size of the watershed. For these small DB/LA ratio lakes maintaining or restoring good quality native cover type in the watershed will likely have a positive and observable influence on the lake.

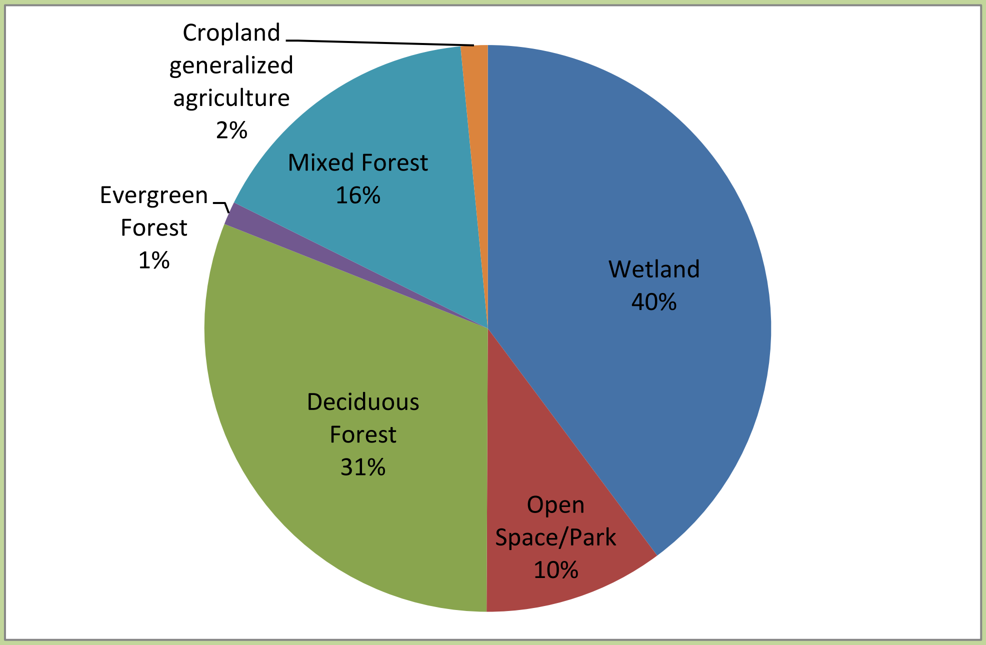
Internal loading refers to phosphorus (and other nutrients) that are present in the lake bottom sediment. Some of the phosphorus in a lake ecosystem continually falls to the bottom and becomes part of the sediment layer and is generally unavailable for plants. Under conditions of low dissolved oxygen, however, this phosphorus can go back into the water column and be taken up by algae and macrophytes. The amount of phosphorus contained in the sediment can be quite high, resulting from centuries of deposition. The phenomenon of internal loading can therefore make available a large amount of phosphorus to the algae and plants of the lake and typically happens at spring and fall overturn periods. Even if sources of phosphorus outside of the lake are reduced, the internal loading can still enrich the lake and cause eutrophic conditions.

Because it is often challenging to work out how these several factors interact to influence the water quality of a specific lake, the Wisconsin Department of Natural Resources developed the "Wisconsin Lake Modeling Suite" (WiLMS) as a lake water quality planning tool (WDNR, 2003). WiLMS is a computer program into which the user enters information about the lake (e.g., surface area, depth, and nutrient measures) and the watershed (e.g., acreage and cover type). The model also has information about average rainfall, aerial deposition of materials, and cover type characteristics that it uses to help predict nutrient (phosphorus) loading scenarios to the lake.

In this project, we applied the WiLMS models to Finger Lake. The 87 acre lake has a watershed of 318.5 acres and a drainage basin/lake area ratio of about 4 to 1. This is a relatively low ratio. Lakes with this size ratio combined with a mostly natural watershed cover type are likely to have high quality (oligotrophic) characteristics, although this is not the case with Finger Lake (mesotrophic). The lake volume is 869.2 acre-feet and the mean lake depth is 9.99 feet. The WiLMS model calculates the annual runoff volume as 371.5 acre-feet and the annual difference between precipitation and evaporation (precipitation minus evaporation) as 5.5 inches. The hydraulic loading for Finger Lake is 411.3 acre-feet per year and the areal water load is 4.7 feet per year. The WiLMS model calculates the annual lake flushing rate as 0.47 times per year and the water residence time (retention time) as 2.11 years.

The cover types in the Finger Lake watershed are shown in Figure 3 with their respective acreages. Wetland cover type is the predominant land cover at 40%. Deciduous forest cover is also important, comprising about 31% of the watershed.

Figure 3. Finger Lake watershed land cover types.



Note: the "wetlands" category also includes the surface area of the lake.

Table 1 presents output from the WiLMS model for non-point source phosphorus input to Finger Lake. No point-source data is available for Finger Lake. The WiLMS model indicated that 24.2 kg (53.4 pounds) of phosphorus are most likely delivered to the lake each year from watershed runoff and from direct deposition onto the lake surface (via precipitation and airborne particles). The WiLMS model predicts that most of the phosphorus delivered to Finger Lake comes from wetland and forest cover types, the most prevalent cover types in the watershed.

Table 1. WiLMS estimated non-point source phosphorus loading based on watershed land use type and acres.								
Land Use	Land Use Acres	Loading (kg/ha-year)				Loading kg/year		
		Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop Ag.	0	0.50	1.00	3.00	0	0	0	0
Mixed Agricultural	4.89	0.30	0.80	1.40	6.5	1	2	3
Pasture/Grass	0	0.10	0.30	0.50	0	0	0	0
High Density Urban (1/8 acre)	0	1.00	1.50	2.00	0	0	0	0
Mid Density Urban (1/4 acre)	0	0.30	0.50	0.80	0	0	0	0
Rural Residential (>1 acre)	32.69	0.05	0.10	0.25	5.5	1	1	3
Wetlands	126.74	0.10	0.10	0.10	21.2	5	5	5
Forest	154.1	0.05	0.09	0.18	23.2	3	6	11
Lake Surface	87.0	0.10	0.30	1.00	43.6	4	11	35
				Totals	100.0	14	25	57

The WiLMS generated an estimate of internal loading of phosphorus. These data are presented in Table 2. The model predicts that about 2 pounds (1 kg) of phosphorus are released each year from Finger Lake sediments and available to algae and aquatic plants. The model calculates a predicted phosphorus retention coefficient as 0.77 (this represents the fraction of phosphorus entering the lake that is lost by settling to the sediment). The observed phosphorus retention coefficient is 0.74 indicating that phosphorus is available about as the model predicts.

Table 2. WiLMS Method 1 – Complete Phosphorus Mass Budget.	
Parameter	**Value**
Phosphorus Concentration of Lake (input into model)	12.5 mg/m^3
Phosphorus Inflow Concentration	47.7 mg/m^3
Areal External Loading	68.8 mg/m^2-year
Predicted Phosphorus Retention Coefficient *(the predicted fraction of phosphorus entering the lake that is lost by settling to the sediment)*	0.77
Observed Phosphorus Retention Coefficient	0.74
Internal Load (amount released annually from the sediment)	2 pounds (1 kg)

The WiLMS also allow us to manipulate the cover type acreages as an illustration of how watershed cover can influence the delivery of phosphorus to a lake. As an example, we re-ran the non-point source data model, but altered landscape composition to simulate the effect of converting 200 acres of the forest cover type to row crop agriculture. The results are dramatic. Under the hypothetical agricultural condition, 99.5 kg of phosphorus would be delivered to the lake each year from runoff as compared to the 24.2 kg estimated as the most likely loading to come from the existing watershed (under the actual conditions in the watershed).

Literature Cited

Brylinsky, M. 2004. *User's Manual for Prediction of Phosphorus Concentration In Nova Scotia Lakes: A Tool for Decision Making.* Version 1.0. Prepared For The Nova Scotia Water Quality Objectives and Model Development Steering Committee, Nova Scotia Department of Environment and Labour. Prepared by Acadia Centre for Estuarine Research Acadia University Wolfville, Nova Scotia B4P 2R6 January 2004.

Shaw, B. Mechenich, C, and Klessig, L. 2004. *Understanding Lake Data (G3582).* Board of Regents of the University of Wisconsin System. Madison, WI.

WDNR. 2003. *Wisconsin Lake Modeling Suite.* PUBL-WR-363-94.

Appendix B

Aquatic Plant Survey Tables and Figures

Table of Contents

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

Summary Statistic	Value	Notes
Total number of sites on grid	248	Total number of sites on the original grid (not necessarily visited)
Total number of sites visited	126	Total number of sites where the boat stopped, even if much too deep to have plants.
Total number of sites with vegetation	73	Total number of sites where at least one plant was found
Total number of sites shallower than maximum depth of plants	101	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	72.28	Number of times a species was seen divided by the total number of sites shallower than maximum depth of plants.
Simpson Diversity Index	0.71	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.)	14.0	The depth of the deepest site sampled at which vegetation was present.
Number of sites sampled with rake on rope	20	
Number of sites sampled with rake on pole	106	
Average number of all species per site (shallower than max depth)	1.28	
Average number of all species per site (vegetated sites only)	1.77	
Average number of native species per site (shallower than max depth)	1.28	Total number of species collected. Does not include visual sightings.
Average number of native species per site (vegetated sites only)	1.77	Total number of species collected including visual sightings.
Species Richness	18	
Species Richness (including visuals)	30	
Floristic Quality Index (FQI)	33.23	An assessment metric designed to evaluate the closeness that the flora of an area is to that of undisturbed conditions.

Table 2. Plant species recorded and distribution statistics for the 2018 Finger 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
Southern naiad	Najas quadalupensis	65.35	90.41	51.16	66	66	1.38
Wild celery	*Vallisneria americana*	17.82	24.66	13.95	18	18	1.00
Muckgrass	*Chara sp.*	8.91	12.33	6.98	9	9	1.00
Large-leaf pondweed	*Potamogeton amplifolius*	6.93	9.59	5.43	7	9	1.00
Dwarf water-milfoil	*Myriophyllum tenellum*	5.94	8.22	4.65	6	6	1.00
Spatterdock	*Nuphar variegata*	2.97	4.11	2.33	3	17	1.00
Ribbon-leaf pondweed	*Potamogeton epihydrus*	2.97	4.11	2.33	3	4	1.00
Vasey's pondweed	*Potamogeton vaseyi*	2.97	4.11	2.33	3	4	1.00
Slender waterweed	*Elodea nuttallii*	2.97	4.11	2.33	3	3	1.00
Pickerelweed	*Pontederia cordata*	1.98	2.74	1.55	2	25	1.00
Nitella	*Nitella sp.*	1.98	2.74	1.55	2	2	1.50
Creeping spikerush	Eleocharis palustris	0.99	1.37	0.78	1	14	1.00
Three-way sedge	*Dulichium arundinaceum*	0.99	1.37	0.78	1	9	1.00
Narrow-leaved bur-reed	*Sparganium angustifolium*	0.99	1.37	0.78	1	4	1.00
Pipewort	*Eriocaulon aquaticum*	0.99	1.37	0.78	1	4	1.00
Floating-leaf bur-reed	Sparganium fluctuans	0.99	1.37	0.78	1	3	1.00
Brown-fruited rush	*Juncus pelocarpus f. submerses*	0.99	1.37	0.78	1	1	1.00
Slender naiad	*Najas flexilis*	0.99	1.37	0.78	1	1	1.00
Softstem bulrush	*Schoenoplectus tabernaemontani*				Visual	20	
Marsh cinquefoil	*Comarum palustre*				Visual	2	
Common bladderwort	*Utricularia vulgaris*				Visual	1	
Golden hedge-hyssop	*Gratiola aurea*				Visual	1	
Quillwort	*Isoetes sp.*				Visual	1	
Spiral-fruited pondweed	*Potamogeton spirillus*				Visual	1	
Variable pondweed	*Potamogeton gramineus*				Visual	1	
Water horsetail	*Equisetum fluviatile*				Visual	1	
Water smartweed	*Polygonum amphibium*				Visual	1	

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
Watershield	*Brasenia schreberi*				Visual	1	
Waterwort	*Elatine minima*				Visual	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.

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

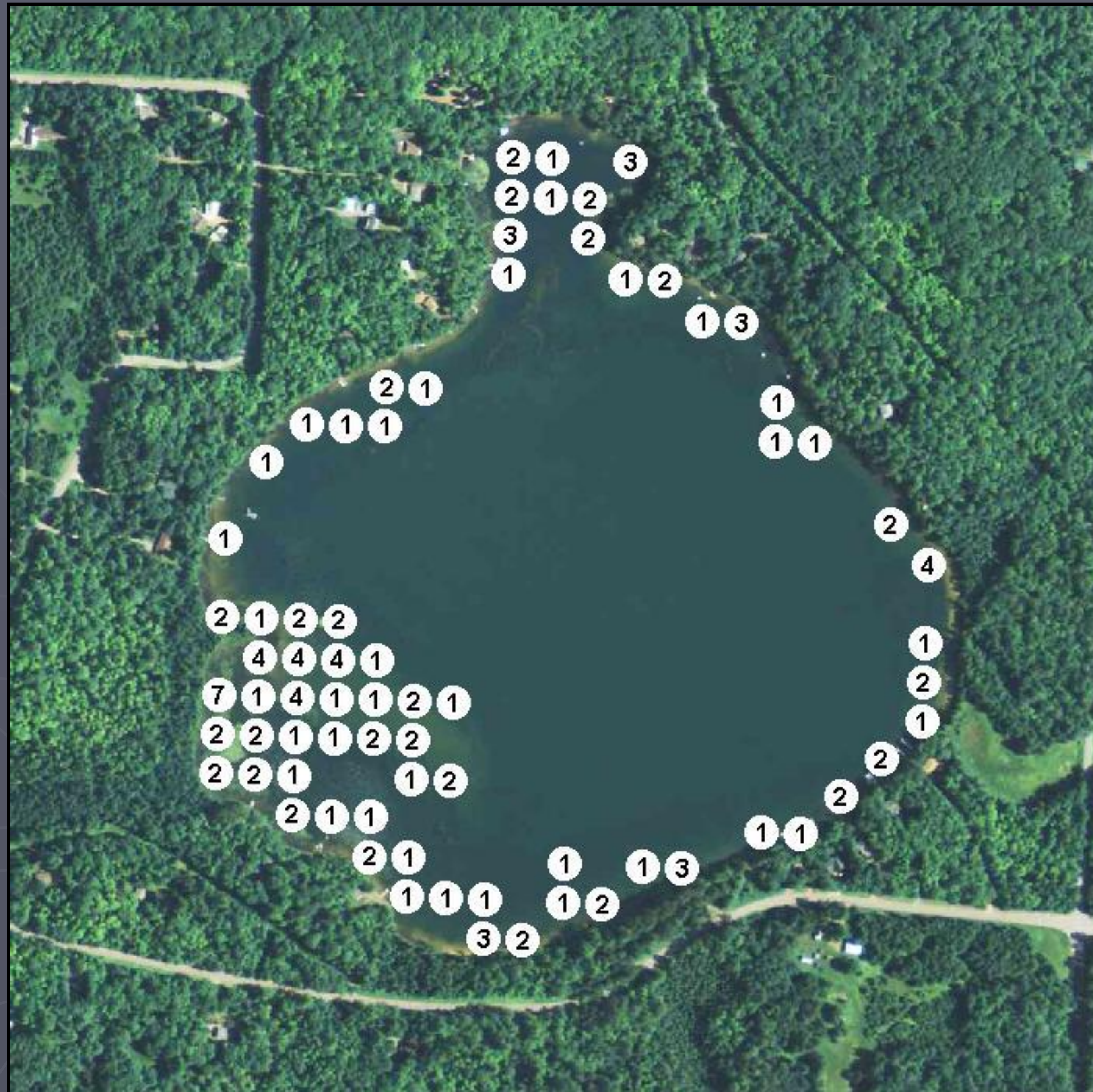
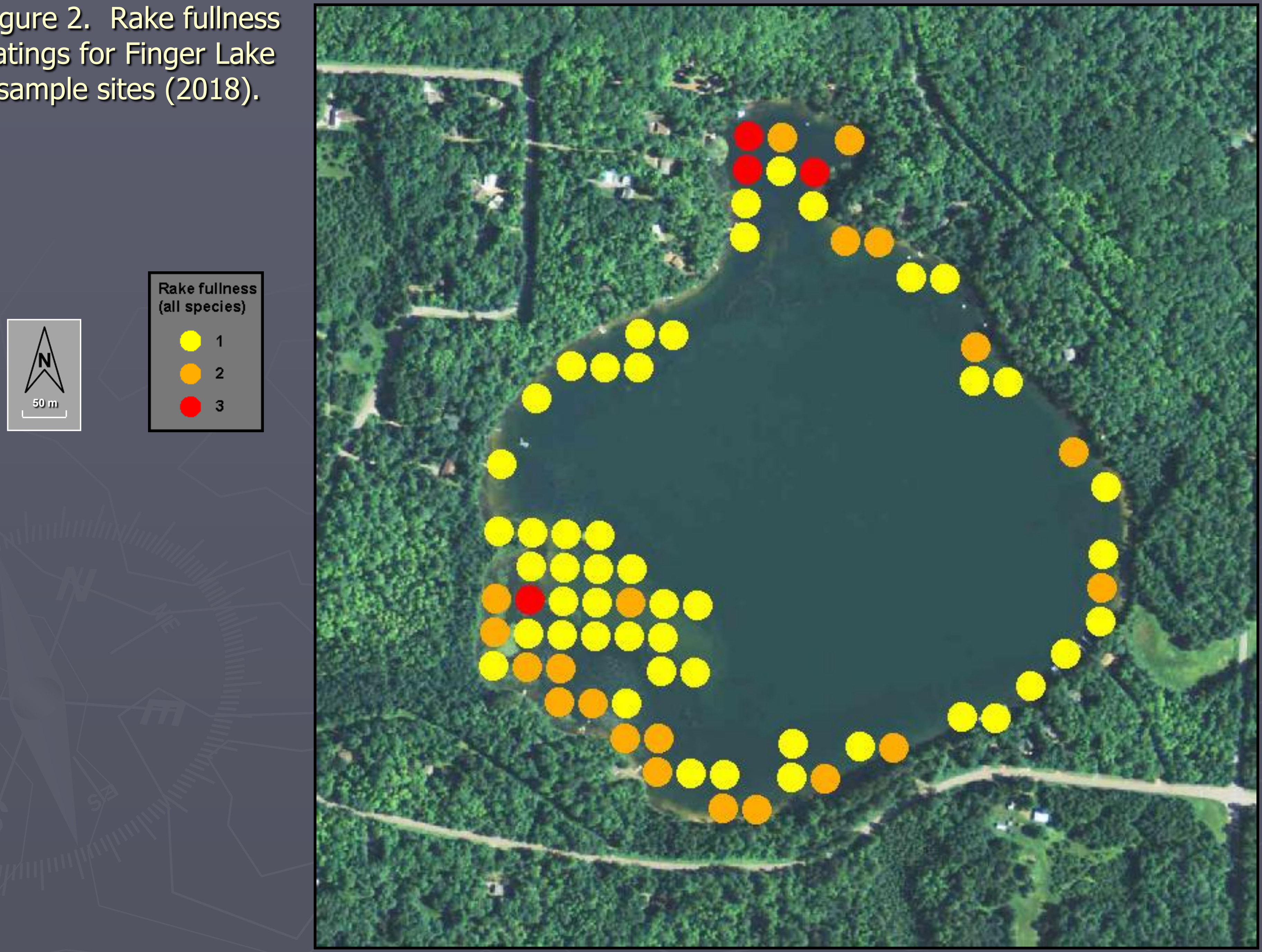


Figure 2. Rake fullness ratings for Finger Lake sample sites (2018).



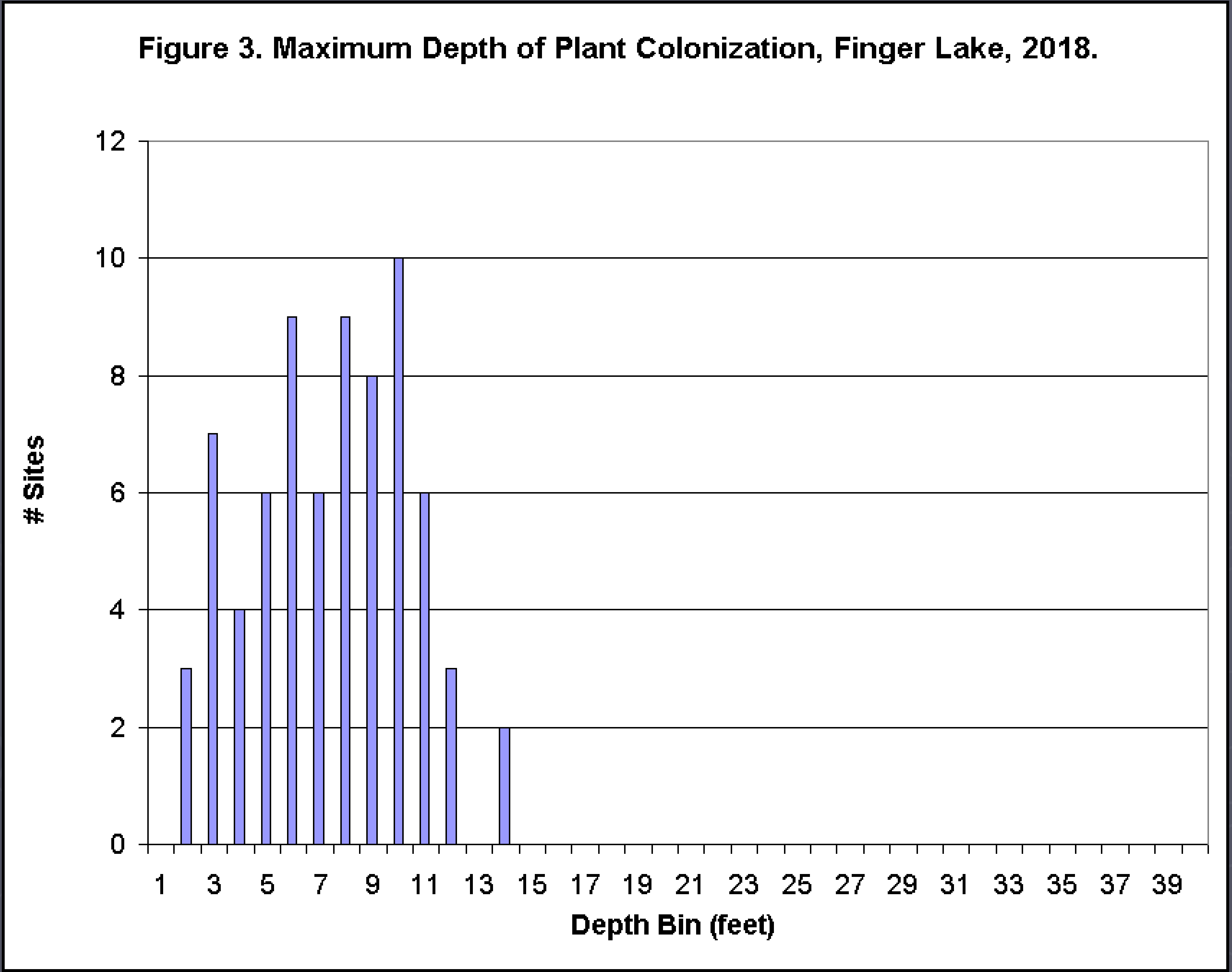


Figure 3. Maximum Depth of Plant Colonization, Finger Lake, 2018.
Sites
Depth Bin (feet)
0
2
4
6
8
10
12
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39

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

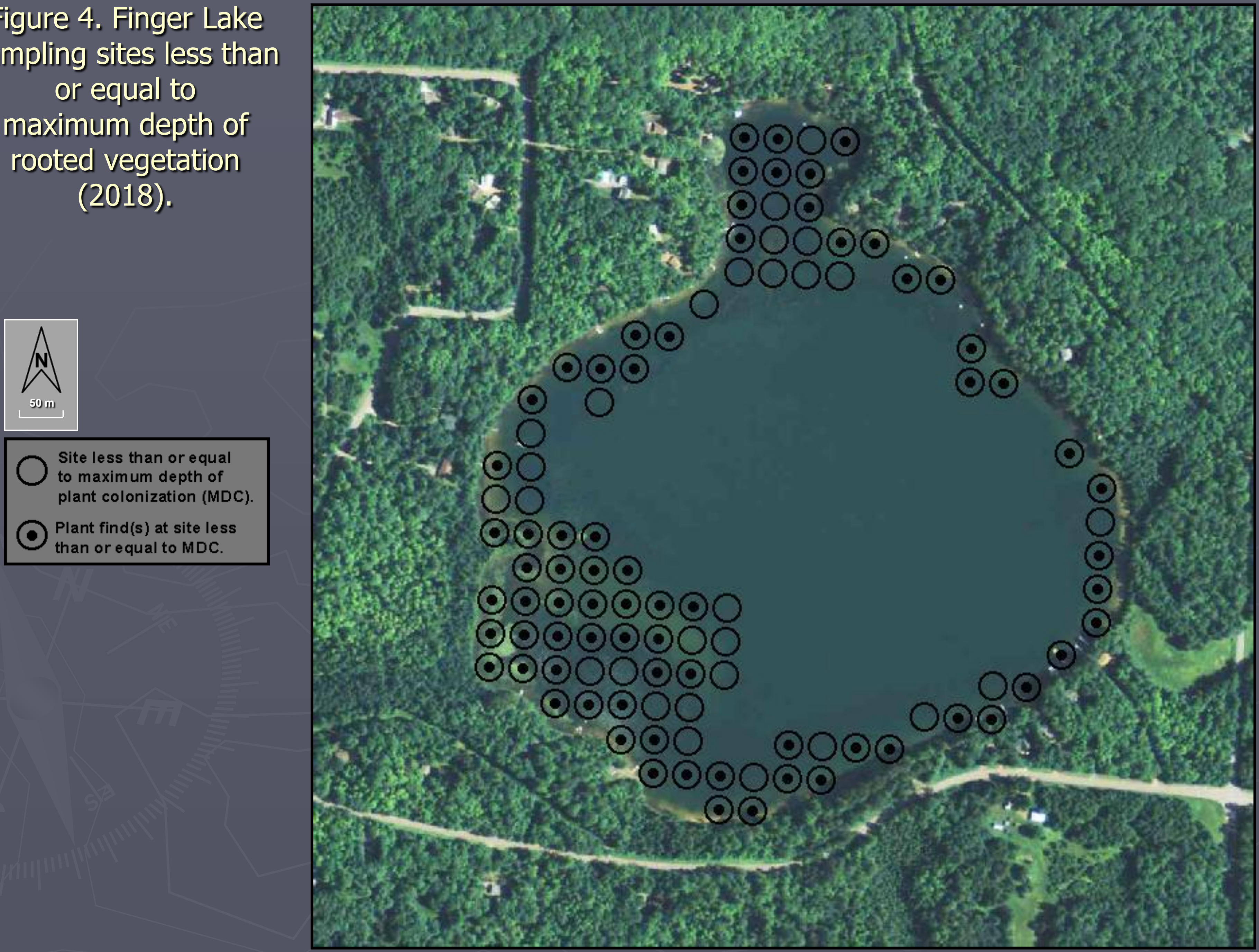


Figure 5. Finger Lake substrate encountered at point-intercept plant sampling sites (2018).

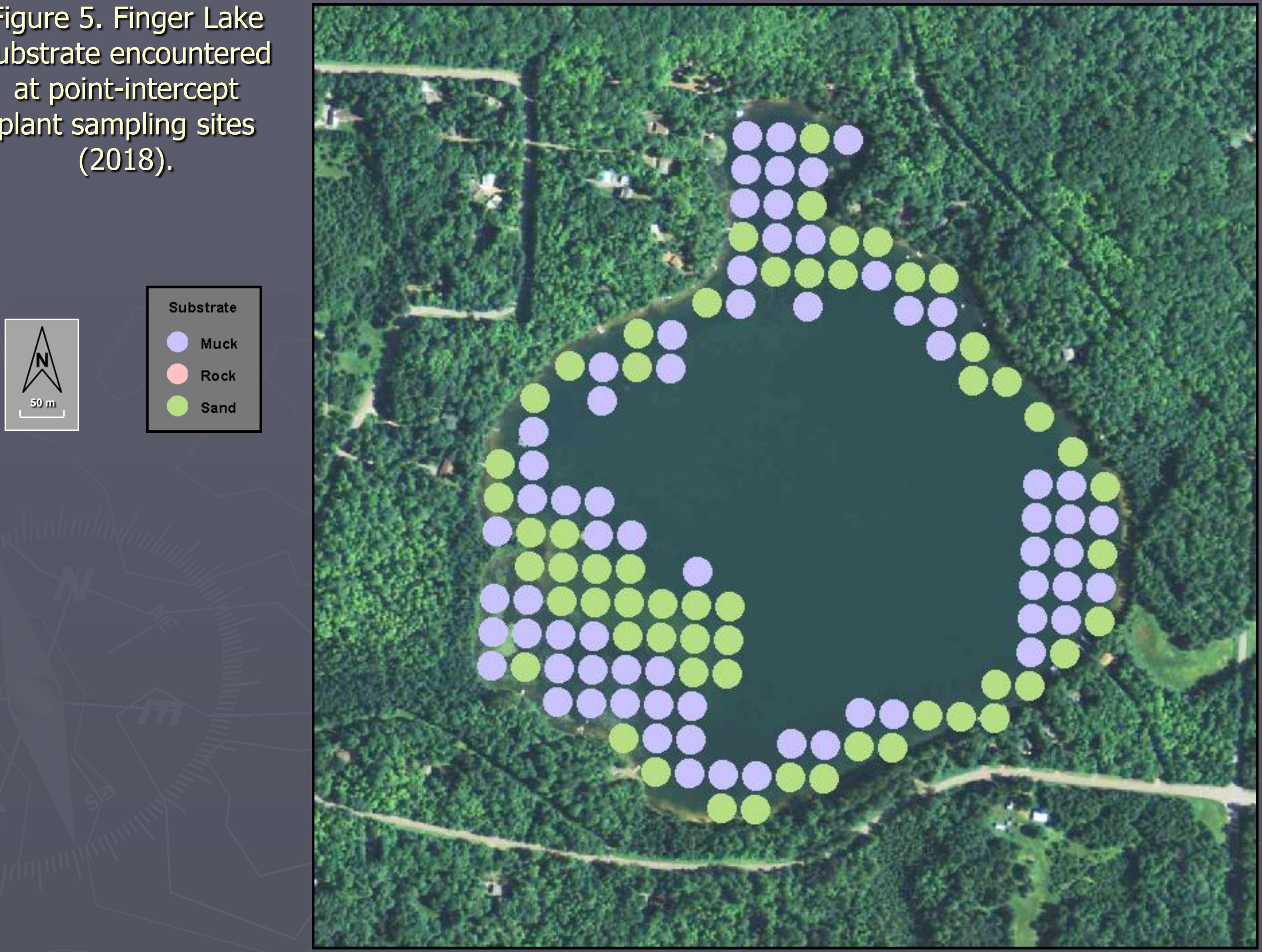


Figure 6. Finger Lake aquatic plant occurrences for 2009, 2013, and 2018 point-intercept surveys

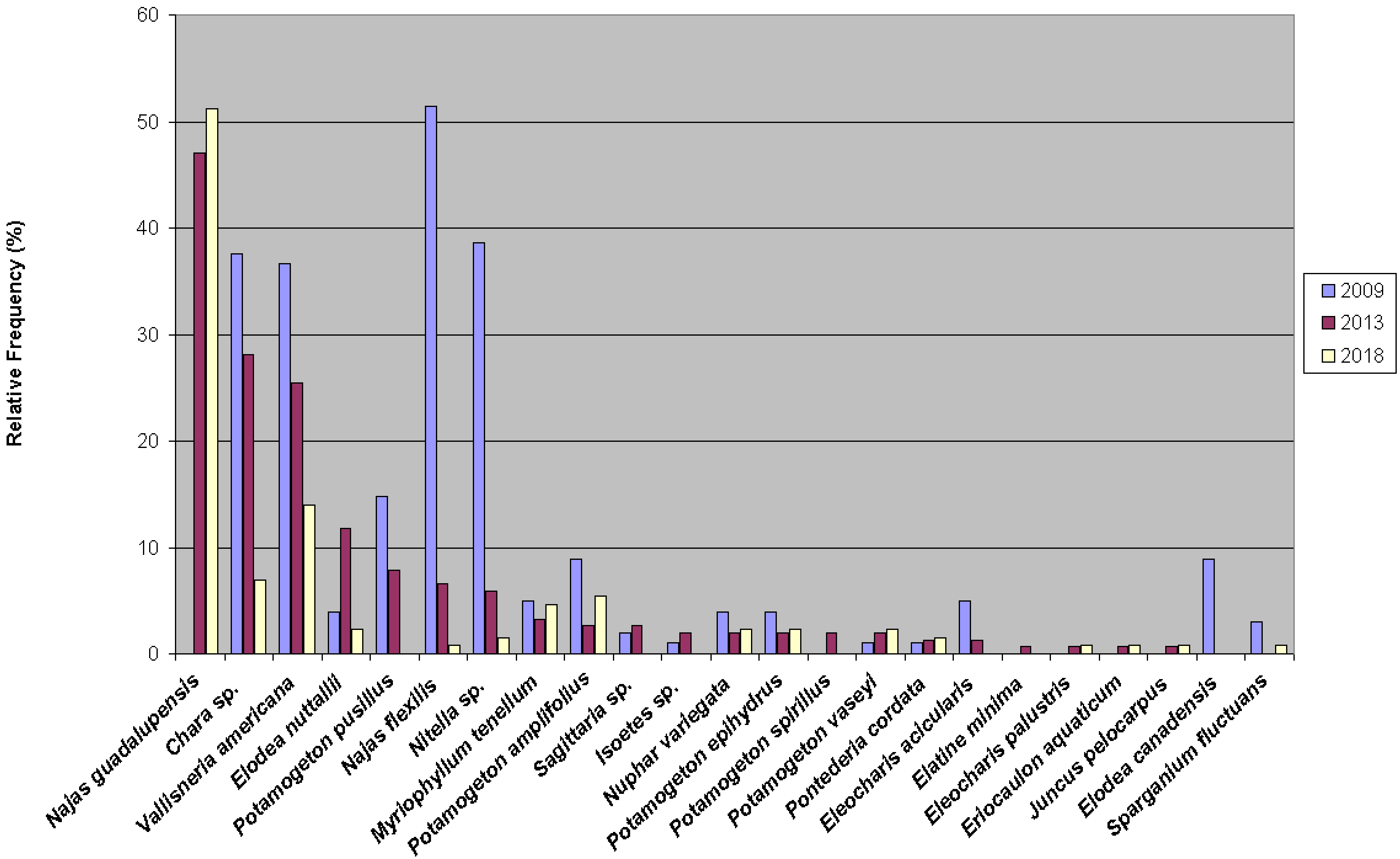


Figure 7. Finger Lake point-intercept plant sampling sites with emergent and floating aquatic plants (2018).

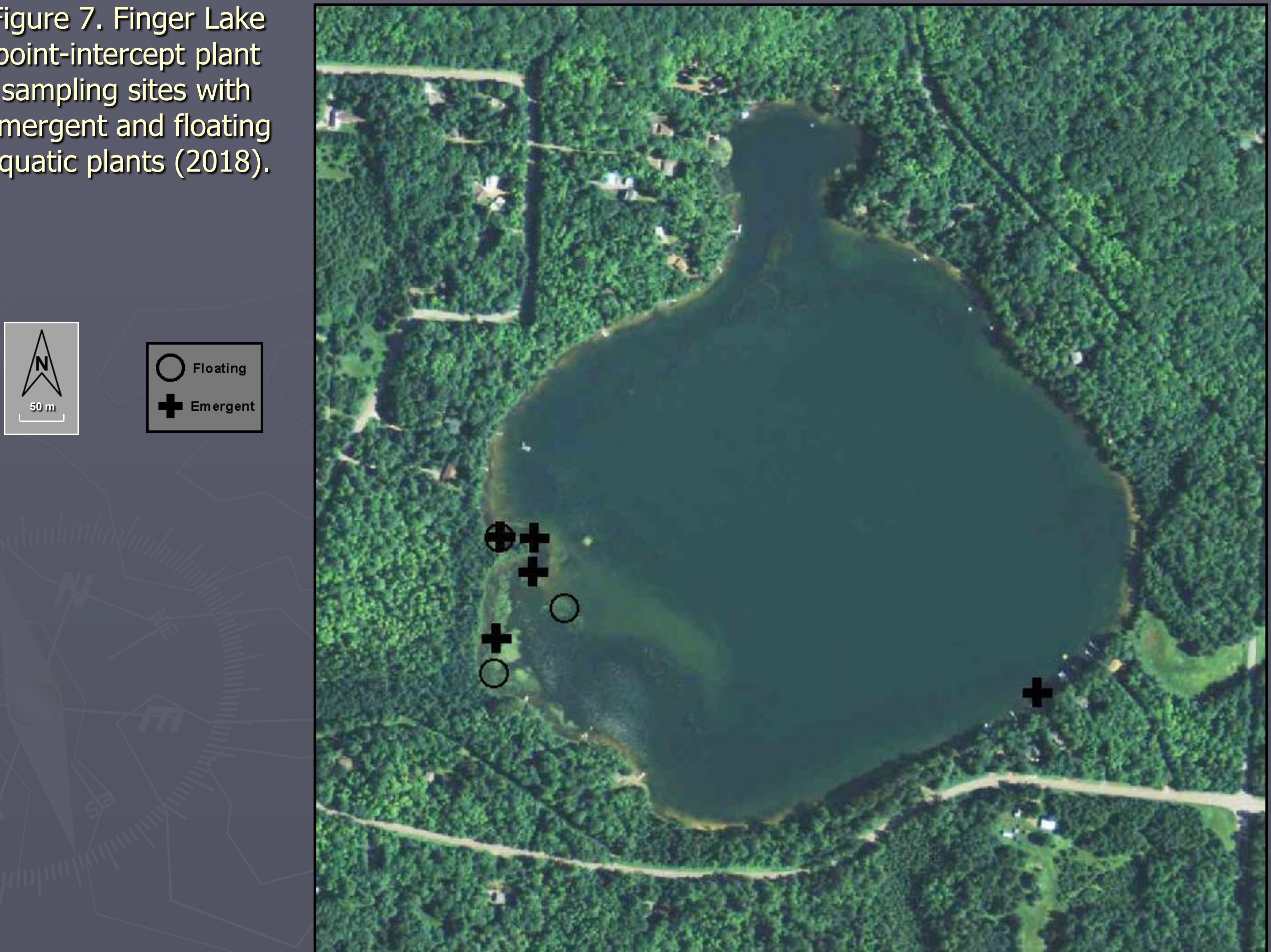


Figure 8. Distribution of plant species, Finger Lake (2018).

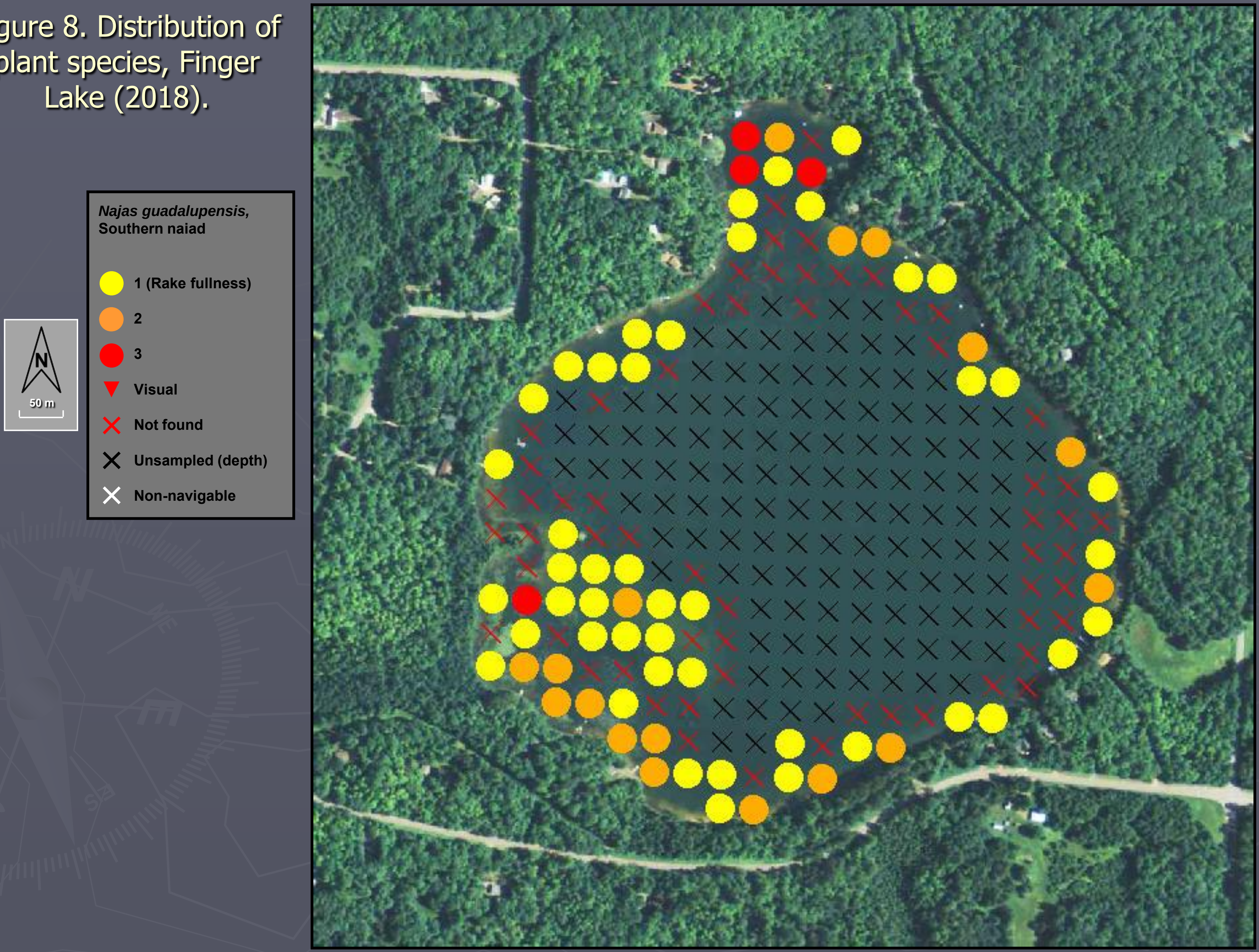


Figure 9. Distribution of plant species, Finger Lake (2018).

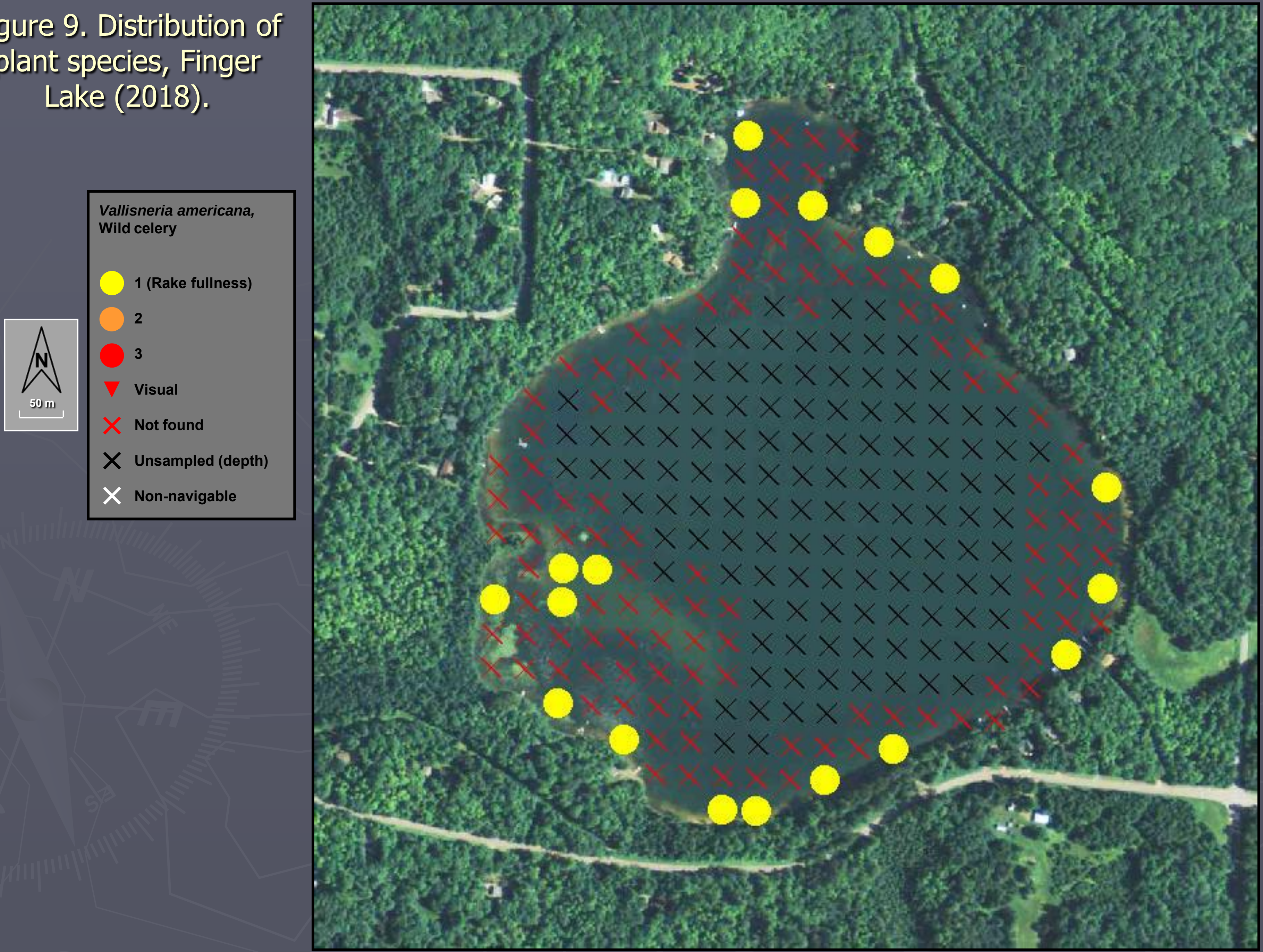


Figure 10. Distribution of plant species, Finger Lake (2018).

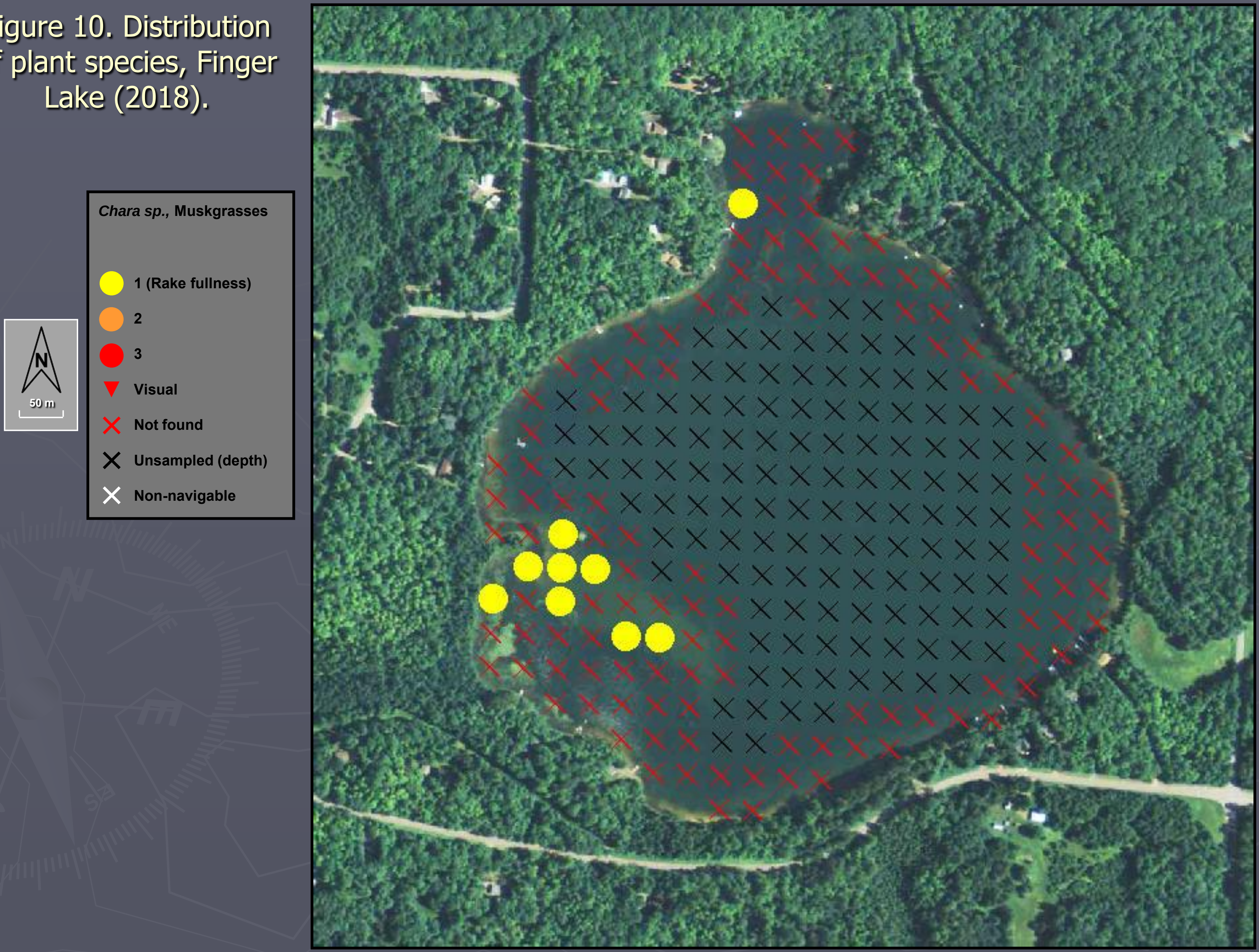


Figure 11. Distribution of plant species, Finger Lake (2018).

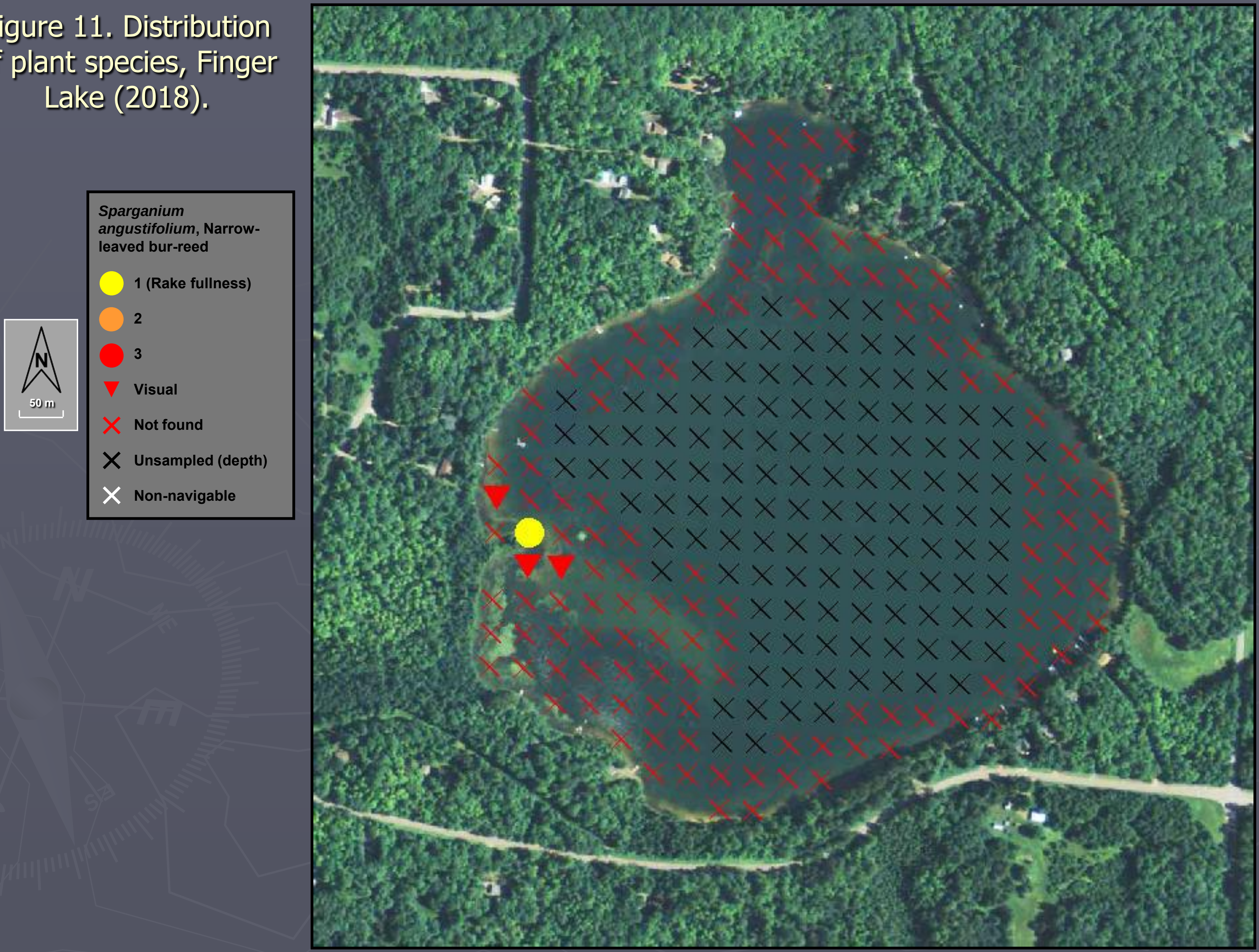


Figure 12. Distribution of plant species, Finger Lake (2018).

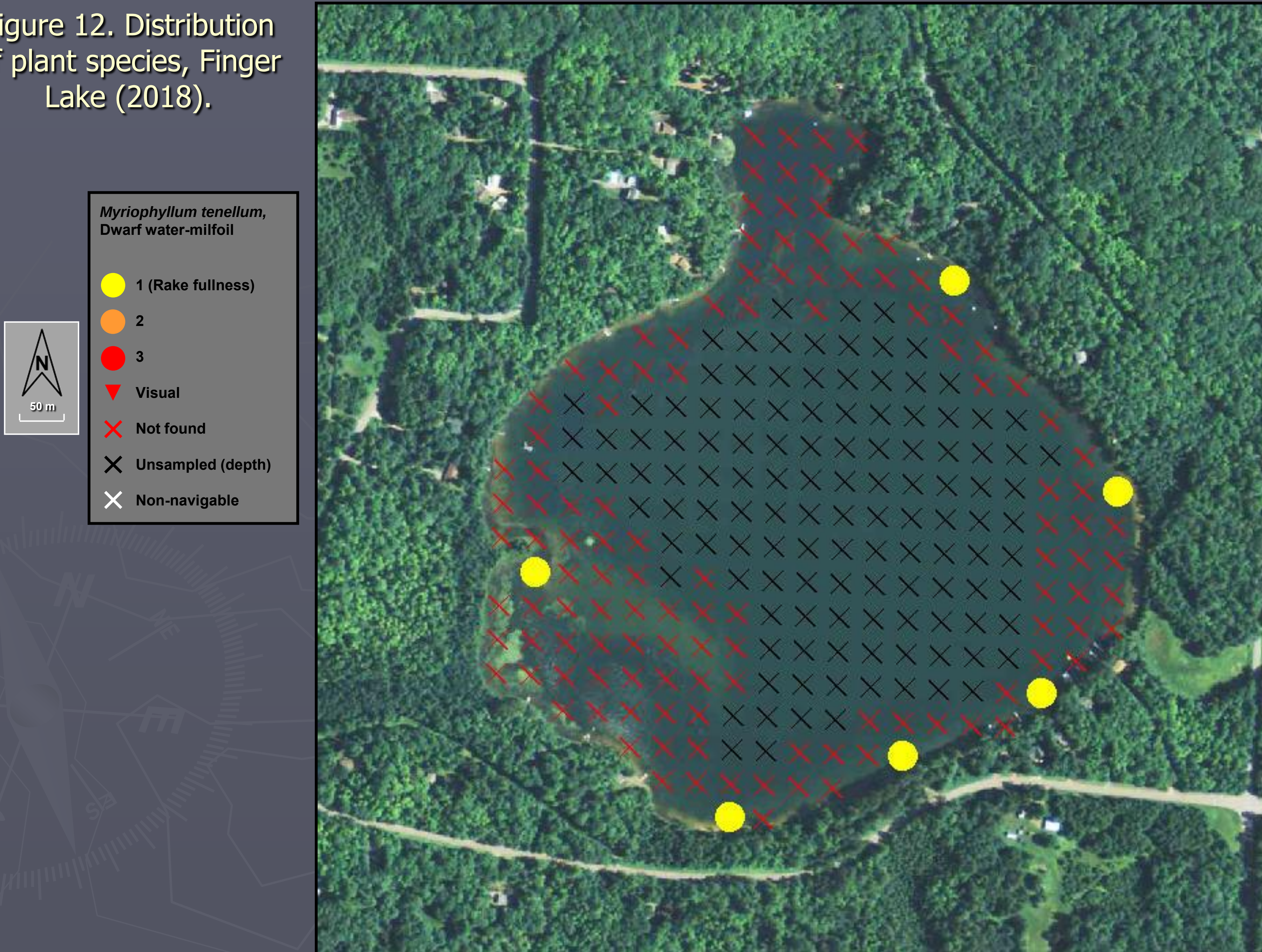


Figure 13. Distribution of plant species, Finger Lake (2018).

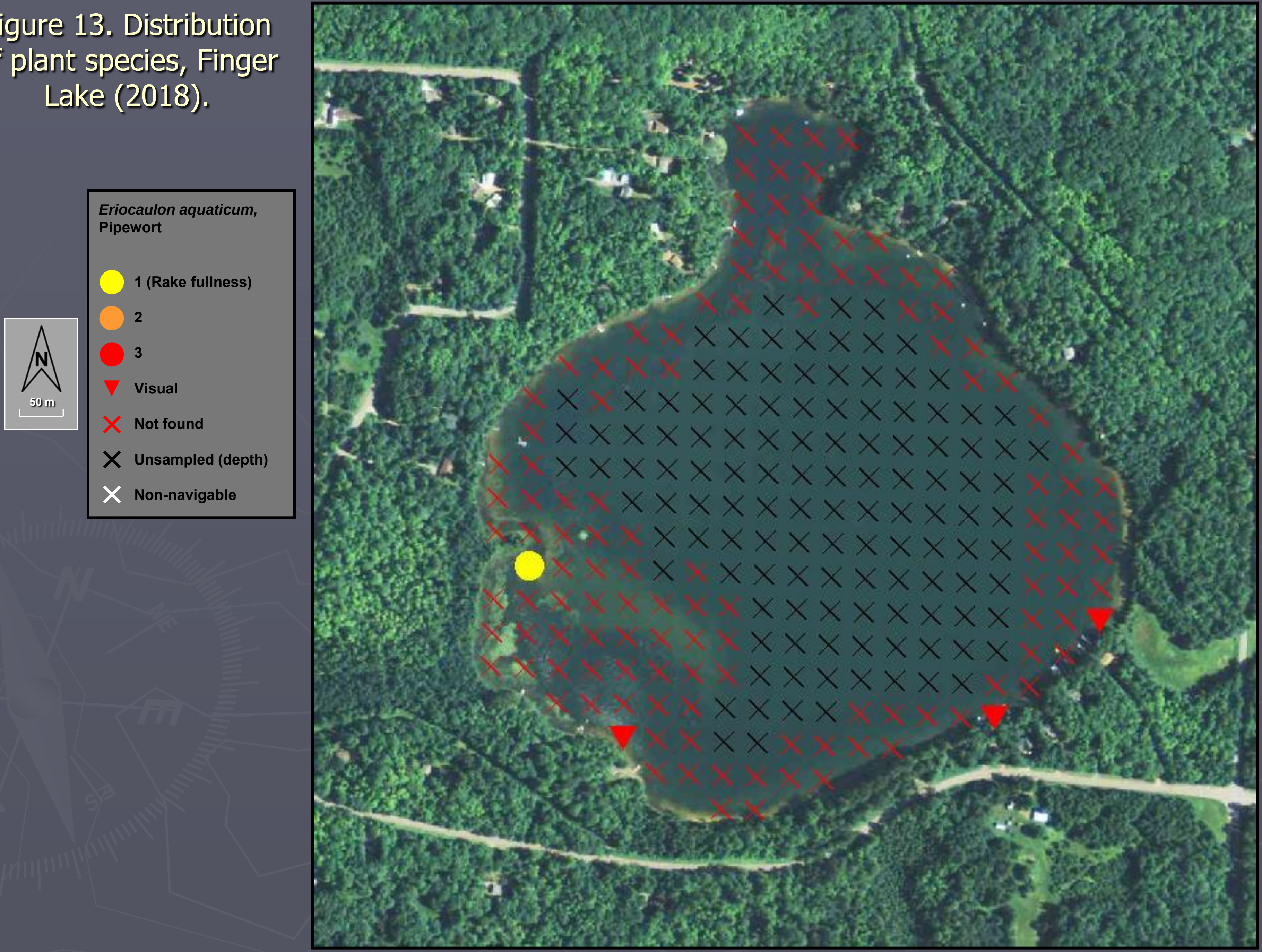


Figure 14. Distribution of plant species, Finger Lake (2018).

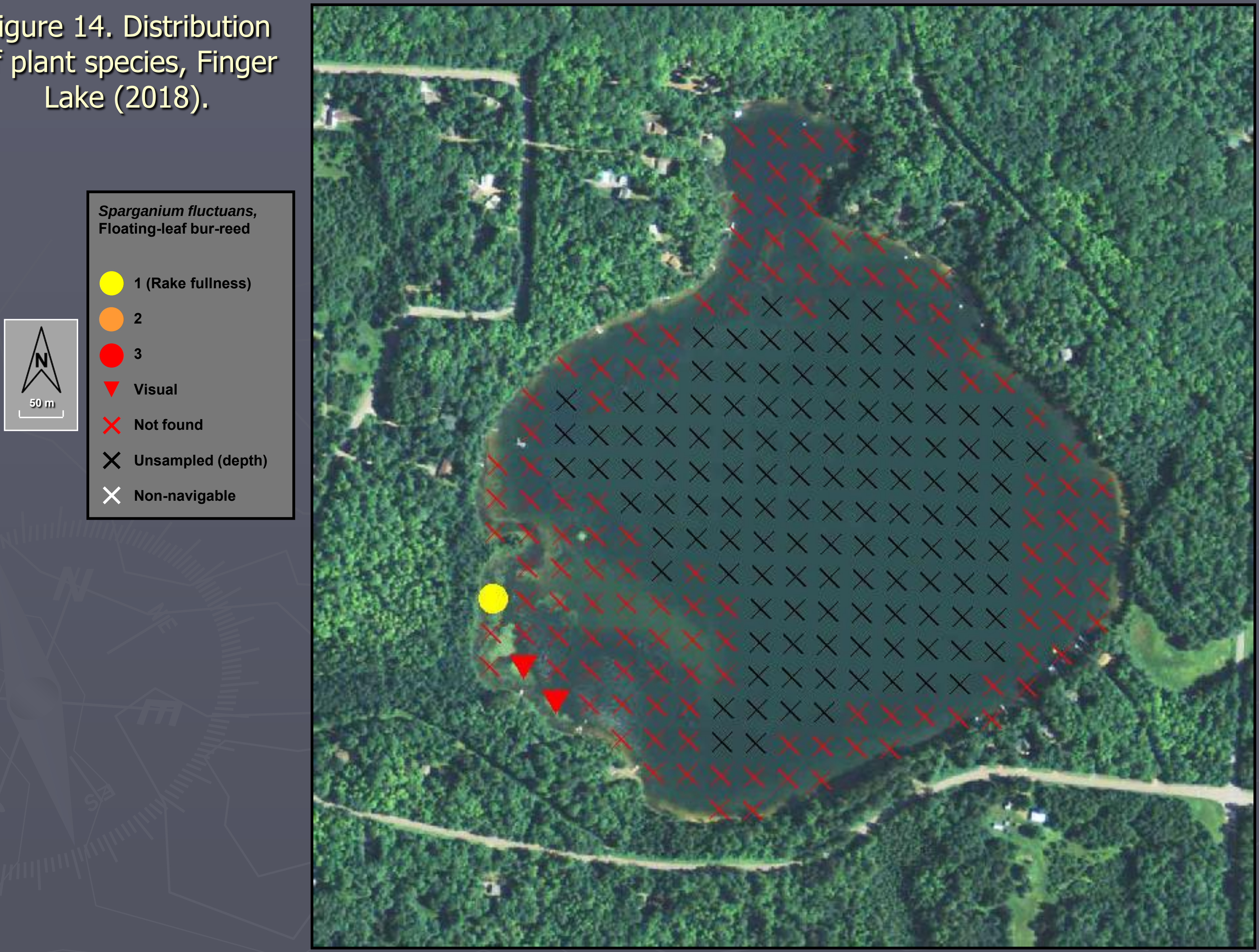


Figure 15. Distribution of plant species, Finger Lake (2018).

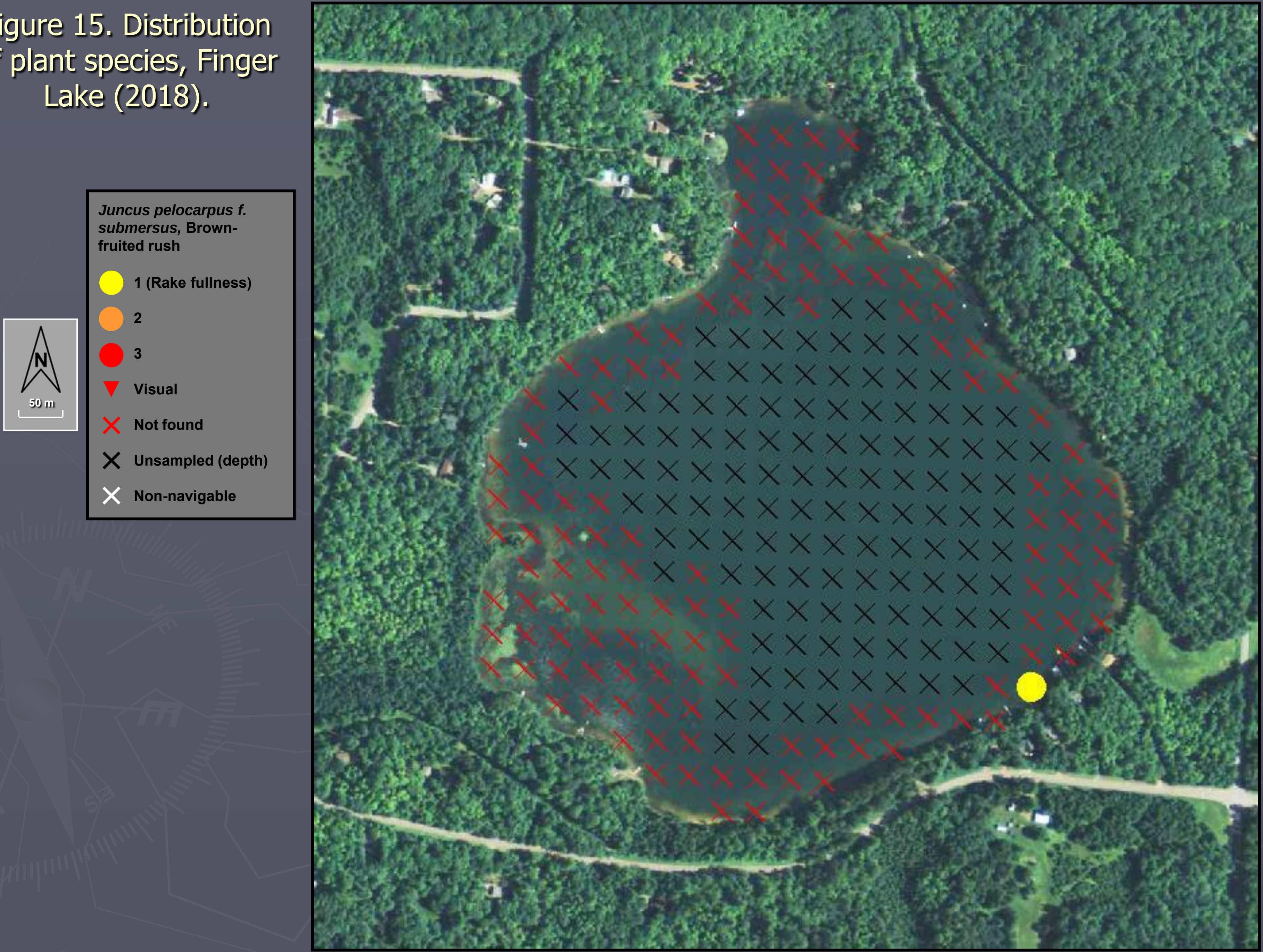
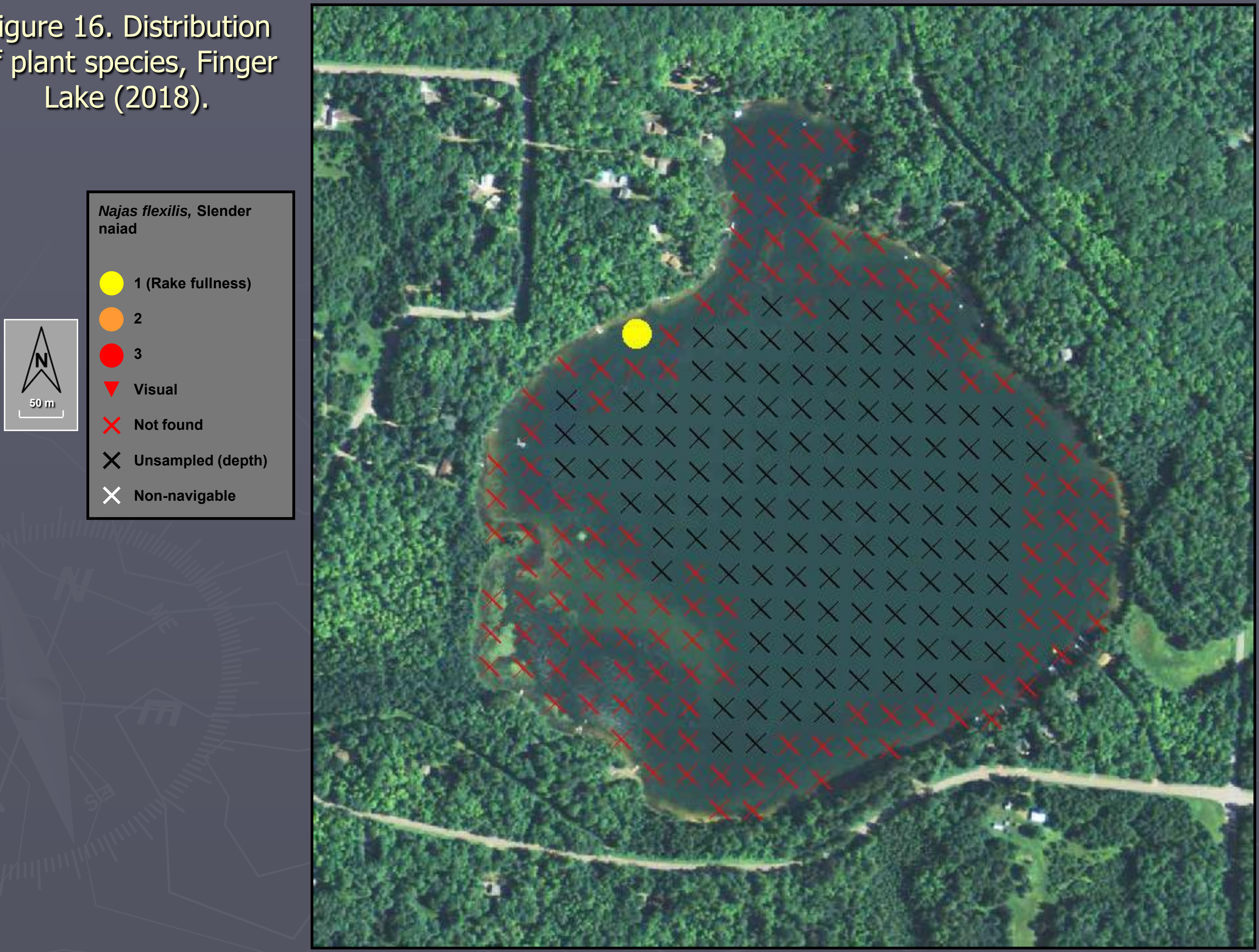


Figure 16. Distribution of plant species, Finger Lake (2018).



Scale for Finger Lake sample sites (2018)

Appendix 4

2013 Aquatic Plant Report

Finger Lake Aquatic Plant Survey

Susan Knight
Trout Lake Station
UW-Madison Center for Limnology
WI DNR
November 2013

Summary

Susan Knight, Chris Winter and Erick Fruehling performed a point-intercept aquatic plant survey on Finger Lake (WBIC 984700) on August 5-6, 2013. The sampling grid included 248 points of which 117 sites had vegetation. We found 21 (23 including plants seen but not collected on the rake) plant species, including floating and submersed species, growing to a maximum of 19.6 feet. Floristic Quality Index was 33.54 and the Aquatic Macrophyte Community Index was 56. There was a diversity of plant growth types and no invasive species, though southern naiad was a large presence with a frequency of occurrence of 47%. A similar plant survey done in 2009 found a similar flora but without the southern naiad. The species richness has not declined, but the large presence of one species, southern naiad, where it had not existed four years ago, indicates the aquatic plant community in this lake should be monitored.

Introduction and Methods

Susan Knight, Chris Winter and Erick Fruehling participated in a point-intercept aquatic plant survey on Finger Lake (WBIC 984700) on August 5-6, 2013. Using a point intercept sampling technique, we used a rake on a pole (good for depths up to 15') and a rake on a rope (used for sites deeper than 15') to sample plants.

We worked as a team of three, with one person driving the boat and navigating to each point, a second person raking, identifying each species and determining abundance and a third person recording data. At each site we determined depth and bottom substrate (as muck, sand or rock). We recorded the total rake fullness as 0 (no plants), 1 (a few plants on the rake), 2 (rake approximately half-full) or 3 (rake overflowing with plants). We also rated the abundance (using a scale of 1 to 3) of each species found at each point. At each site we looked for species observed within 6 feet of the boat, but not actually collected on the rake (visuals). As we neared shore, we also conducted a boat survey to collect comments about the shoreline and shoreline vegetation.

Using data collected in the survey, we calculated Floristic Quality Index (Nichols 1999) and Aquatic Macrophyte Community Index (Nichols et al. 2000) as tools for assessing the floristic integrity of Finger Lake and to compare it to other nearby lakes. FQI is a computation assessing lake quality using two parameters: the number of species present and the coefficient of conservatism (C) for each species. C ranges from 1-10 and indicates how pristine an environment a species requires. These values were assigned by a panel of botanists for each plant species in Wisconsin. FQI is based on species recognized by Nichols (1999) as native aquatics. Some species collected are not included in this measure for several reasons: not all aquatic/wetland transition species are included (e.g. *Lysimachia terrestris*), identification is uncertain (e.g. moss or *Sparganium* sp.), or it may be an introduced species (none in this study). Also, visuals are not included in the FQI. Therefore, the total number of plants identified may be greater than the number of species contributing to the FQI. The C value of each species is averaged to compute an average C value for the lake and this value is multiplied by the square root of the number of species seen on the lake. AMCI is a sum of seven parameters, each scaled 1-10 (for a maximum total of 70), and is another assessment of lake quality using plant data.

Results

The grid included 248 sampling points. We visited 244 points, the rest being on shore or deeper than the maximum growing depth of plants, determined to be 19.6 feet (Figure 1). The plants were well distributed at almost all depths, though they fell off sharply below 17 feet. We determined there were 153 points as shallow as or shallower than 19.6 feet and, of these, 117 sites, or 76.47%, had vegetation (Table 1). There were 3 sites deemed non-navigable (on shore, Figure 2 and others).

We found a variety of substrate types, with muck dominating the central basin and sand in much of the shallow areas of the lake and very little rock (Figure 2). There is a fairly regular depth distribution throughout the lake (Figure 3).

We found a total of 23 species, including 21 found on the rake, and 2 visuals (seen within 6’ of the boat, Table 2, Figure 4). Southern naiad was the most abundant species found with a frequency of occurrence of 47% at sites shallower than the maximum depth of plants (Figure 5). Muskgrass *(Chara* sp., 28%, Figures 6,7) and wild celery (*Vallisneria americana*, 25%, Figure 8) were also abundant (Table 2). We found a variety of plant types, including floating (spatterdock, *Nuphar variegata*) and emergent (pickerelweed, *Pontederia cordata*) plants as well as many submersed species. There was also a variety of plant growth forms, with both short, stiff rosette species, such as dwarf water-milfoil (*Myriophyllum tenellum*) and quillwort (*Isoetes* sp.), typical of sandy, low nutrient and often wave swept sites and also leafier plants, such as slender waterweed (*Elodea nuttallii*) and small pondweed (*Potamogeton pusillus*, Figure 9). Together, the species diversity and the lack of exotics indicate good water quality and a good aquatic plant community.

We found an average of 1.67 species per site, with a few sites having 6 to 8 species (Figure 10). Sites with high plant density (rake fullness of 3, Figure 11) were distributed through most of the west and north parts of the lake.

The Floristic Quality Index (FQI, Nichols 1999,) was 33.54 (Tables 1, 3) and is greater than Nichols’ (1999) findings of Lakes in the Northern Lakes and Forests Region (Table 3). FQI can be high because the average coefficient of conservatism is high and/or the number of species is high. In Finger, compared to the other lakes, the species diversity was slightly greater than other Washington township lakes while the average coefficient of conservatism was about average of other nearby lakes. Finger Lake values were greater than the average for regional lakes.

The Aquatic Macrophyte Community Index (AMCI, Nichols et al. 2000), was 56 out of a maximum of 70 (Tables 1, 4), the same as in 2009. AMCI takes into account seven variables, all scaled to a maximum of 10. Three factors, the percent littoral area vegetated, the maximum depth of rooted plants and the lack of exotic species rated the maximum score of 10. The sensitive species index measures the occurrence of a certain list of plant species (deemed indicators of good plant habitat by Nichols [2000]) and is relatively low for Finger. The Simpson diversity index (measuring diversity and evenness of species distributions) of 84 corresponds to a 6 on the AMCI scale, and is relatively low because southern naiad dominated at so many sites. A lake with the same number of species but with a more even distribution would have a higher Simpson Diversity score. The submersed species value attempts to capture a complicated quality of a lake assessing the balance of emergent, floating and submersed plants. The original sampling scheme enlisted by Nichols would have sampled emergent and floating-leaved species that grow closer to shore more frequently than our point intercept procedure. Though this value is relatively low for Finger, the submersed species value does not reflect a problem. The total AMCI score of 56 is slightly lower than lakes in the northern lakes and forest region, because of the relatively low Simpson's Diversity Index, few sensitive species (according to Nichols' formula) and few floating or emergent species. We found no Threatened or Endangered species but Vasey's pondweed (*Potamogeton vaseyi*), a species of Special Concern (meaning it is on a watch list) was found at three sites.

Discussion

Clearly the biggest change from the Finger Lake 2009 point intercept survey is the current widespread and abundant presence of southern naiad. Though this may indicate a growing problem, several factors should be kept in mind. Though the rake fullness of southern naiad is greater (1.81) than it was for slender naiad (1.38), the 2009 frequency of slender naiad (*Najas flexilis*) is about the same as the combined frequencies of southern and slender naiads in 2013. The rake fullness and frequencies together suggest that there has been a rough exchange of one *Najas* species for the other. Second, although southern naiad is new to Finger and recently has become much more common in northern Wisconsin, it is a native species and the long term consequences of its presence are unclear. The species richness has not decreased in Finger Lake, but the prevalence of this one species bears watching. Though there were reports of floating "rafts" of southern naiad prior to our survey, cool rainy conditions seemed to have caused the "rafts" to sink so that they were not visible at the surface on the two days of the 2013 survey. The survey revealed that southern naiad is not as prevalent on Finger Lake as it has become in Fishtrap Lake (Vilas County, frequency of occurrence greater than 90% in 2009) though it could still be increasing on Finger and should be watched.

Combined, all the variables we use to describe a plant community indicate Finger Lake is a healthy lake. Species richness and FQI reflect a diversity of plants, with many of them relying on a high quality aquatic environment. The maximum depth of plants is also a good indication of good water quality. The lack of invasive plants is a clear indication of a healthy system.

If the frequency of occurrence of southern naiad increases and species richness decreases, this will be a matter of concern. We should repeat this point intercept survey in no more than five years.

References

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

Nichols , S., S. Weber and B. Shaw. 2000. A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26(5):491-502.

Table 1. Finger Lake Summary

	2009	2013
Total number of points on grid	248	248
Total number of points sampled	247	244
Total # of sites with vegetation	101	117
Total # of sites shallower than maximum depth of plants	144	153
Frequency of occur. at sites shallower than maximum depth of plants (%)	70.1	76.5
Simpson Diversity Index	0.86	0.84
Maximum depth of plants (ft)	17.0	19.6
Average # of native species per site (vegetated sites only)	2.27	2.04
Species Richness (including visuals)	21	23
FQI	28.75	33.54
AMCI	56	56

Table 2. Finger Lake 2013. Frequency of occurrence of species at sites shallower than maximum depth of plants.

	Scientific Name	Common Name	Frequency of Occurrence
1	*Najas guadalupensis*	Southern naiad	47.06
2	*Chara* sp.	Muskgrass	28.10
3	*Vallisneria americana*	Wild celery	25.49
4	*Elodea nuttallii*	Slender waterweed	11.76
5	*Potamogeton pusillus*	Small pondweed	7.84
6	*Najas flexilis*	Slender naiad	6.54
7	*Nitella* sp.	Stonewort	5.88
8	*Myriophyllum tenellum*	Dwarf water-milfoil	3.27
9	*Potamogeton amplifolius*	Large-leaf pondweed, cabbage	2.61
10	*Sagittaria* sp.	Arrowhead	2.61
11	*Isoetes* sp.	Quillwort	1.96
12	*Nuphar variegata*	Spatterdock	1.96
13	*Potamogeton epihydrus*	Ribbon-leaf pondweed	1.96
14	*Potamogeton spirillus*	Spiral-fruited pondweed	1.96
15	*Potamogeton vaseyi*	Vasey's pondweed	1.96
16	*Pontederia cordata*	Pickerelweed	1.31
17	*Eleocharis acicularis*	Needle spikerush	1.31
18	*Elatine minima*	Waterwort	0.65
19	*Eleocharis palustris*	Creeping spikerush	0.65
20	*Eriocaulon aquaticum*	Pipewort	0.65
21	*Juncus pelocarpus*	Brown-fruited rush	0.65

Table 3. Comparison of Floristic Quality Index Values, Washington Township Lakes and Regional Average

Lake	FQI	Number of Species	Average C*
Anvil	30.6	17	7.4
Finger 2009	28.8	16	7.2
Finger 2013	33.5	21	7.5
Bass	28.3	18	6.7
Tinsel	28.0	12	8.1
Harmony	28.0	12	8.1
Spirit	25.9	11	7.8
Spring Meadows	25.3	16	6.3
Rade	23.0	9	7.7
Northern Lakes and Forests, Lakes Average (Nichols 1999)	24.3	13	6.7
			*Coefficient of Conservatism

Table 4. Aquatic Macrophyte Community Index Finger Lake 2013

	Northern Lakes and Forests Region*	Finger Lake 2009		Finger Lake 2013		Maximum
	Median	AMCI raw value	AMCI scaled value	AMCI raw value	AMCI scaled value	AMCI Value
Max depth of plant growth (m)	3.5	5.18	10	5.97	10	10
Littoral area vegetated (%)	75	70.14	10	76.47	10	10
Submersed Species (relative %)	80	95.63	6	97.5	6	10
Taxa Number	18	17(21)	8	21 (23)	9 (9)	10
Exotic Species (relative %)	0	0	10	0	10	10
Simpson's Diversity Index	88	86	7	84	6	10
Sensitive species (relative %)	20	6.99	5	6.8	5	10
Total	**57**		**56**		**56**	**70**
	*Data collected prior to 2000, Nichols et al. 2000					

Figure 1. Maximum Depth of Plant Colonization in Finger Lake 2013.

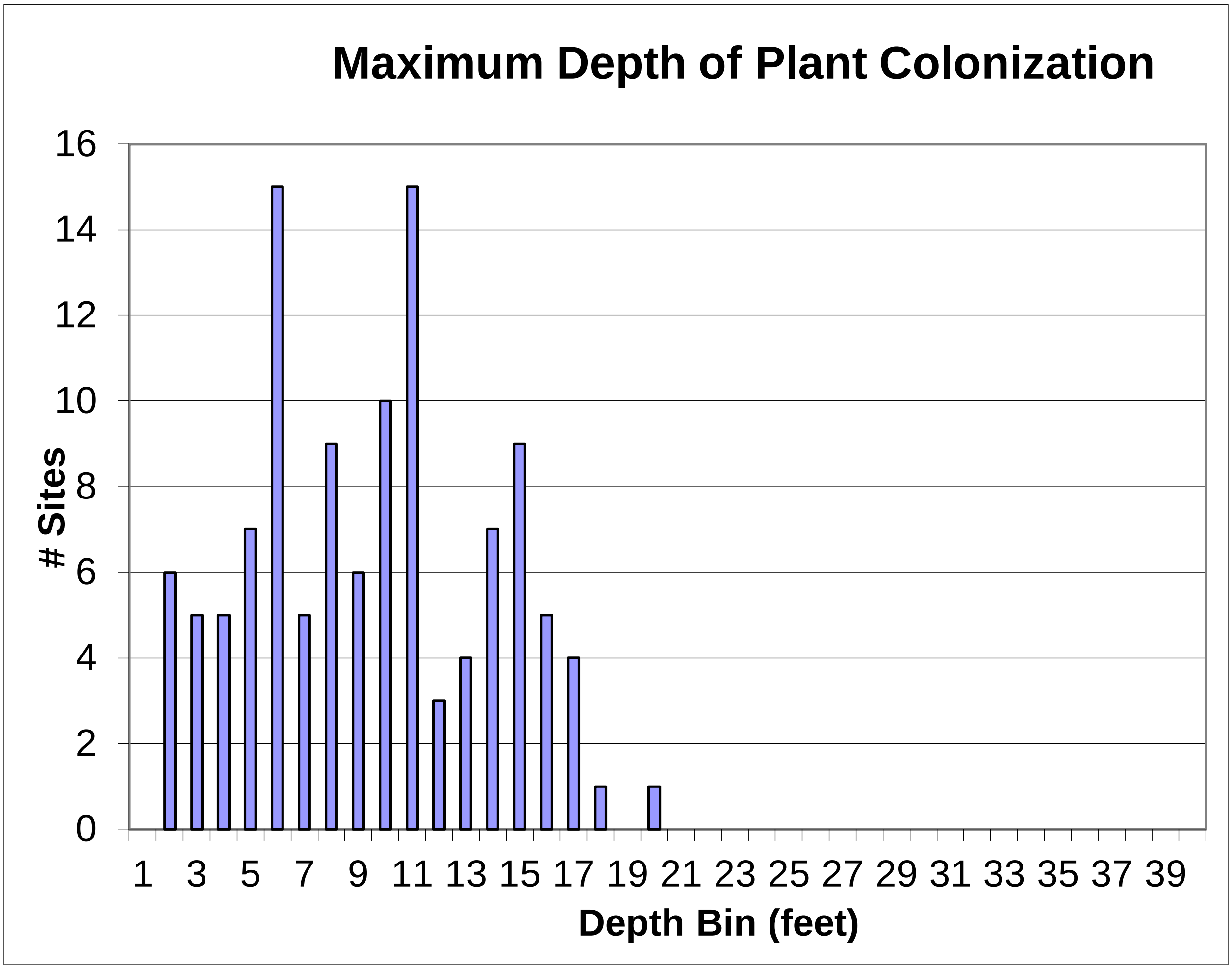


Figure 2. Bottom substrates in Finger Lake

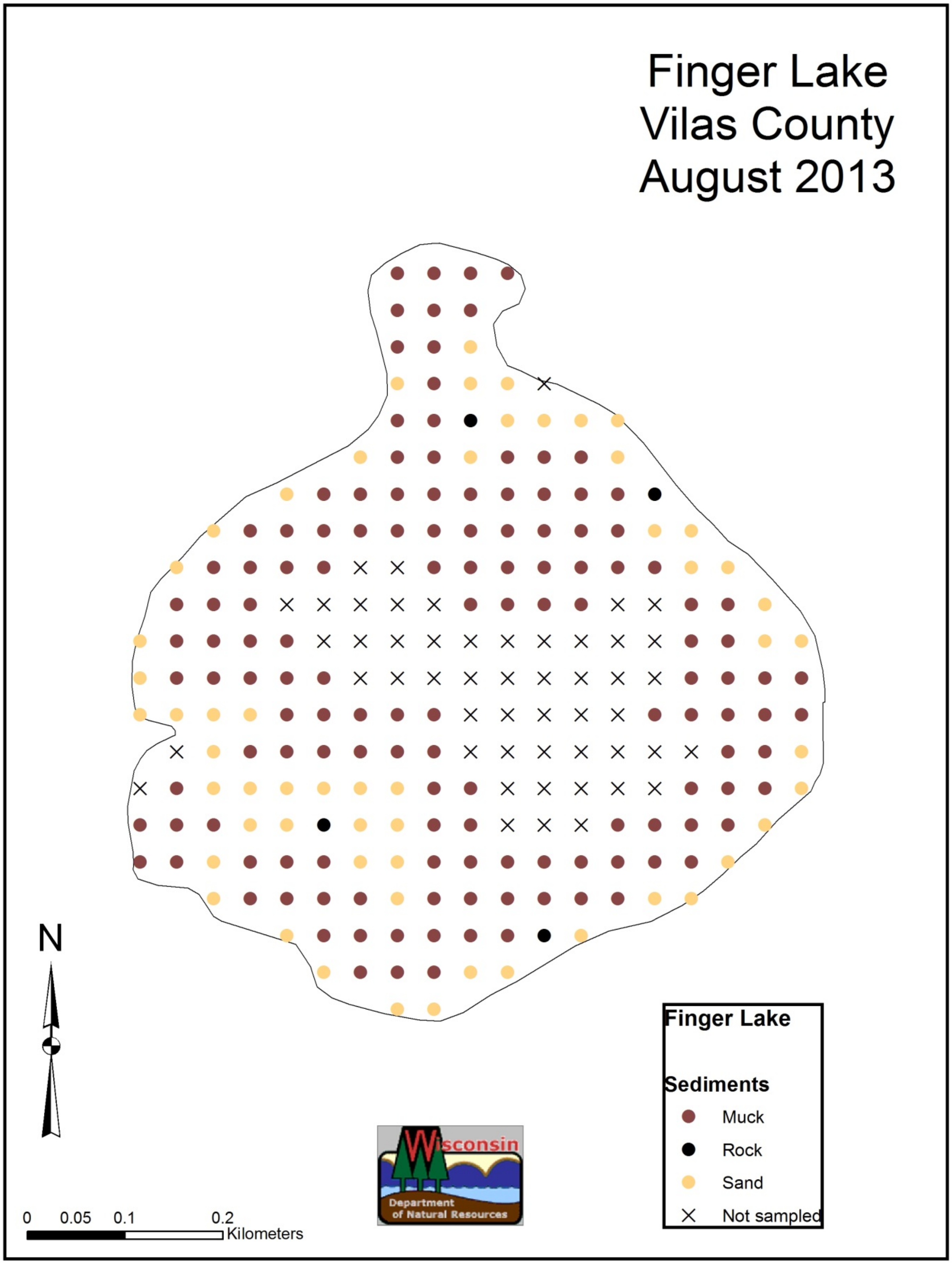


Figure 3. Depth distribution in Finger Lake.

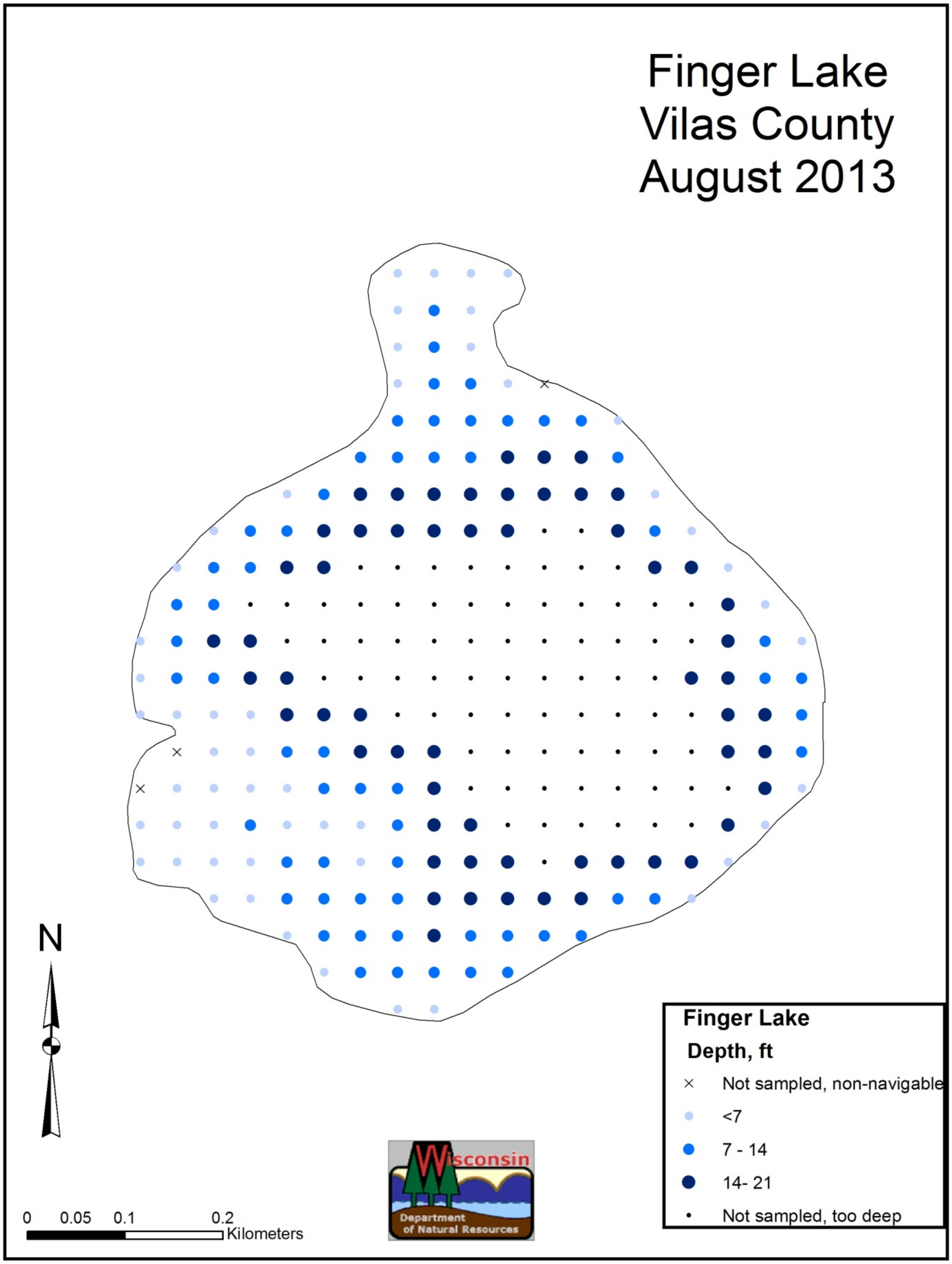


Figure 4. Frequency of occurrence of species found shallower than the maximum depth of plants.

2009 and 2013.

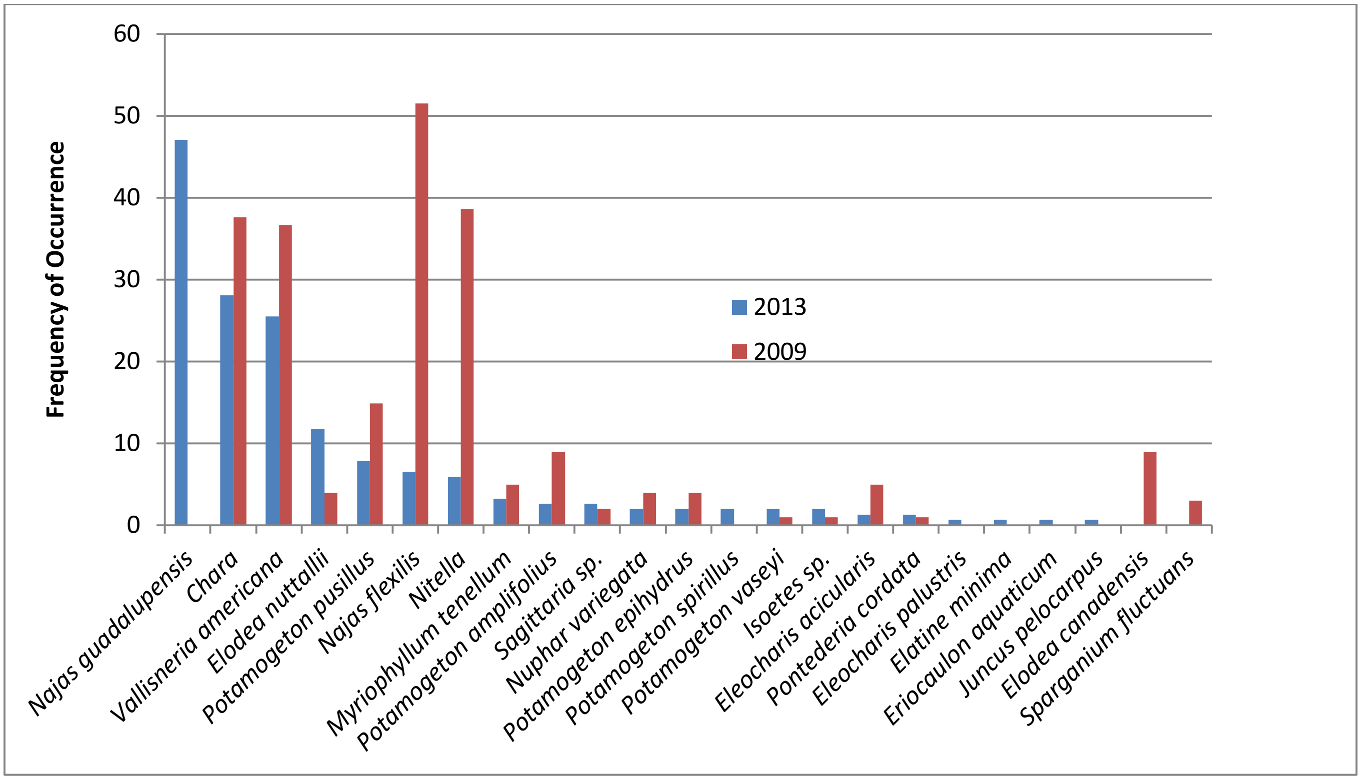


Figure 5. Rake fullness of southern naiad on Finger Lake 2013.

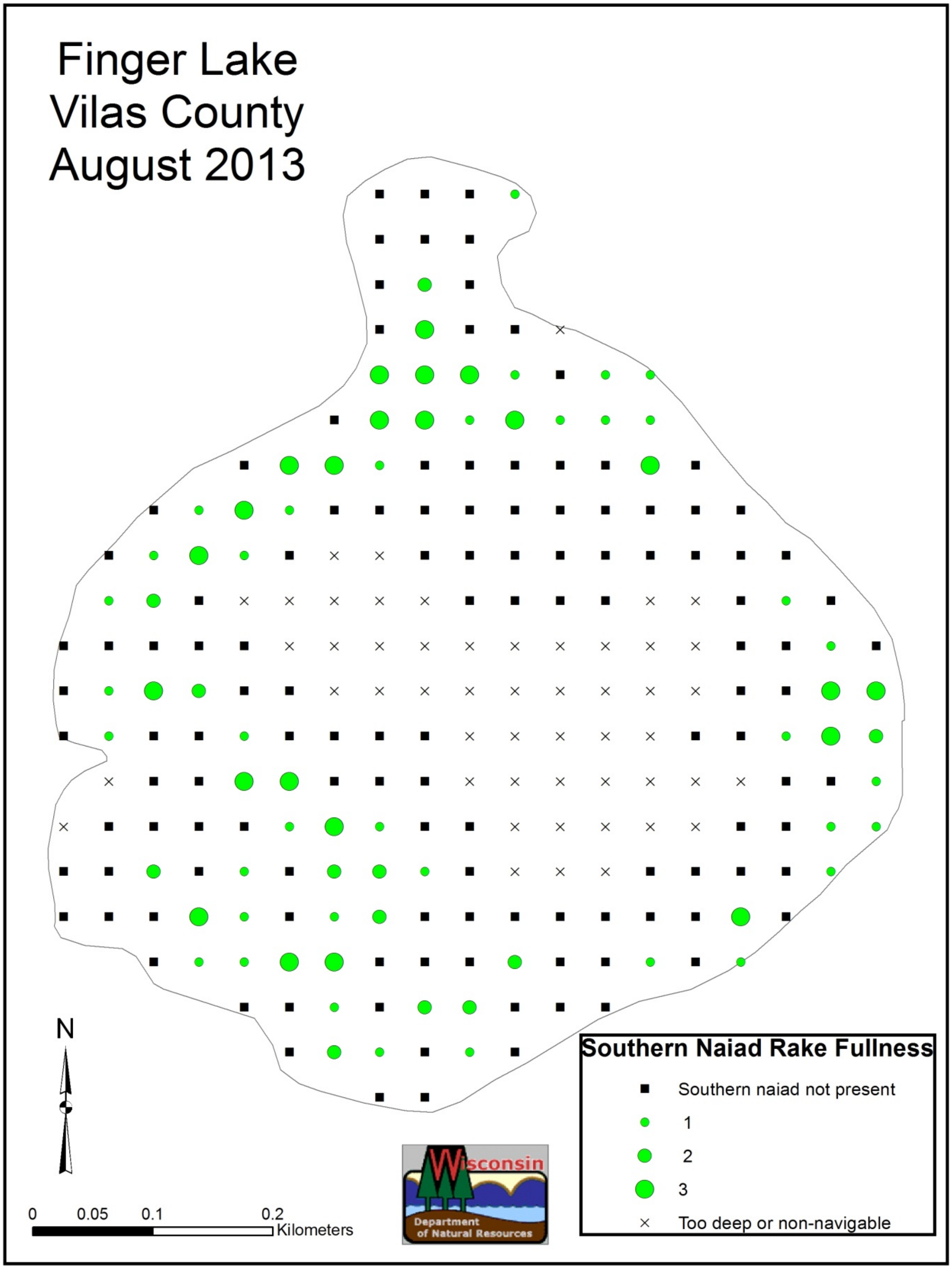


Figure 6. Southern naiad and stonewort (Chara).

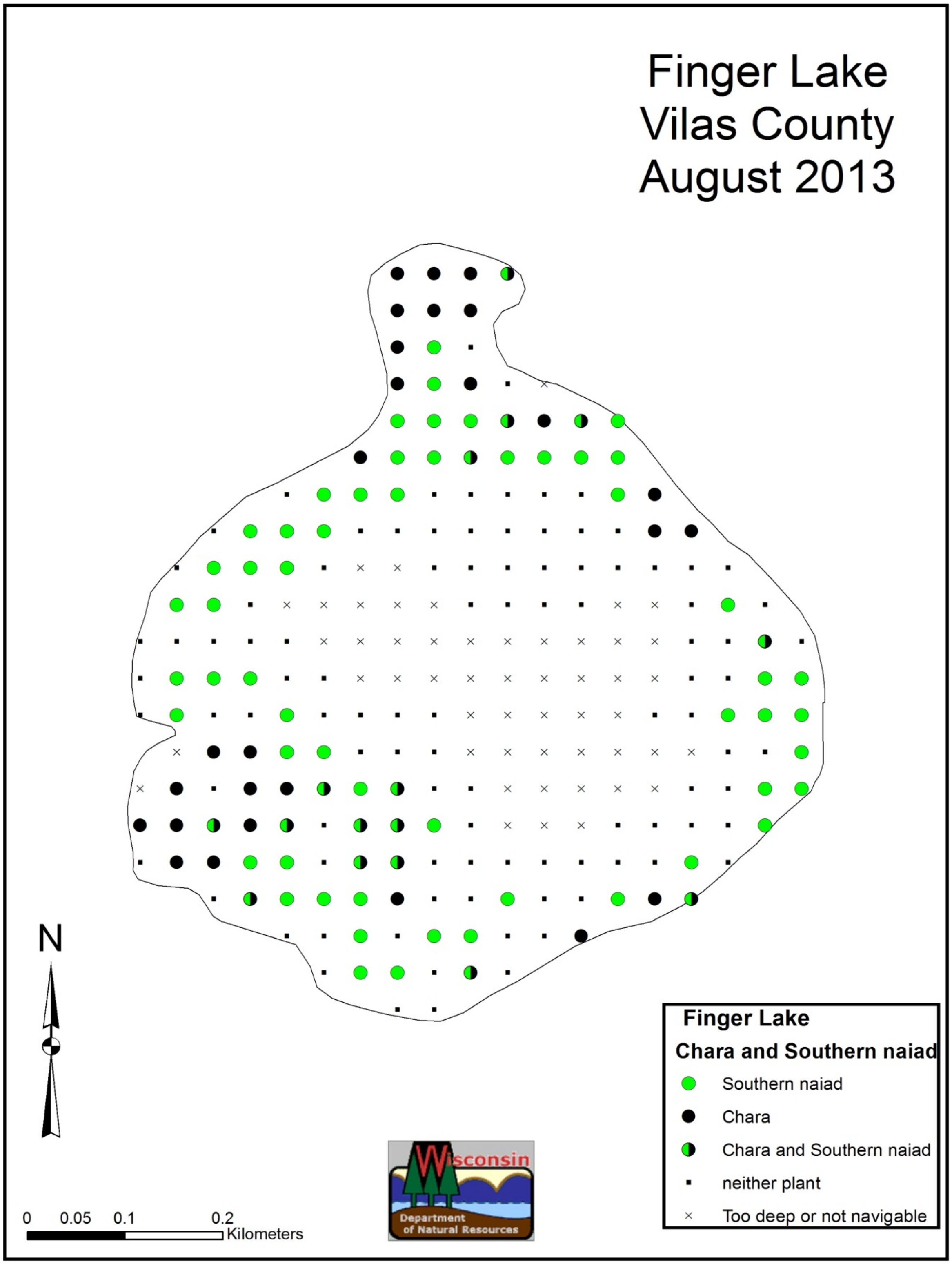


Figure 7. The distribution of Chara and Nitella.

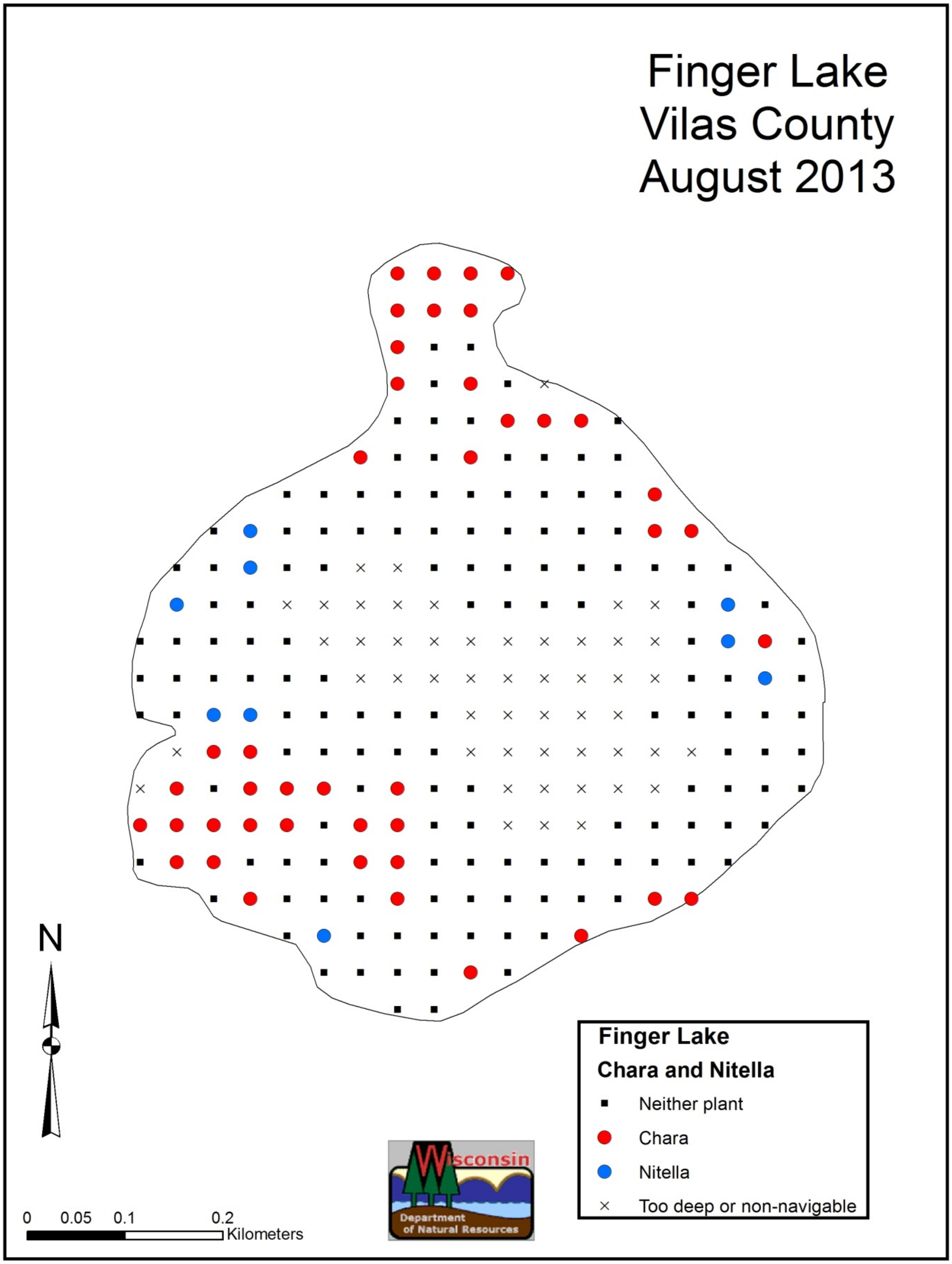


Figure 8. Wild celery.

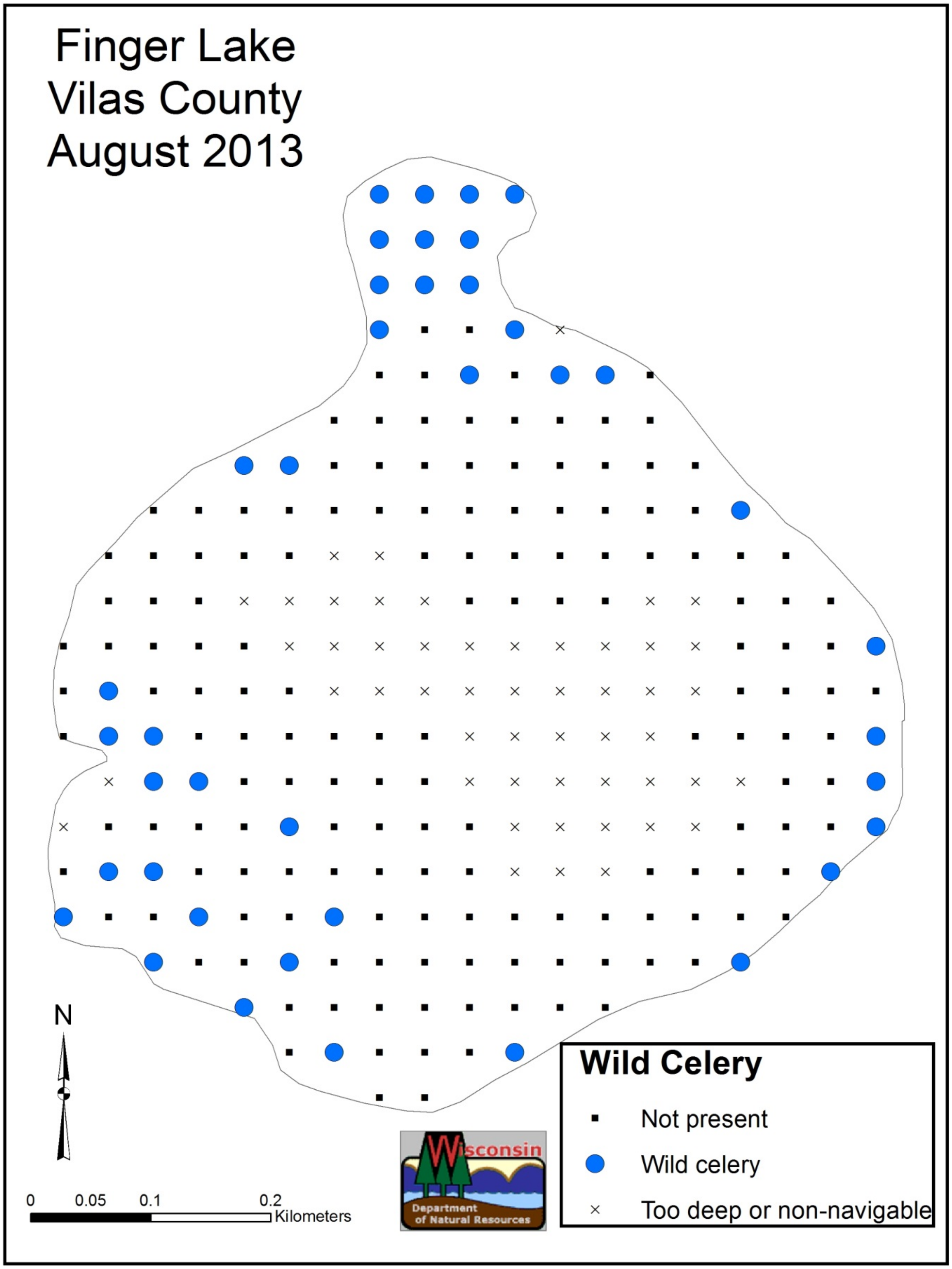


Figure 9. Slender waterweed and small pondweed.

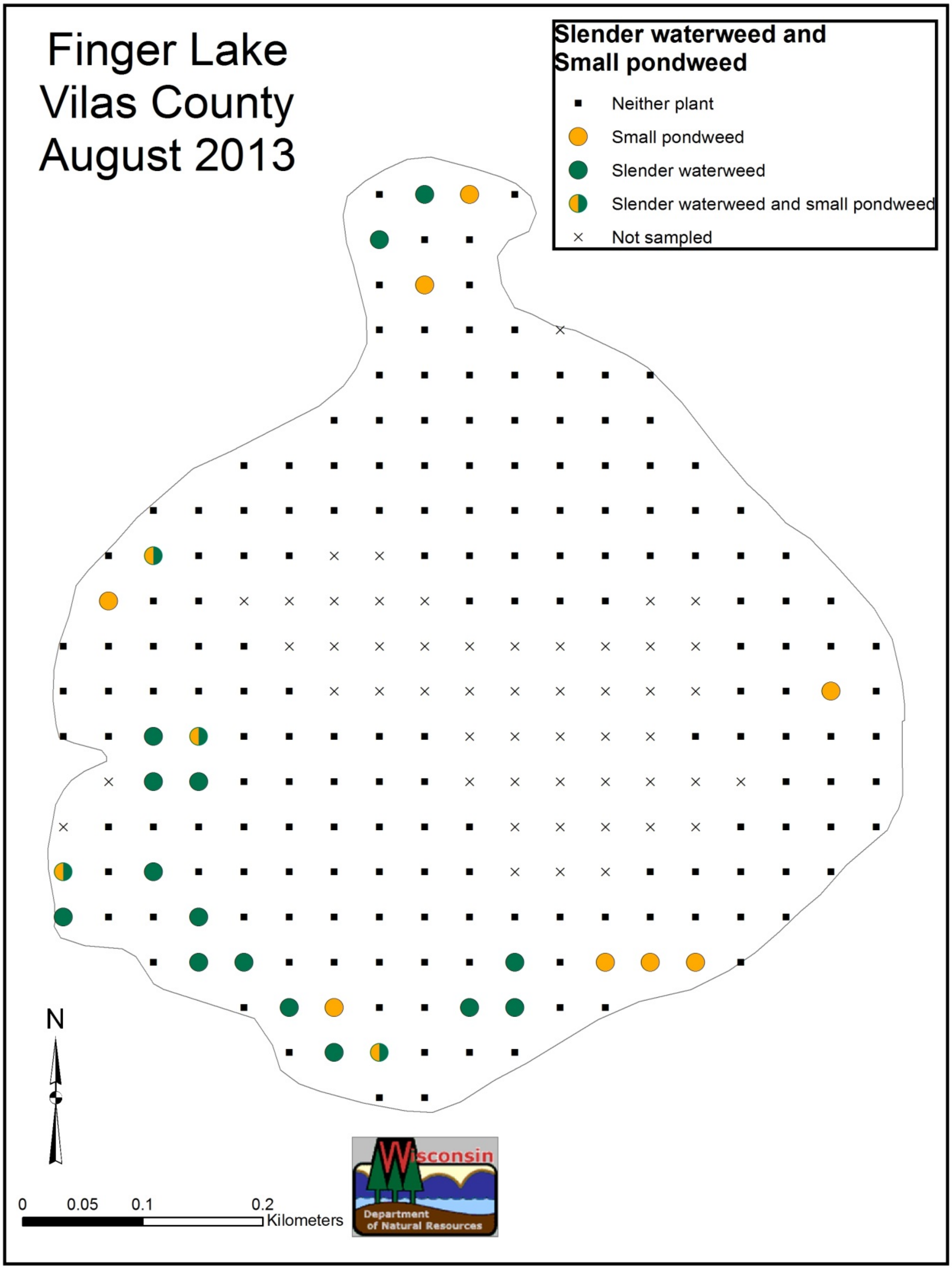


Figure 10. Number of species at each site on Finger Lake

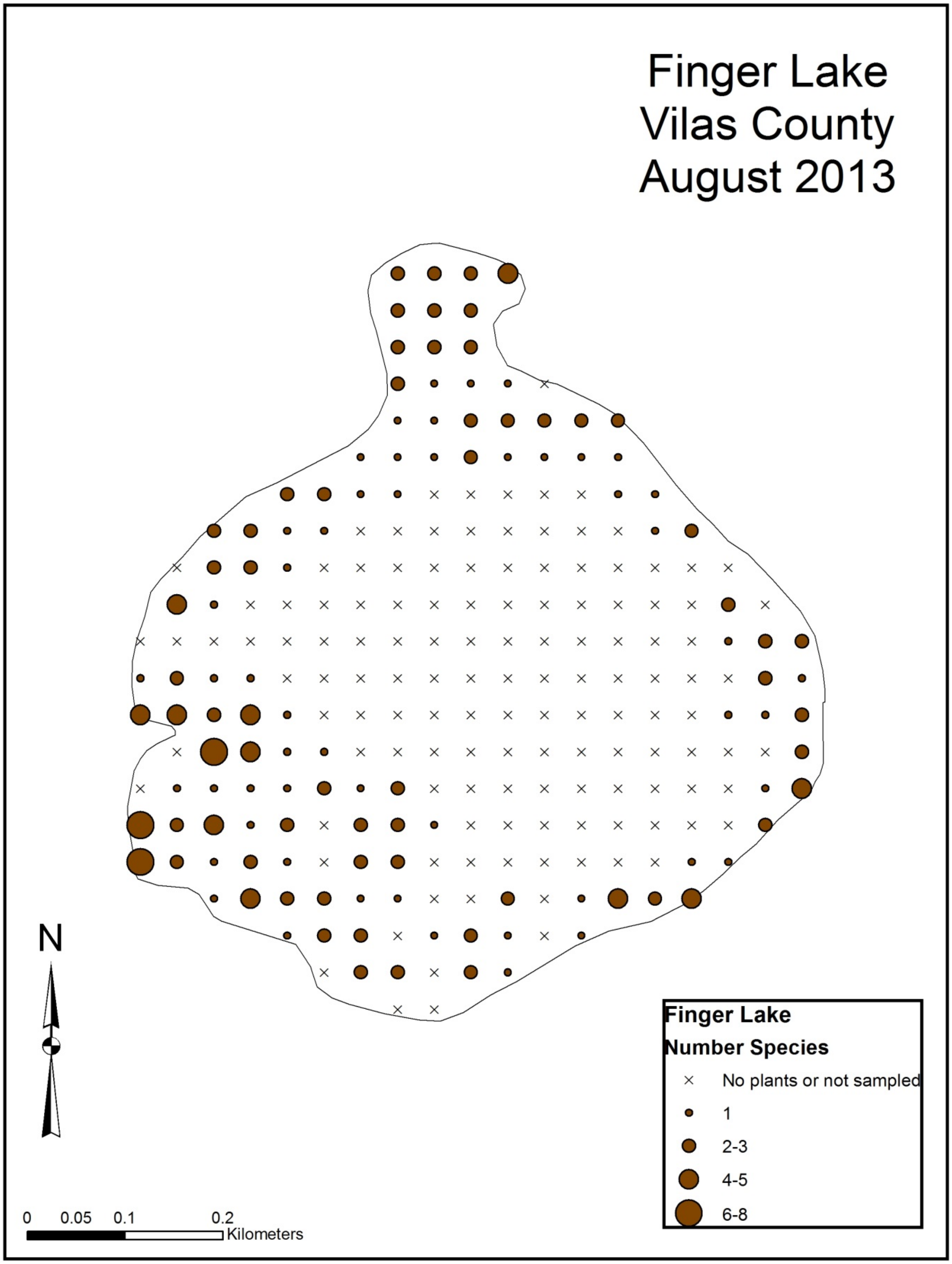
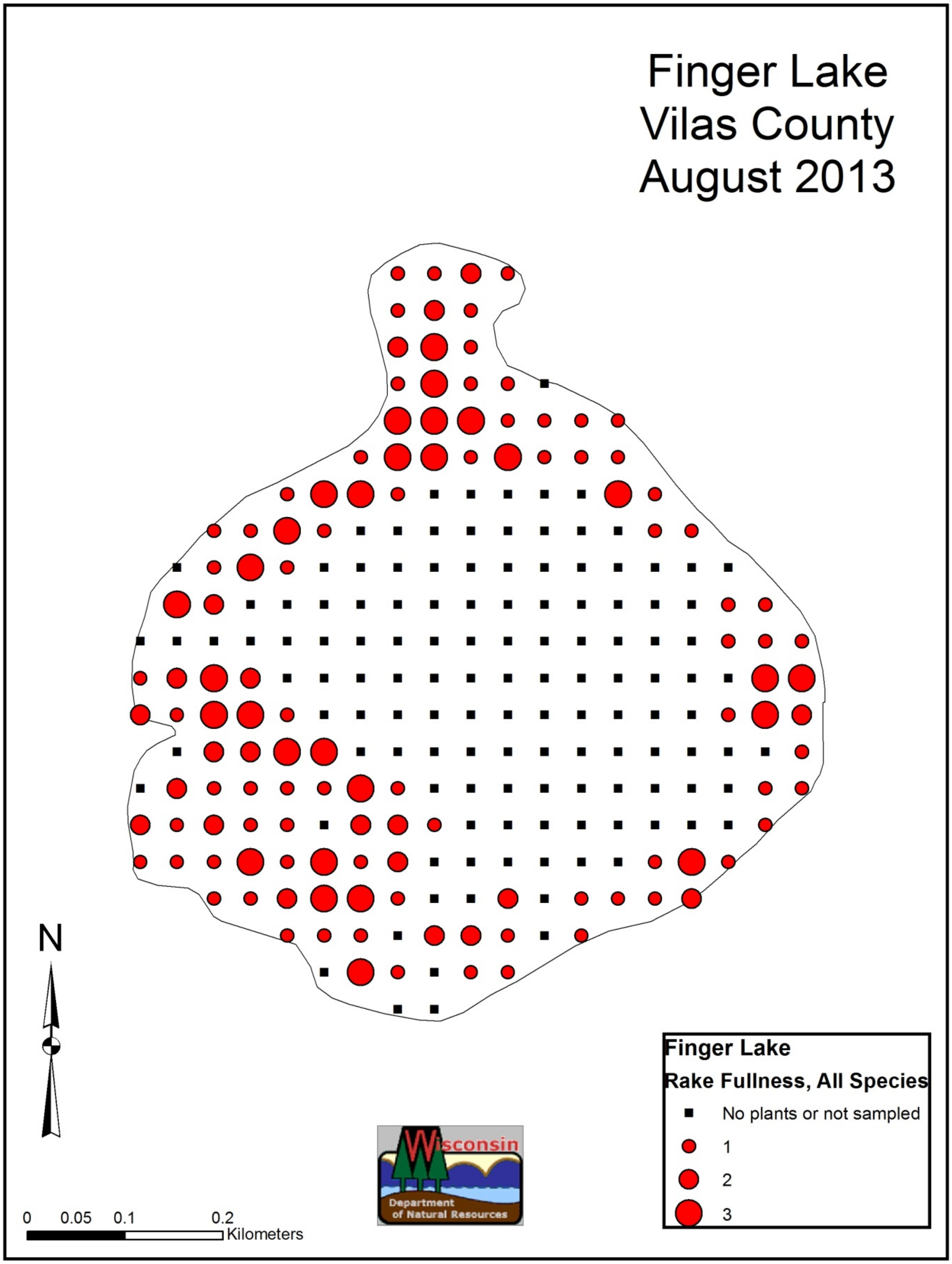


Figure 11. Rake fullness on Finger Lake



Appendix 5

Water Quality Report

Appendix 5

Review of Finger Lake Water Quality

Table of Contents

Review of Finger Lake Water Quality

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

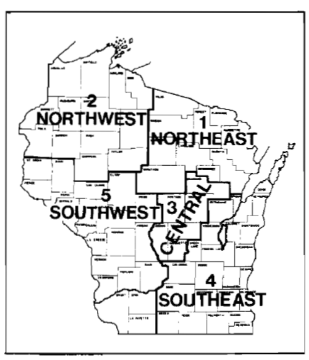
Introduction

Finger Lake is located in Vilas County, Wisconsin. It is an 87 acre spring fed lake with a maximum depth of 31 feet. The Waterbody Identification Code (WBIC) is 984700. The purpose of this review is to assemble and interpret water quality data for Finger Lake in order to establish a baseline against which future water quality monitoring can be compared. Water quality data were retrieved from the Wisconsin DNR SWIMS database (WDNR 2019b) between 1995 and 2018. Secchi disk measurements have been collected by Citizen Lake Monitoring Network (CLMN) volunteers from 1995 to 2018. Chlorophyll *a* and total phosphorus were also collected in 2013-2018 by CLMN volunteers.

Comparison of Finger Lake with other datasets

Lillie and Mason's *Limnological Characteristics of Wisconsin Lakes* (1983) is an excellent resource for evaluating and comparing water quality measures from lakes in northern Wisconsin. For their treatment, Wisconsin is divided into five regions. Vilas County lakes are in the Northeast Region (Figure 1). Water quality measures from a lake of interest can be compared to other lakes within the region using this resource.

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 presents the water temperature profile for Finger Lake in April 2016 and May 2018. These samples show stratification at approximately 10 feet. In June (Figure 3), the temperature profiles show some stratification from surface to bottom. In July, temperature profiles show definite stratification (Figure 4). During this time, the lake usually stratified between 10 and 15 feet. August temperature profiles (Figure 5) were fairly similar between years (with the possible exception of 2017).

Figure 2. Finger Lake temperature profile, April 2016 and May 2018.

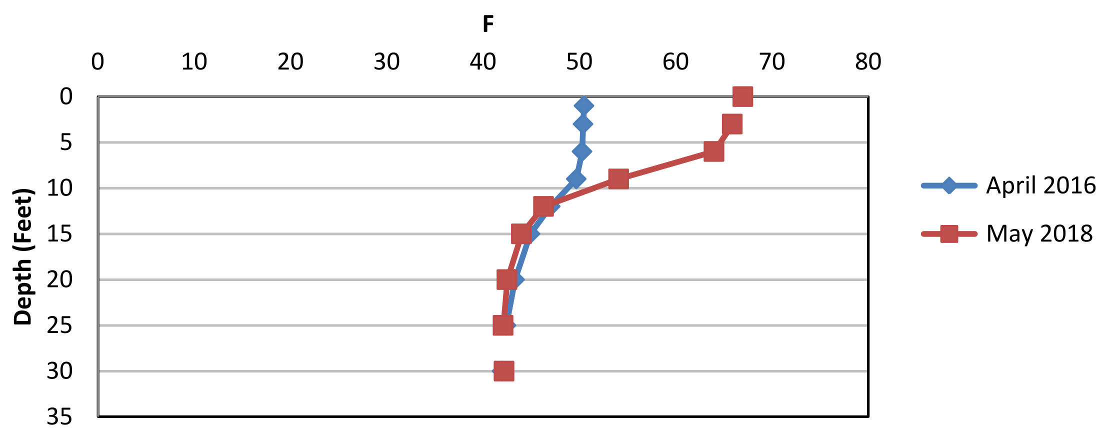
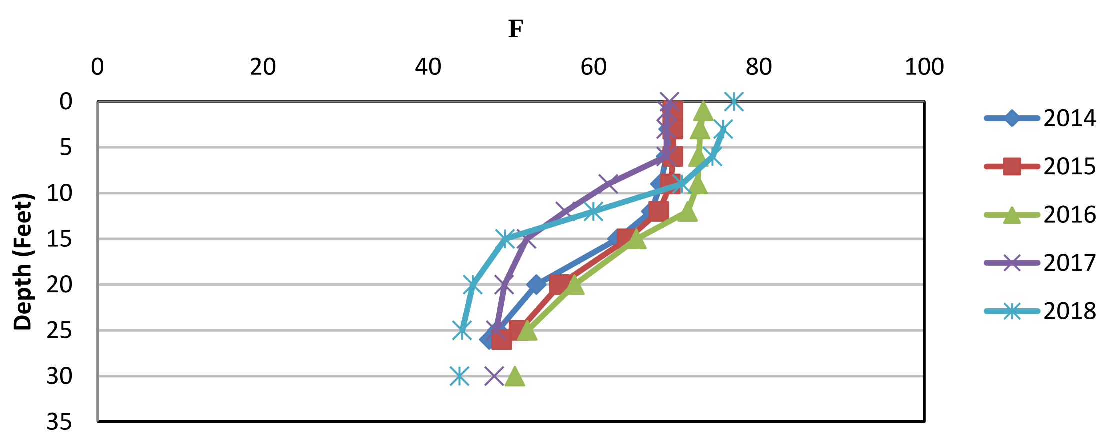
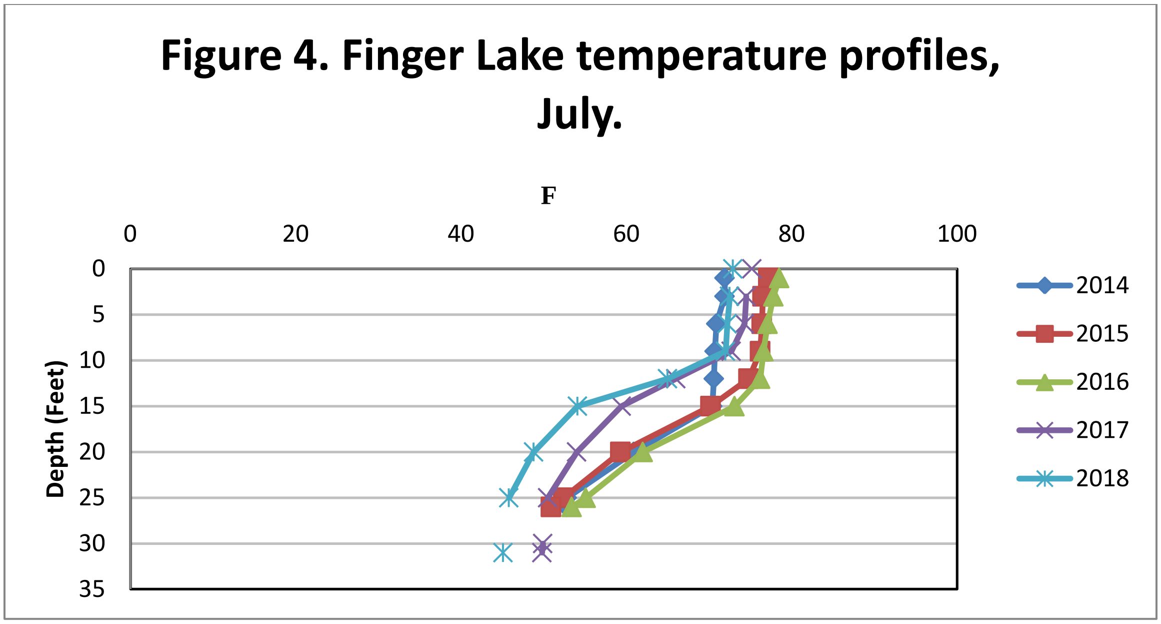
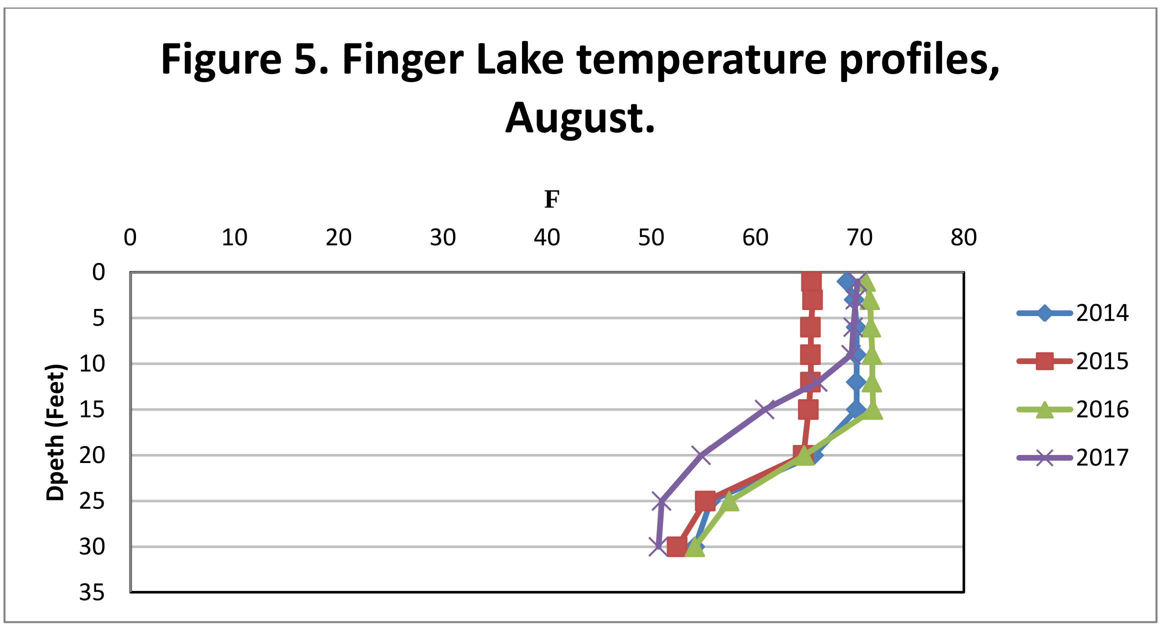


Figure 3. Finger Lake temperature profiles, June.







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 that occurs during daylight hours, but reduced by respiration of plants, decomposer organisms, fish, and invertebrates. The amount of D.O. available in a lake, particularly in the deeper parts of a lake, is critical to overall health. Finger Lake D.O. profiles for April through August are displayed in Figures 6 through 9. Surface D.O. levels were between 8.7 and 10.5 mg/L in the April 2016 and May 2018 (Figures 6).

Depending on the year, June surface D.O. levels (Figure 7) varied between 7.46 and 9.12 mg/L. In July and August the surface dissolved oxygen profiles varied from 7.37-8.39 mg/L (Figure 8 and 9).

Figure 6. Finger Lake dissolved oxygen profile, April and May.

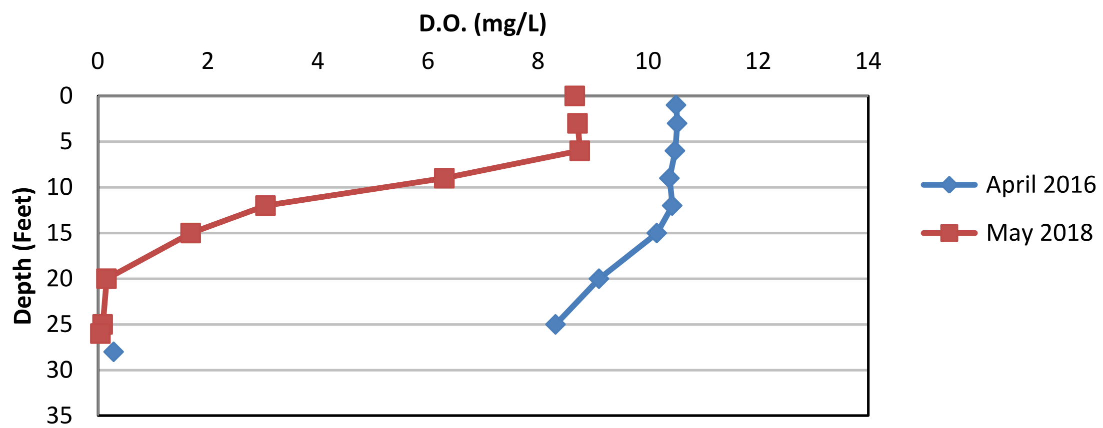
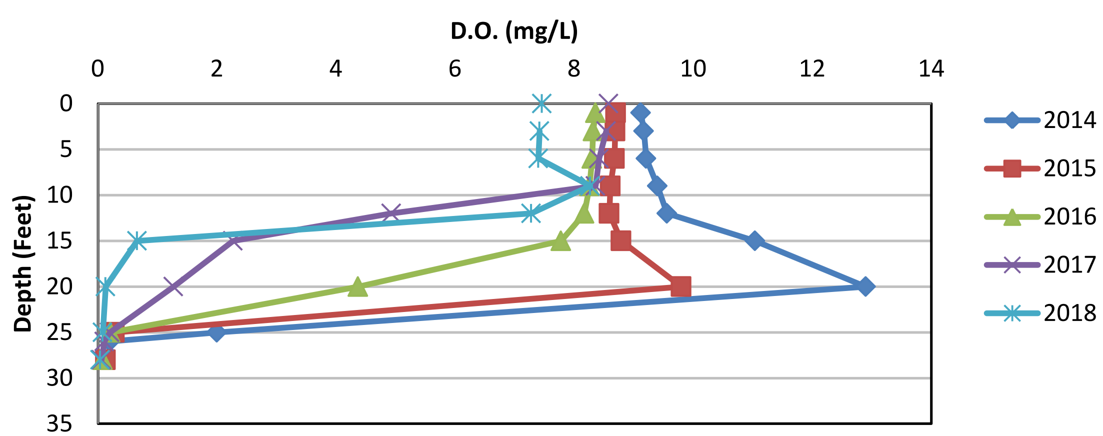
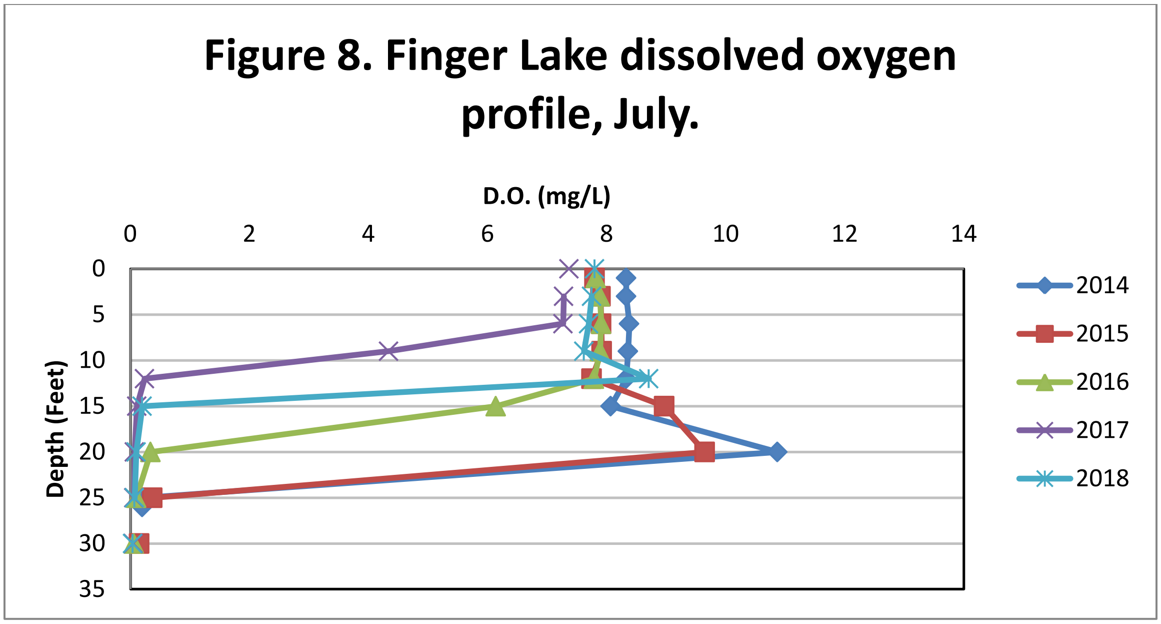
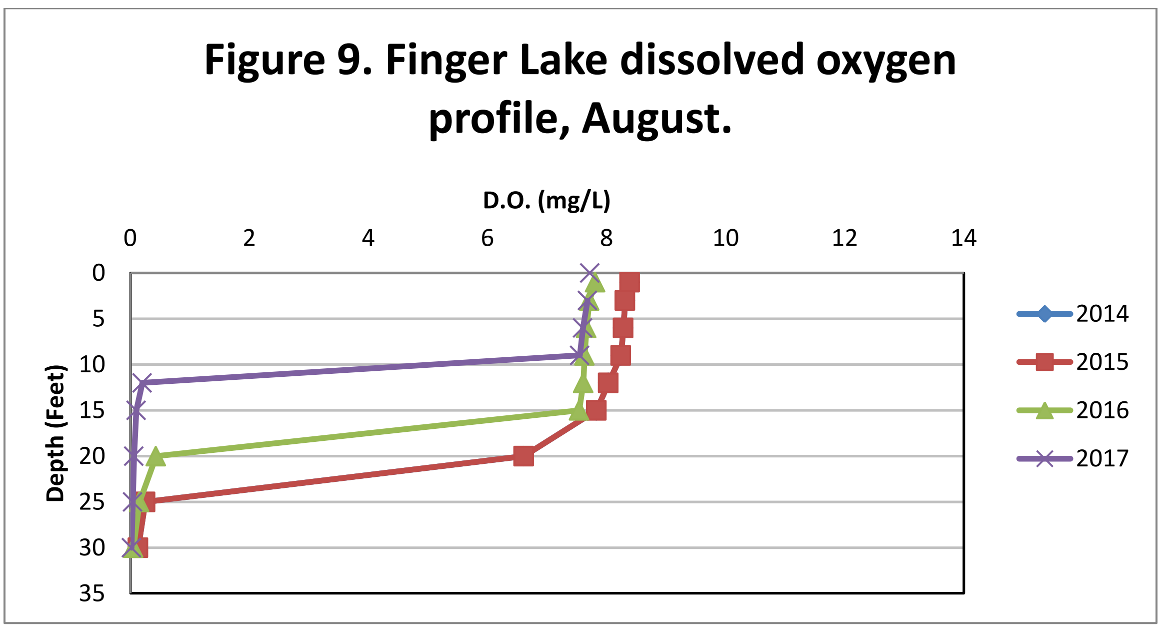


Figure 7. Finger Lake dissolved oxygen profile, June.





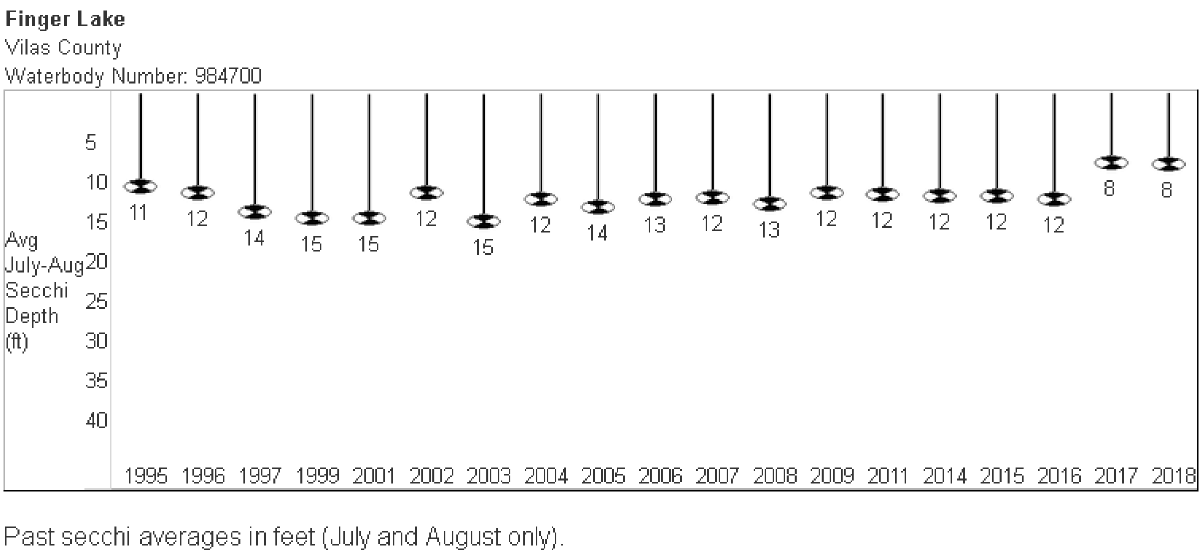


Water Clarity

Water clarity has two main components: turbidity (suspended materials in the water 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. The depth at which the disk disappears is noted and then the disk is slowly brought up to where it is just visible again and the depth noted. The mean value between these two measures is recorded as the Secchi depth.

Figure 10 displays the July and August mean Secchi depths from 1995 to 2018. The water clarity averages during these months were remarkably consistent between 1995 and 2016 and would be classified as "good" with respect to water clarity (Table 1). The average readings in 2017 and 2018 indicate that the water transparency had diminished. It is important to monitor this to see if the trend continues. The shallowest Secchi depth was 8.0 feet in 2017 and 2018, and the deepest reading was at 15.38 feet in 2003 (Figure 11).

Figure 10. Finger Lake Secchi depth averages (July and August only).



(WDNR, 2019b)

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

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

Figure 11. Finger Lake's July and August Secchi Data: Mean, Min, Max, and Secchi Count (1995-2018) *(WDNR, 2019b).*

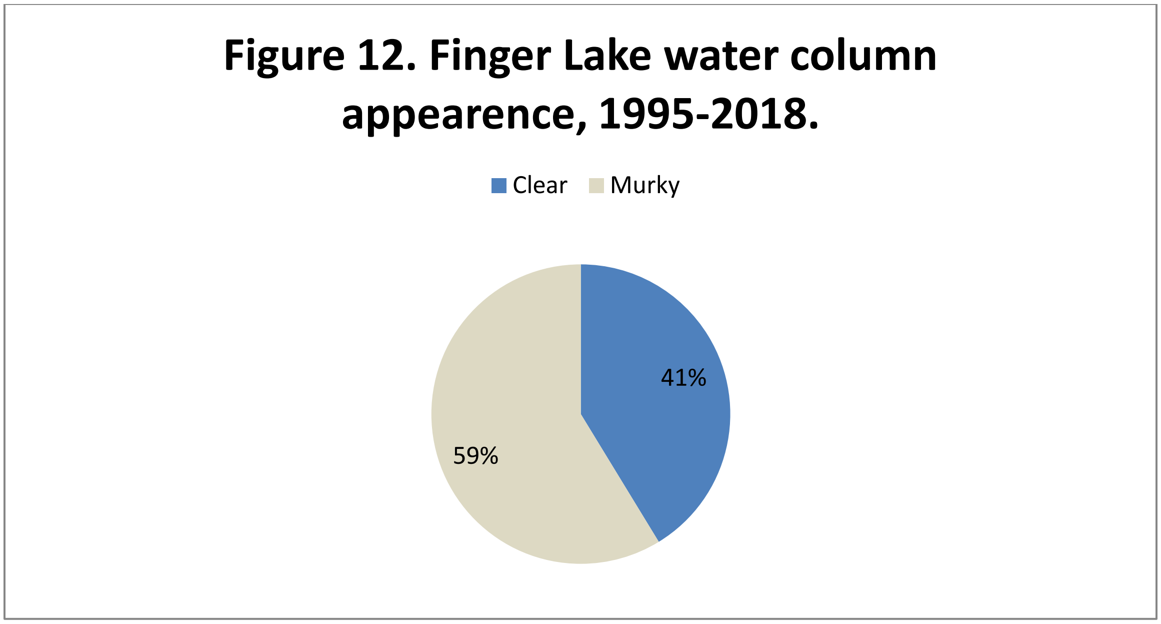
Year	Secchi Mean	Secchi Min	Secchi Max	Secchi Count
1995	11	11	11	1
1996	11.81	9.5	14.5	4
1997	14.2	11.75	16.5	5
1999	15	15	15	1
2001	15	14.5	15.5	4
2002	11.75	11.5	12	4
2003	15.38	14.5	16	4
2004	12.5	10.5	13.5	6
2005	13.67	13.5	14	3
2006	12.6	11	13.5	5
2007	12.33	12	12.5	3
2008	13.25	13	13.5	4
2009	11.88	11.5	12	4
2011	12	11	12.5	4
2014	12.25	11	13.5	2
2015	12.25	10.5	14	2
2016	12.5	12	13	2
2017	8	7	9	2
2018	8.25	7.5	9	2

Report Generated: 01/03/2019

Turbidity

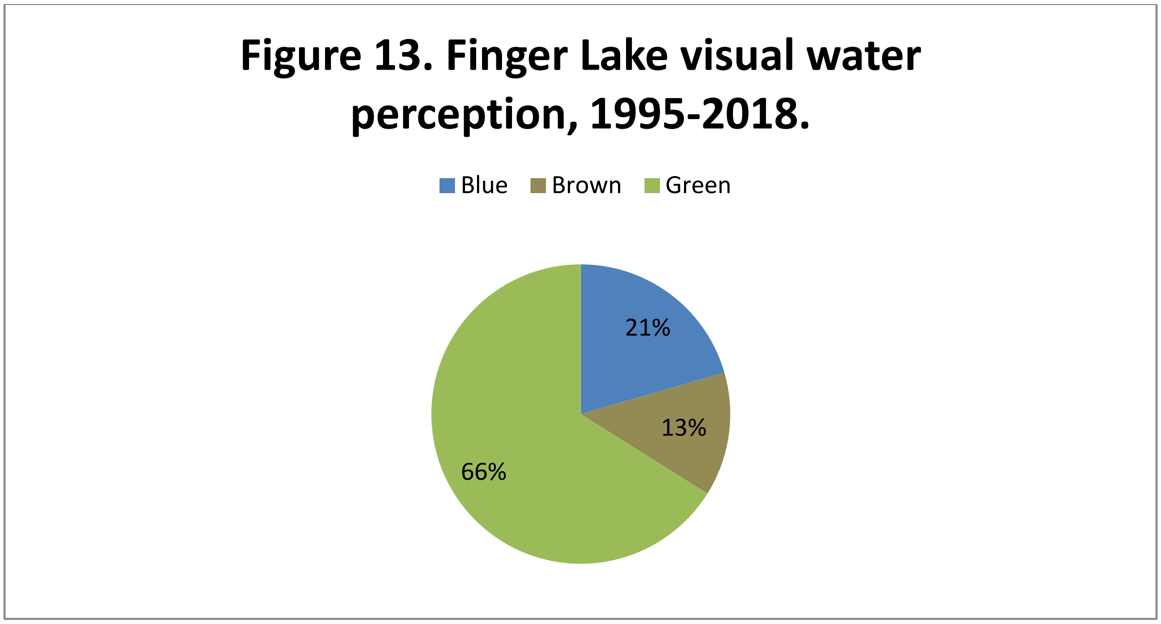
Turbidity is another measure of water clarity, but is caused by suspended particulate matter rather than dissolved organic compounds (Shaw et al., 2004). Particles suspended in the water dissipate light and reduce the depth to which light can penetrate. This affects the depth at which plants can grow. 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. Finger Lake turbidity has not been tested, and should be included in future water quality sampling.

While checking Secchi depth, CLMN volunteers also rate the water clarity and describe the water as "clear" or "murky." From 1995 to 2018, 41% of volunteers rated the water as "clear" (Figure 12).



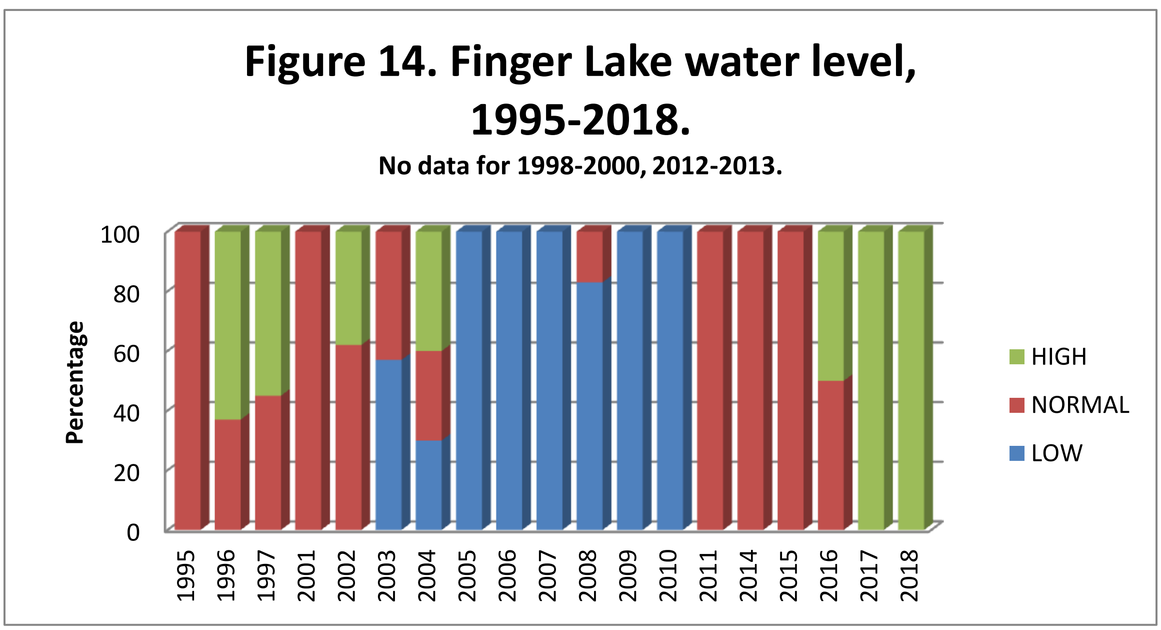
Water Color

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. Finger Lake color has not been tested, and should be included in future water quality sampling. CLMN also recorded their perceptions of water color in Finger Lake. Since 1995, 21% of volunteers indicated the water appeared "blue" in color and 66% indicated the water appeared "green" in color and 13% said it appeared "brown" in color (Figure 13).



Water Level

When CLMN volunteers collect Secchi depth readings, they also record the lake level as "high," "normal," or "low." Figure 14 indicates that in 2005-2007 and 2009 and 2010 the water level in Finger Lake appeared "low." In 2017 and 2018, the water level appeared "high".

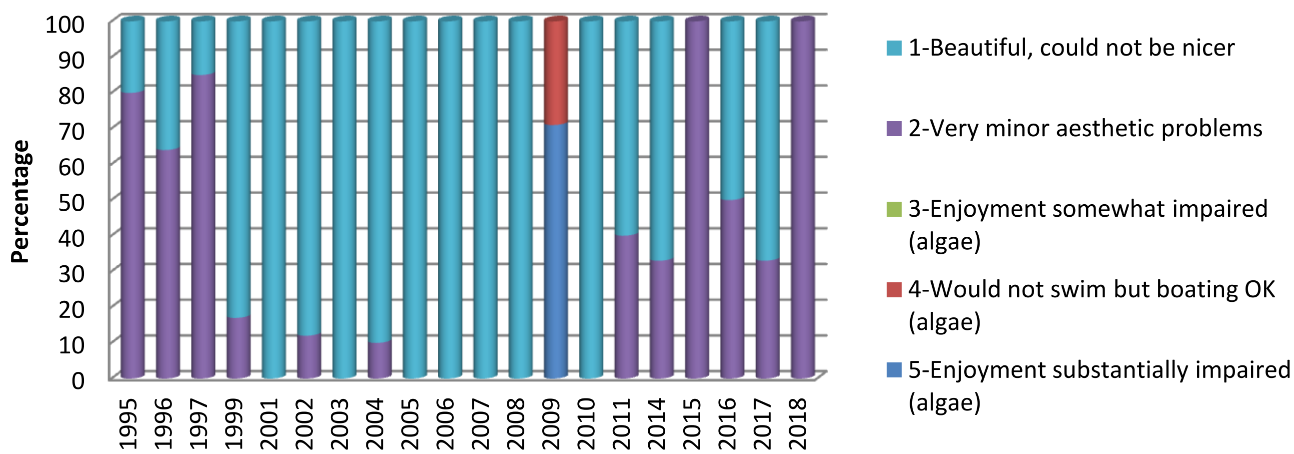


User Perceptions

The CLMN also 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 15. In 2001, 2003, 2005-2008, and 2010, 100% of CLMN volunteers recorded Finger Lake to be "beautiful, could not be better." The values varied in all other years. The rating of a 4 or 5 only occurred in 2009.

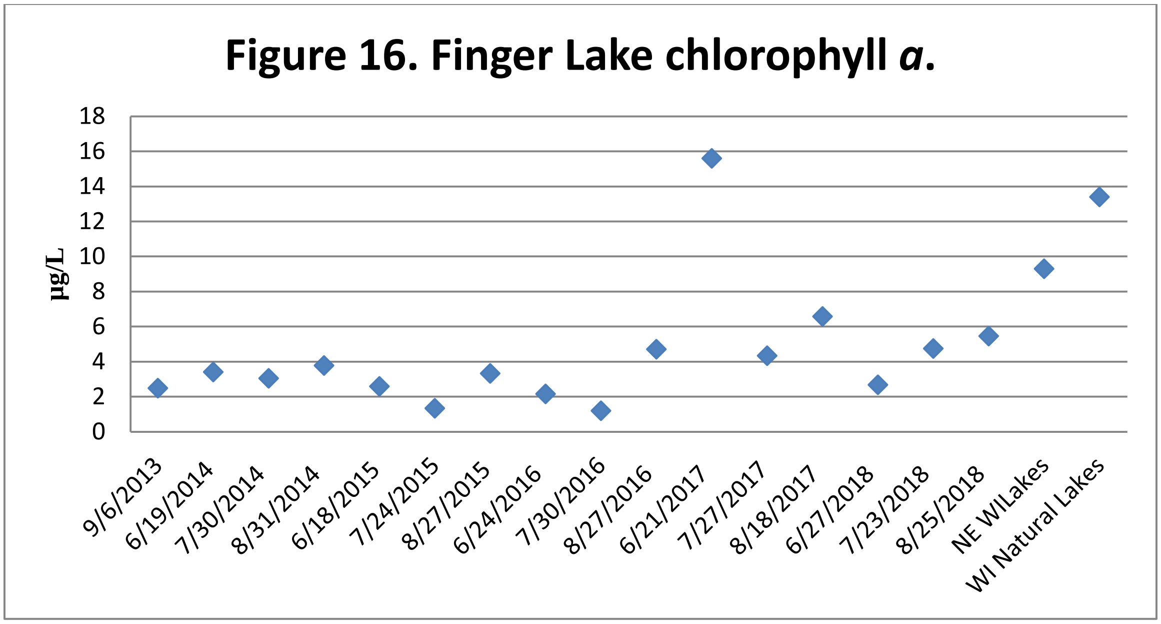
Figure 15. Finger Lake aesthetic value 1995-2018.

No data for 1998, 2000, 2012, and 2013.



Chlorophyll *a*

Chlorophyll *a* is the photosynthetic pigment that makes plants and algae green. Chlorophyll *a* in lake water is 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* values were below nuisance levels and well below the average levels for Wisconsin natural lakes (Figure 16). On June 21, 2017 the chlorophyll *a* value was above 10 µg/L but below 20 µg/L.



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).

Finger Lake total phosphorus values were considered "good" to "very good," (Figure 18) and are comparable to the region and state values (Figure 17). On June 21, 2017 the total phosphorus value was above 20 µg/L.

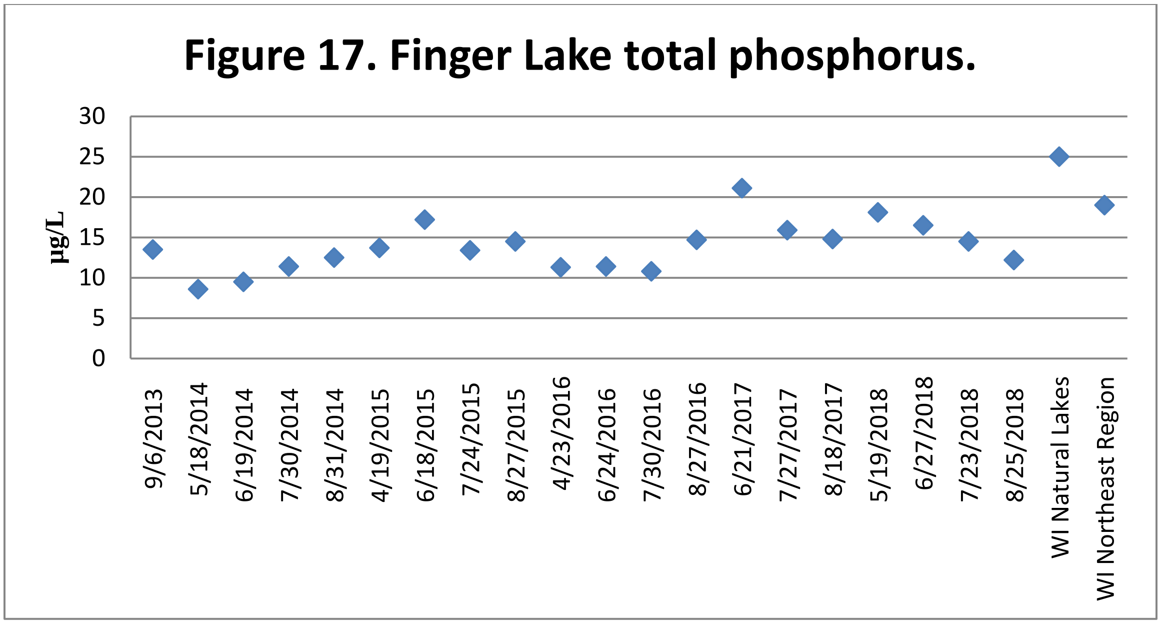
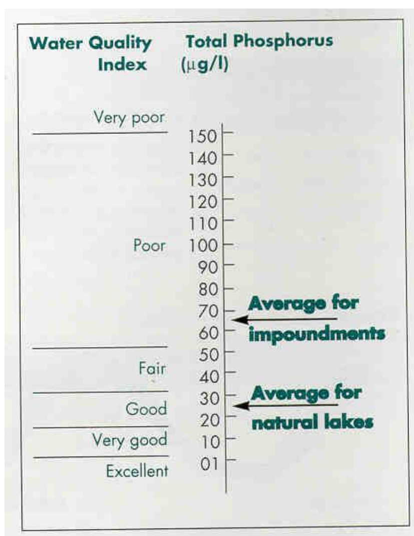


Figure 18. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments (Shaw et al., 2004).



Trophic State

Trophic state is another indicator of water quality (Carlson, 1977). Lakes are typically 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 (1995-2018), chlorophyll *a* (2014-2018), and total phosphorus (2014-2018) using data collected from the CLMN. Figure 19, classifying Finger Lake as "mesotrophic" the majority of the years sampled (Table 2).

Figure 19. Finger Lake Trophic State Index, (1995-2018). *(WDNR, 2019b)*

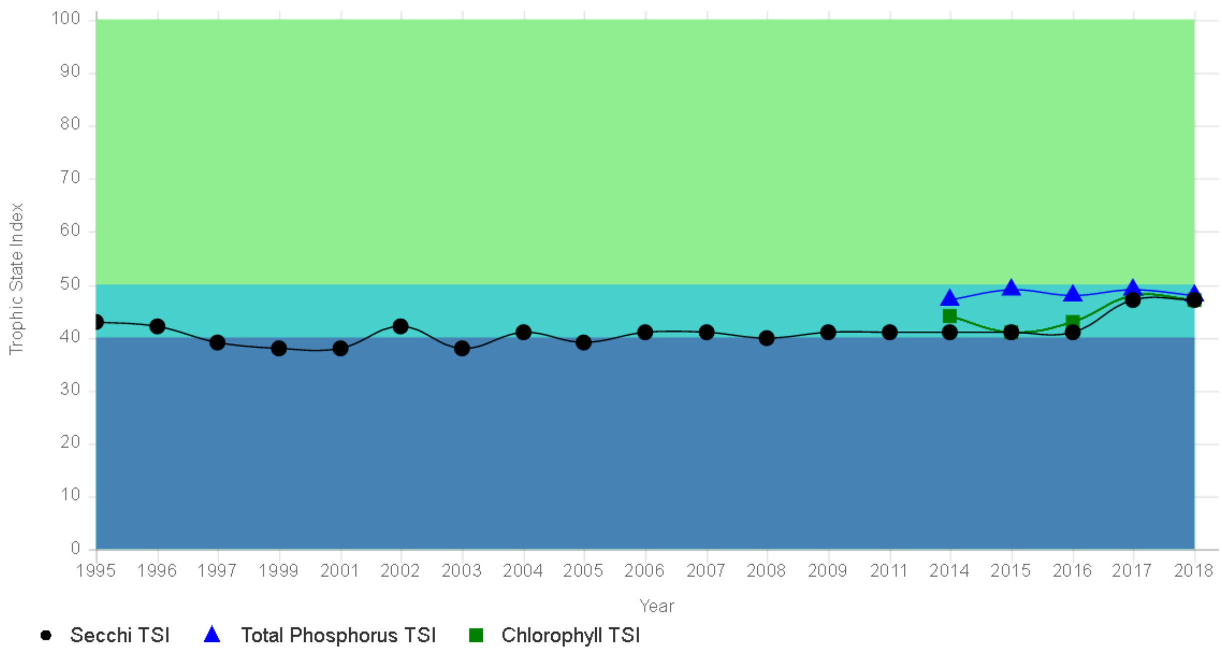


Table 2. Trophic State Index.	
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth 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, 2019b)

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. 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 ammonia, 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). Finger Lake nitrogen has not been tested, and should be included in future water quality sampling.

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). Finger Lake chloride has not been tested, and should be included in future water quality sampling.

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). Finger Lake sulfate has not been tested, and should be included in future water quality sampling.

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). Finger Lake conductivity has not been tested, and should be included in future water quality sampling.

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 hard water, 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. 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. Finger Lake pH has not been tested, and should be included in future water quality sampling.

Table 4 shows the effects pH levels less than 6.5 can 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. Finger Lake alkalinity has not been tested, and should be included in future water quality sampling. Table 5 shows the levels of sensitivity to acid rain.

Table 5. Sensitivity of Lakes to Acid Rain (Shaw et al., 2004).

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

Hardness

Hardness levels in a lake are affected by the soil minerals, bedrock type, 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 ($CaCO_3$). Finger Lake hardness has not been tested, and should be included in future water quality sampling.

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. Finger Lake calcium and magnesium hardness has not been tested, and should be included in future water quality sampling.

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). Finger

Lake sodium and potassium have not been tested, and should be included in future water quality sampling.

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. In general, organic carbon compounds are a result of decomposition processes from dead organic matter such as plants. When water contacts high 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. Finger Lake DOC has not been tested, and should be included in future water quality sampling.

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. Finger Lake silica has 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. Finger Lake aluminum has 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. Finger Lake aluminum has 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 Finger 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 Finger Lake, and future sampling should include this parameter. A sediment survey data is unknown for Finger Lake, so 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 Finger Lake, so future water quality sampling should include this parameter.

Ice Out and Ice On

Ice out data has not been collected and could be recorded.

Aquatic Invasive Species

There is one invasive species found in Finger Lake: Chinese mystery snail (documented in 2013). White Water Associates biologist conducted a WDNR AIS Early Detection Survey on 7/22/2018 and also found only the Chinese mystery snail. A detailed report is found in Appendix H.

Descriptions of Invasive Species Found in Project Area

Chinese mystery snails are from Southeast Asia and Eastern Russia and were likely released to the Great Lakes from an aquarium (Kipp et al., 2015). The snail does not seem to have a significant impact on native species, but its ecological and anthropological threat comes from its potential to transmit parasites and diseases (Kipp et al., 2015). It is illegal to introduce the Chinese mystery snail into Wisconsin waters.

Literature Cited

Camargo, Julio A., Álvaro Alonso (Lead Author); Raphael D. Sagarin (Topic Editor). 02 April 2007. *Inorganic nitrogen pollution in aquatic ecosystems: causes and consequences.* In: Encyclopedia of Earth. Eds. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). Retrieved 2017. <http://www.eoearth.org/article/Inorganic_nitrogen_pollution_in_aquatic_ecosystems:_causes_and_consequences>

Carlson, R.E. 1977. *A Trophic State Index for Lakes.* Limnology and Oceanography. 22: 361-369.

Kipp, R.M., A.J. Benson, J. Larson, and A. Fusaro. 2015. *Cipangopaludina chinensis malleata*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved 2017. <http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1045>

Lillie, R. A. and J. W. Mason. 1983. *Limnological Characteristics of Wisconsin Lakes.* Wis. Dept. of Natural Resources Tech. Bull. Page 138. Madison, WI.

Olszyk, D. 1980. *Biological Effects of Acid Rain*. Testimony, Wis. Public Service Commission Docket No. 05-EP-2. 5 pp.

Shaw, B. Mechenich, C, and Klessig, L. 2004. *Understanding Lake Data (G3582).* Board of Regents of the University of Wisconsin System. Madison, WI.

University of Wisconsin-Madison, Center for Limnology, Vander Zanden Lab. *Aquatic Invasive Species Smart Prevention.* Retrieved 2017. http://www.aissmartprevention.wisc.edu/

Wisconsin Department of Natural Resources. 2019a. *Lake Pages.* Retrieved January 2018. <http://dnr.wi.gov/lakes/LakePages/LakeDetail.aspx?wbic=1527800&page=waterquality>

Wisconsin Department of Natural Resources. 2019b. *Surface Water Integrated Monitoring Systems (SWIMS) Database.* Retrieved January 2019. <http://dnr.wi.gov/topic/surfacewater/swims/>

Appendix 6

Littoral Zone and Shoreline Report

Finger Lake Littoral Zone and Shoreline Survey

Introduction

Finger Lake's littoral and shoreline zones were assessed in 2016 by White Water field biologists using the US Environmental Protection Agency's (EPA) National Lakes Assessment (NLA) protocol and the Wisconsin Department of Natural Resources (WDNR) Supplemental Lakeshore Assessment protocol. The intention of the National Lakes Assessment (NLA) project was to provide a comprehensive assessment for lakes, ponds, and reservoirs across the United States (USEPA, 2009). This assessment at Finger Lake will stand as a baseline against which future changes can be measured and can be used to compare Finger Lake with other lakes measured using the same protocols.

Methods

Ten physical habitat (P-Hab) stations were spaced equidistantly around the lake (Figure 1 and 2). At each site, biologists recorded information about the littoral zone bottom substrate, littoral zone aquatic macrophytes (plants), littoral zone fish cover, riparian zone canopy, understory and ground cover, shoreline substrates, human influences, classification of fish habitat, bank features, any invasive species observed (terrestrial or aquatic), land cover, human development and the number of piers between sites.

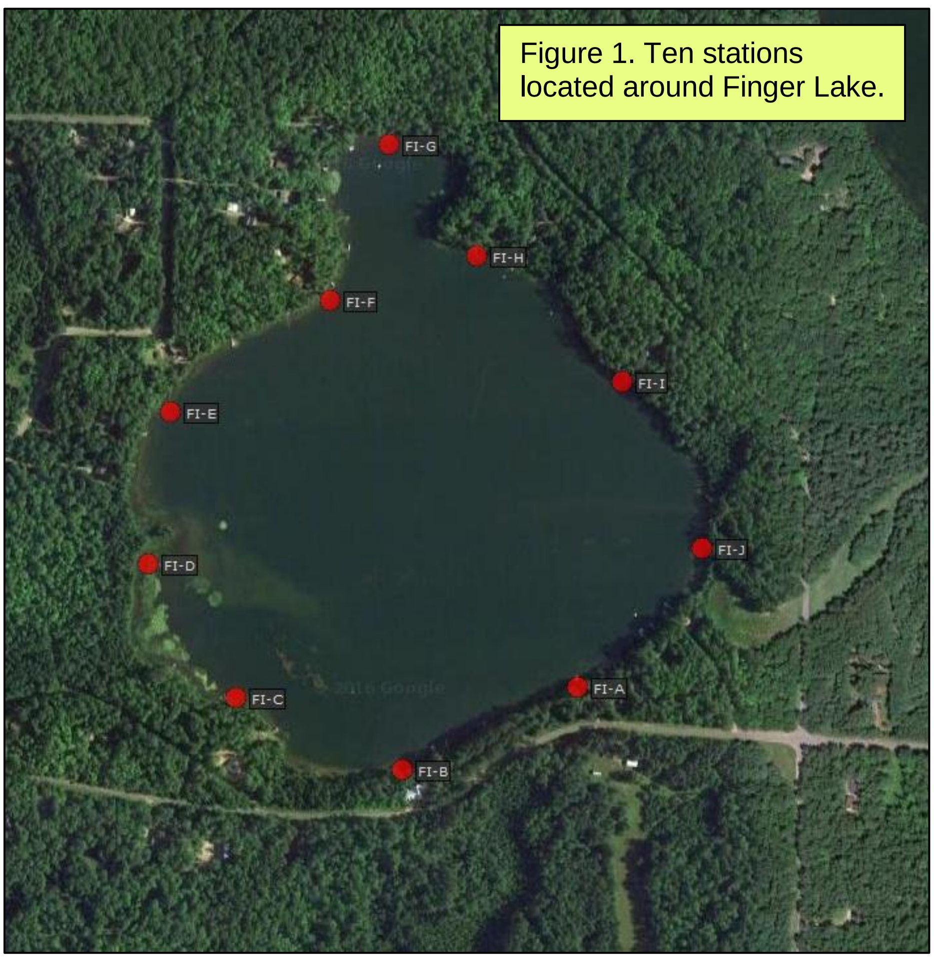


Figure 1. Ten stations located around Finger Lake.

At each P-Hab site, biologists collected macroinvertebrates for later identification. A fecal indicator sample was collected at one site to be analyzed for levels of *E. coli*.

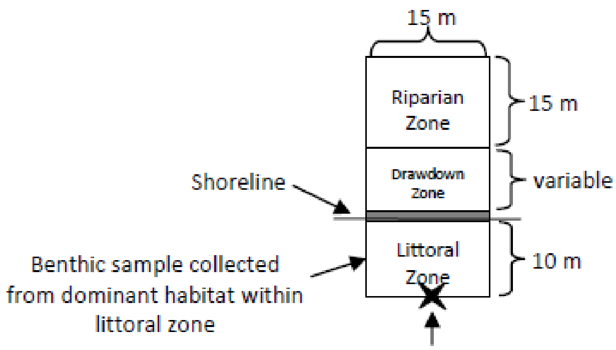


Figure 2. Dimensions and layout of a P-Hab station.

Results

The average depth of the ten stations was 2.79 feet (the range was from 1.6 to 5.3 feet). No surface film was observed at any of the ten stations.

Table 1 contains the littoral zone bottom substrate data collected from the ten Finger Lake sampling stations. Bedrock and boulders were not observed as a bottom substrate at any station. Cobble was present at two stations. Gravel was present at three stations. Sand was present at nine stations. Silt, clay and muck were encountered at two stations. Woody debris was present at nine stations. Brown colored sediment occurred at all the stations. No odor was associated with the substrate at any station.

Table 1. USEPA Habitat Characterization – Littoral Zone Bottom Substrate.

Station	A	B	C	D	E	F	G	H	I	J
Bedrock	0	0	0	0	0	0	0	0	0	0
Boulders	0	0	0	0	0	0	0	0	0	0
Cobble	0	0	0	0	0	0	0	0	1	2
Gravel	1	0	0	0	0	0	0	0	2	2
Sand	4	0	4	1	4	4	4	4	4	4
Silt, Clay, Muck	0	4	0	3	0	0	0	0	0	0
Woody Debris	3	1	2	0	3	2	1	1	1	1
Color	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown	Brown
Odor	None	None	None	None	None	None	None	None	None	None

Bedrock (>4000mm); Boulders (250-4000mm); Cobble (64-250mm); Gravel (2-64mm); Sand (0.02-2mm); Silt, Clay, or Muck (<0.06mm, not gritty). 0=Absent (0%); 1=Sparse (<10%); 2=Moderate (10-40%); 3=Heavy (40-75%); 4=Very Heavy (>75%)

Table 2 presents the observations made on aquatic macrophytes in the littoral zone. Submergent aquatic plants were observed at nine stations. Emergent macrophytes were observed at all stations. Two of the ten stations had floating macrophytes present. Total macrophyte cover had sparse (four stations), moderate (one station), heavy (three stations), and very heavy (two stations) coverage. Macrophytes extended lakeward at four stations.

Table 2. USEPA Habitat Characterization – Littoral Zone Aquatic Macrophytes.

Station	A	B	C	D	E	F	G	H	I	J
Submergent	0	1	2	2	2	1	1	1	1	1
Emergent	2	3	4	4	2	4	3	1	1	1
Floating	0	0	0	3	1	0	0	0	0	0
Total Aquatic Macrophyte Cover	1	3	4	4	2	3	3	1	1	1
Do macrophytes extend lakeward from plot?	No	No	Yes	Yes	Yes	No	Yes	No	No	No
0=Absent (0%); 1=Sparse (<10%); 2=Moderate (10-40%); 3=Heavy (40-75%); 4=Very Heavy (>75%)										

Littoral zone fish cover observations are presented in Table 3. Aquatic and/or inundated herbaceous vegetation was observed at all ten stations, having coverage's of sparse (three stations) and moderate (two stations). Woody debris and snags greater than 0.3 meters in diameter were observed at nine stations and had sparse (seven stations) and moderate (two stations) coverage. Woody brush/woody debris less than 0.3 meters in diameter was found at eight stations and had sparse (five stations), moderate (two stations), and heavy (one station) coverage. Inundated live trees (greater than 0.3 meters in diameter) were observed at four sites. Overhanging vegetation within one meter of the surface was observed at six stations. Ledges or sharp drop-offs were not observed. Boulders were not observed. Finally, human structures (such as docks, landings, etc.) were observed at two stations and were sparse.

Table 3. USEPA Habitat Characterization – Littoral Zone Fish Cover.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Aquatic & Inundated Herbaceous Cover	3	3	4	4	2	3	2	1	1	1
Woody Debris/Snags >0.3 m dia.	1	1	2	0	2	1	1	1	1	1
Woody Brush/ Woody Debris <0.3 m dia.	2	0	3	1	1	1	2	0	1	1
Inundated Live Trees >0.3 m dia.	0	0	2	0	1	2	0	0	0	1
Overhanging veg. w/in 1 m of surface	2	1	3	0	3	3	0	0	0	2
Ledges or Sharp Drop-offs	0	0	0	0	0	0	0	0	0	0
Boulders	0	0	0	0	0	0	0	0	0	0
Human Structures (docks, landings, etc.)	1	0	1	0	0	0	0	0	0	0
0=Absent (0%); 1=Sparse (<10%); 2=Moderate (10-40%); 3=Heavy (40-75%); 4=Very Heavy (>75%)										

Table 4 shows observations made at the riparian zone canopy (>5 meters high), understory (0.5 to 5 meters), and ground cover (<0.5 meters). Mixed (conifer and deciduous) canopy type was observed at all ten stations. The coverage of big trees (>0.3 meters diameter) was moderate (two stations), heavy (seven stations), and very heavy (one station). Coverage of small trees (<0.3 meters diameter) was sparse (two stations), moderate (five stations), and heavy (three stations). Mixed understory type was observed at all then stations. Coverage of understory woody shrubs and saplings was moderate (eight stations), and heavy (one station) coverage. Understory tall herbs, grasses, and forbs were present at five stations with sparse coverage and moderate at three stations. Ground cover of woody shrubs and saplings were observed at nine stations with coverages of sparse (four stations), moderate (three stations), and heavy (two stations). Groundcover herbs, grasses, and forbs were observed at seven stations with sparse (five stations), and moderate (one station) coverage. Standing water or inundated vegetation was not observed. Barren, bare dirt or buildings was not observed.

Table 4. USEPA Habitat Characterization – Riparian Zone.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
CANOPY (>5 m high)										
Type	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix
Big Trees (Trunk >0.3 m dia.	3	2	3	3	3	3	4	2	3	3
Small Trees (Trunk <0.3 m dia.	2	3	3	2	2	1	3	2	1	2
UNDERSTORY (0.5 to 5 m high)										
Type	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix	Mix
Woody Shrubs and Saplings	2	2	3	2	2	2	2	0	2	2
Tall Herbs, Grasses, Forbes	1	1	0	2	2	2	1	0	1	1
GROUND COVER (<0.5 m high)										
Woody Shrubs and Saplings	1	2	3	3	2	2	1	0	1	1
Herbs, Grasses and Forbes	1	1	0	1	2	0	1	1	0	0
Standing Water/ Inundated Veg.	0	0	0	0	0	0	0	0	0	0
Barren, Bare Dirt, or Buildings	0	0	0	0	0	0	0	0	0	0
0=Absent (0%); 1=Sparse (<10%); 2=Moderate (10-40%); 3=Heavy (40-75%); 4=Very Heavy (>75%); Mix = Mixed conifer and deciduous; Dec = Deciduous										

Table 5 presents observations recorded on the riparian shoreline substrate zone. Bedrock and boulders was not observed at any of the ten stations. Cobble substrate was observed at one station with coverage of sparse. Gravel substrate was observed at three stations and was sparse (one station) and moderate (two stations) in coverage. Sand substrate was observed at all then stations and was sparse (one station) and very heavy (nine stations). Silt, clay, or muck substrate was observed at one station and was sparse. Woody debris was observed at nine stations with sparse (three stations), moderate (four stations), heavy (one station), and very heavy (one station) coverage. Vegetation or other was observed at eight stations with coverage's of sparse (two stations), moderate (one station), heavy (two stations), and very heavy (three stations).

Table 5. USEPA Habitat Characterization – Riparian Zone – Shoreline Substrate Zone.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Bedrock	0	0	0	0	0	0	0	0	0	0
Boulders	0	0	0	0	0	0	0	0	0	0
Cobble	0	0	0	0	0	0	0	0	1	0
Gravel	2	1	0	0	0	0	0	0	2	0
Sand	4	4	4	1	4	4	4	4	4	4
Silt, Clay, Muck	0	0	0	4	0	0	0	0	0	0
Woody Debris	2	2	4	0	2	3	2	1	1	1
Vegetation or other	0	0	3	4	3	4	4	2	1	1
0=Absent (0%); 1=Sparse (<10%); 2=Moderate (10-40%); 3=Heavy (40-75%); 4=Very Heavy (>75%)										

Observations of human influence in the riparian zone are shown in Table 6. Human influence was moderately low. Buildings were observed inside the plot at two stations and outside the plot at six stations. Docks or boats were observed inside the plot at two stations and outside the plot at seven stations. Roads or railroads were observed outside the plot at eight stations. Lawn was observed inside the plot at three stations and outside the plot at four stations. All other human influences (commercial development, park facilities/manmade beach, walls, dykes, revetments, landfill/trash, powerlines, row crops, pasture/range/hayfield, and orchards) were not observed at any of the ten stations.

Table 6. USEPA Habitat Characterization – Riparian Zone – Human Influence Zone.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Buildings	P	C	P	0	0	P	P	PC	0	P
Commercial	0	0	0	0	0	0	0	0	0	0
Park Facilities/ manmade beach	0	0	0	0	0	0	0	0	0	0
Docks/Boats	PC	0	C	0	P	P	P	P	P	P
Walls, dykes, revetments	0	0	0	0	0	0	0	0	0	0
Landfill/Trash	0	0	0	0	0	0	0	0	0	0
Roads or Railroad	P	P	P	0	0	P	P	P	P	P
Powerline	0	0	0	0	0	0	0	0	0	0
Rowcrops	0	0	0	0	0	0	0	0	0	0
Pasture/Range/Hayfield	0	0	0	0	0	0	0	0	0	0
Orchard	0	0	0	0	0	0	0	0	0	0
Lawn	PC	PC	0	0	0	P	0	C	0	P
0 = Not Present; P = Present outside plot; C = Present within plot										

Table 7 reports the observations made on littoral fish macrohabitat classification. Human disturbance was observed at six stations. Cover class was patchy (five stations), continuous (four stations), and no or little coverage (one station). Cover type was recorded as woody and vegetated at nine stations and only vegetation at one station. Dominant substrate was sand/gravel at nine stations, mud/muck at one station, and cobble/boulder at one station.

Table 7. USEPA Habitat Characterization – Littoral Zone Macrohabitat Classification.

Station	A	B	C	D	E	F	G	H	I	J
Human Disturbance	Low	Low	Low	None	None	None	None	Low	Low	Low
Cover Class	Cont	Patchy	Cont	Cont	Patchy	Cont	Patchy	No/Lit	Patchy	Patchy
Cover Type	Woody Veg	Woody Veg	Woody Veg	Veg	Woody Veg	Woody Veg	Woody Veg	Woody Veg	Woody Veg	Woody Veg
Dominant Substrate	S/G	S/G	S/G	M/M	S/G	S/G	S/G	S/G	S/G C/B	S/G

Mod = Moderate; Cont = Continuous Cover; Art = Artificial; No/Lit = No or Little Cover; Bould = Boulder; Veg = Vegetation; M/M = Mud/Muck; C/B = Cobble/Boulder; S/G = Sand/Gravel

Plot bank features are presented in Table 8. Bank angle was considered gradual at six stations, steep at two stations, and near vertical at two stations. The vertical height from waterline to the high water mark was zero. The horizontal distance from waterline to the high water mark was zero.

Table 8. USEPA Habitat Characterization – Within Plot Bank Features.

Station	A	B	C	D	E	F	G	H	I	J
Angle	Steep	Steep	Grad	Grad	Grad	Grad	Grad	Grad	NV	NV
Vertical Height (m) to HWM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horizontal Distance (m) to HWM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

HWM = High Water Mark; Flat = <5 degrees; Grad = Gradual (5-30 degrees); Steep (30-75 degrees); NV=Near vertical/undercut (>75°)

Table 9 displays the invasive plant and invertebrate species found in Finger Lake. Chinese mystery snails were present at nine stations.

Table 9. USEPA Habitat Characterization – Invasive Plant and Invertebrate Species.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Target Invasive Species in Littoral Plot	CMS	CMS	CMS	None	CMS	CMS	CMS	CMS	CMS	CMS
Target Invasive Species in Shore-line/Riparian Plot	None	None	None	None	None	None	None	None	None	None
Target Invasive Species include: Zebra or Quagga Mussel, Eurasian Water-milfoil, Hydrilla, Curly Pondweed, African Waterweed, Brazilian Waterweed, European Water Chestnut, Water Hyacinth, Parrot Feather, Yellow Floating Heart, Giant Salvinia, Purple Loosestrife, Knotweed (Giant or Japanese), Hairy Willow Herb, Flowering Rush, Other Banded Mystery Snail (BMS) and Chinese Mystery Snail (CMS)										

The WDNR Supplemental Methodology data are presented in Tables 10 and 11. Table 10 shows thirty-nine pieces of small woody material (>5cm diameter) counted at eight of the ten littoral zone transects. Forty-seven pieces of large woody material were found at eight stations. None of the five target invasive species (Japanese stiltgrass, reed canary grass, Phragmites, cattails, or yellow iris) were observed. The Chinese mystery snail was observed at nine stations.

Table 10. WDNR Supplemental Methodology– Wood and Invasive Plant Species.										
Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Wood: >5cm diameter	7	7	7	0	3	4	4	0	6	1
Wood: >10cm diameter	8	6	9	0	8	5	8	2	1	0
Invasive: Japanese stiltgrass	No	No	No	No	No	No	No	No	No	No
Invasive: Reed canary grass	No	No	No	No	No	No	No	No	No	No
Invasive: Phragmites	No	No	No	No	No	No	No	No	No	No
Invasive: Cattails	No	No	No	No	No	No	No	No	No	No
Invasive: Yellow Iris	No	No	No	No	No	No	No	No	No	No
Chinese mystery snail presences see Table 9.										

Table 11 tabulates that lawn (three stations riparian plant and two stations for upland plot) were found in Finger Lake. Pavement was found in one riparian plot and three upland plots. Seawalls rip rap and artificial beaches were not present on the study plots. Residences were observed in the riparian plot of three stations and were observed in the upland plot at seven stations. Commercial buildings were not observed. Structures were observed in one upland plot. There were no boat lifts or swim rafts observed at any of the stations. A dock was observed at two stations. The WDNR protocol called for counting piers between each of the ten stations. Thirty-one piers were counted between stations on the perimeter of Finger Lake.

Table 11. WDNR Supplemental Methodology– Land cover, Human Development, and Piers.

(1 number given for riparian plot; if 2 numbers, 1st for riparian plot & 2nd for upland plot)

Station	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
LANDCOVER Key: 0 (0-1%), 1 (>1-10%), 2 (>10-40%), 3 (>40-75%), 4 (>75%)										
Seawall	0	0	0	0	0	0	0	0	0	0
Rip Rap	0	0	0	0	0	0	0	0	0	0
Artificial beach	0	0	0	0	0	0	0	0	0	0
Lawn	1/0	1/1	0	0	0	0/1	0	1/0	0	0
Pavement	0/0	1/1	0	0	0	0/1	0	0	0/1	0
HUMAN DEVELOPMENT										
Residences	1/0	1/1	0/1	0	0/2	0/1	0/1	1/1	0/1	0
Commercial buildings	0	0	0	0	0	0	0	0	0	0
Structures (sheds/boat houses)	0/1	0	0	0	0	0	0/1	0	0	0
Boat lifts	0	0	0	0	0	0	0	0	0	0
Swim rafts	0	0	0	0	0	0	0	0	0	0
Docks	1	0	1	0	0	0	0	0	0	0
NUMBER OF PIERS BETWEEN STATIONS										
From:	A-B	B-C	C-D	D-E	E-F	F-G	G-H	H-I	I-J	J-A
Count	4	1	2	2	4	6	3	4	2	3

The USEPA protocol called for a composite sample of aquatic benthic macroinvertebrates, combining net sweeps from each station into one sample. Table 12 provides the identified invertebrate taxa and counts of individuals by taxa for the composite sample. A total of thirty-two taxa and 821 individual organisms were identified.

Table 12. Composite Benthic Macroinvertebrate Sample from Finger Lake.				
Taxon	**Count**		**Taxon**	**Count**
Nematomorpha	2			
Annelida: Hirudinea (1),Oligochaeta (26)	27		Trichoptera (caddisflies): Hydroptilidae (17), Leptoceridae (2), Molannidae (1), and Odontoceridae (2)	22
Crustacea: Amphipoda (2), Decapoda (1)	3		Coleoptera (aquatic beetles): Dytiscidae (2 larvae), Elmidae (18), Gyrinidae (2 adults), and Haliplidae (2 adults)	24
Arachnoidea: Hydracarina	3		Diptera (true flies): Ceratopogonidae (12), Chaoboridae (1), and Chironomidae (325)	338
Ephemeroptera (mayflies): Baetidae (5), Caenidae (204), Ephemerellidae (3), Heptageniidae (1), and Siphlonuridae (2)	215		Mollusca: Gastropoda: Bithyniidae (40), Physidae (6), Planorbidae (41), Viviparidae-banded mystery snail (10)	97
Anisoptera (dragonflies): Aeshnidae (14), Gomphidae (5), and Libellulidae (15)	34		Mollusca: Pelecypoda: Sphaeriidae	46
Zygoptera (damselflies): Coenagrionidae (9) and Lestidae (1)	10		**Total Taxa**	**821**

Finally, the USEPA protocol called for a fecal indicator sample at the final sampling station (Station J). The collected sample was analyzed for *Escherichia coli* (*E. coli*). The *E. coli* analysis resulted in 7.2 CFU (Colony Forming Units) per 100 milliliters of sample. To place this value in context, the USEPA recommends a water quality advisory (for swimming) when a level of the indicator bacterium *E. coli* exceeds a limit is 235 CFU per 100 milliliters of water.

Table 13 indicates the coordinates of Stations A-J. A photo was taken at each of the ten stations. The station photos are displayed below.

Table 13. Finger Lake USEPA & WDNR Physical Habitat Locations.		
Station	*Latitude*	*Longitude*
A	45.9632223	-89.1796674
B	45.9622753	-89.1825533
C	45.9630963	-89.1852722
D	45.9646143	-89.1867081
E	45.9663473	-89.1863371
F	45.9676123	-89.1837342
G	45.9693893	-89.1827572
H	45.9681213	-89.1813153
I	45.9666863	-89.1789434
J	45.9648003	-89.1776374

An aquatic plant survey was conducted at each of the ten sites by dropping a rake at two, five, and eight meters from shore. The plants were ranked with rake fullness as 1-3 with 3 being the fullest. A depth was recorded with the rake. Table 14 displays the results.

Table 14. WDNR Supplemental Methodology – Aquatic Plant Survey

Plant	Site	Depth (ft)	Shore Distance (m)	Rake Fullness (1-3)
***Chara sp.* (muckgrass)**	A	2.1	2	1
	G	3.5	8	1
***Dulichium arundinaceum* (Three-way sedge)**	B	2.5	2	1
	F	1.5	2	1
***Eleocharis palustris* (Creeping spikerush)**	F	1.5	5	1
***Isoetes* (quilwort)**	A	5.3	8	1
***Juncas pelocarpus* (Brown-fruited rush)**	B	3.5	5	1
	I	2	2	1
***Najas quadalupensis* (Southern naiad)**	B	2.5	2	1
	E	1.5	5	1
	G	3.5	8	1
	H	2.5	5	1
	H	3	8	1
Nitella sp.	C	3.0	8	2
	D	1.5	2	1
	D	2.0	5	1
	D	2.0	8	1
	F	2.5	8	2
***Nuphar variegata* (Spatterdock)**	D	1.5	2	1
***Pontederia cordata* (Pickerelweed)**	C	1.5	2	1
	E	2.5	8	1
	G	2.0	2	1
***Ranunculus aquatilus* (White water crowfoot)**	D	1.5	2	1
	E	1.5	5	1
***Schoenoplectus tabernaemontani* (Softstem bulrush)**	D	1.5	2	1
	D	2.0	5	1
	D	2.0	8	1
***Sparganium floating* (bur-reed)**	B	3.5	5	1
	C	1.5	2	1
	D	2.0	8	1
	E	2.5	8	1
***Utricularia resupinata* (small purple bladderwort)**	A	2.1	5	1
	H	2.5	5	1
***Vallisneria americana* (Wild celery)**	B	4.0	8	1
	H	3	8	1

Station A – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station B – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station C – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station D – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station E – Finger Lake

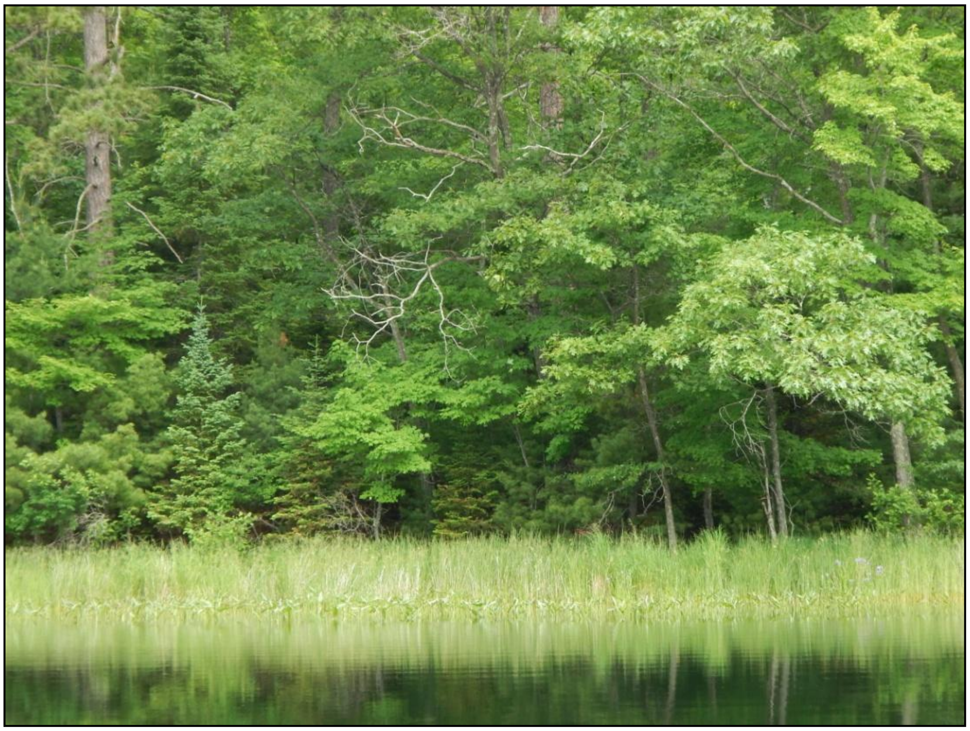
Photograph taken 6/23/2016, White Water Associates, Inc.

Station F – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station G – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.



Station H – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station I – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Station J – Finger Lake

Photograph taken 6/23/2016, White Water Associates, Inc.

Literature Cited

United States Environmental Protection Agency (USEPA). 2009. *National Lakes Assessment: A Collaborative Survey of the Nation's lakes. EPA 841-R-09-001.* U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C. Retrieved 2016. <water.epa.gov/type/lakes/upload/nla_newlowres_fullrpt.pdf>

Appendix 7

Perceived Threats

Threats to Finger Lake

Compiled by William Abba with contributions by White Water Associates, Inc.

Introduction

A key step in the completion of the small scale lake planning project for Finger Lake was to collect perceived threats to the lake and the surrounding area as seen by lake residents. One of the activities conducted at the Friends of Finger Lake Association annual meeting on July 17, 2016, was to ask each resident to fill out a questionnaire during the meeting to collect concerns, threats, and risks to the lake as they perceive them. The purpose of the exercise was explained as the opportunity for White Water Associates to collect resident concerns to ensure they were included in the grant analysis process and to ensure important concerns were not missed. No limitations were given, whatever they felt were the issues and threats to the lake should be included. Residents were allowed to collect their thoughts over the entire hour and a half meeting and were told to leave the questionnaire on the tables at the end of the meeting. No attempt to collate and discuss the issues was made at the meeting. We received 12 questionnaires back at the meeting, about a 50% return. The questionnaire is presented in Exhibit 1.

Results

The results of the survey are summarized in this section. A few general conclusions can be drawn from reading all of the input. First, and expectedly so, the comments from residents mimicked recently discussed issues included in the Association newsletter distributed approximately two months earlier and the topics actually discussed at the annual meeting. This is positive in that it seems to indicate at least some success in our communication tools in highlighting important issues residents need to be aware of and focused on. Some residents did not appear to have awareness of, or possibly enough understanding of, the many issues impacting lakes to include them or comment on them. A small number of residents who are actively involved in lake groups and causes had much to include in their questionnaires. This seems to underscore that communication can have an impact on residents understanding of issues, and the Association needs to continue to improve in this area. Interestingly, this was the most interactive meeting with attendees in recent memory, so clearly members are interested and willing to be engaged.

The results have been collated and summarized below. A brief explanation of each is included. Three topics stood out as most concerning based upon the number of residents mentioning the issue:

1. The Southern Naiad infestation. Not a surprise given this is the first time a significant problem plant has infested the lake. Even though this plant is not designated an “invasive” species, it is none-the-less a significant nuisance on the lake. Many residents have had to deal with heavy plant growth on their shorelines and navigation can be impacted in heavy growth areas. Another concerning aspect of this issue is that the source of this plant will never be known, creating concern over what else could happen in the future and highlighting the inability to completely stop nuisance organisms. Residents

have accepted that this plant is here to stay, but still desire a means to mitigate the negative impacts of its heavy growth.

2. The potential for an invasive species infestation. Residents have seen what a plant can do to the quality of a lake from the Southern Naiad infestation on Finger Lake. They are aware that steps need to be taken to ensure an infestation does not occur on Finger Lake. They are aware of the huge expense of trying to mitigate invasive species and eliminate them from lakes. They are also aware that a non-public access lake like Finger Lake with a very small number of residents could be financially overwhelmed in dealing with invasives. They recognize Finger Lake has some protection because of limited access to the lake, but they also recognize they must be diligent in preventing infestation in the first place.
3. Shoreline protection. Awareness of the importance of shorelines has increased considerably. Residents are now understanding the important role shorelines play in protecting the lake from watershed issues and the role they play in habitat for fish and other lake animals. There is a need to understand exactly what needs to be done to protect shorelines and what the issues actually are. But at least there is a significant awareness that residents need to actively work to address shoreline preservation.

Four additional issues were mentioned but by a smaller number of residents. These include:

1. Zoning law changes/legislative changes. Recent changes to lake shore zoning accountability resulting in the State taking control away from local governments has huge implications. A small group of residents have a deep understanding of the extent of the change and ramifications. Concern continues in anticipation of the upcoming legislative sessions and the changes it may bring.
2. Global climate change. The documented changes to global climate have the potential to significantly impact lake environments. The uncertainty of future changes and impacts raises the level of concern.
3. Changes in fisheries, especially walleye. Over the past years, a well-documented shift in fish populations favoring bass and disadvantaging walleyes has occurred. Concern exists with some residents that we are experiencing this change on Finger Lake also. Bass populations in the lake have increased and catches of walleyes have dropped significantly. No data exists to substantiate this shift, but some residents are concerned about the change especially since little seems to be known on why this shift is taking place.
4. Lake access. Finger Lake has no public access point yet trespassing across private property is on the rise, especially with winter ice fisherman. Trespassing is clearly an issue, but other related concerns are also troubling. Are these fisherman a source of potential invasive species contamination? Are they harvesting the stocked fish without contributing to the cost? These trespassers not only trespass in the winter, but apparently sneak onto the lake after dark in the summer. Finger Lake is penalized in securing aid and grants because it does not have public access, yet when trespassing occurs it actually does have public access.

This list summarizes the issues collected on this questionnaire. The issues were collated into groups of similar concerns to create this summary. A follow up questionnaire mailed to all lake property owners and access lot residents could be sent if there is belief broader information would be obtained. It is unlikely the number of returned questionnaires would be large and it isn't expected many more issues would be identified beyond those detailed here, so this step is not recommended.

Exhibit 1. Finger Lake Threats Questionnaire

One of the key steps in the lake planning grant process is to collect the perceived risks and threats to Finger Lake and the surrounding area as seen by the residents. Collecting this information will ensure the grant report does not miss important concerns that have potential impact on the lake. This exercise will also ensure that the major concerns held by residents will be addressed in the process of conducting the grant analysis.

Please take some time to write down the most important threats, issues, and concerns that you believe could have a detrimental impact on the long and short term health of Finger Lake and the watershed around the lake. Any issue you believe important should be included, no matter the topic. Examples include zoning law changes, changing fisheries populations, invasive species, septic system leakage, run off, changing climate or any other issue that is concerning you. Write down these concerns below with a few sentence explanation to ensure we understand the issue. Use the back of this sheet if more space is needed.

1.) Concern/threat:

2.) Concern/threat:

3.) Concern/threat:

4.) Concern/threat:

Name (*optional but will help us get more info if needed*) ______________________________

White Water Associates staff adds the following list of potential threats to Finger Lake along with a few suggestions as to how Finger Lake riparian residents might act to minimize the threats.

Recreational pressure – Finger Lake is a lightly-used fishing lake primarily for people who live on the lake. A few enter the lake through trespass. It is not likely that the recreational pressure on the lake will increase appreciably over time.

Development pressure – Finger Lake has some areas of residential development as well as areas with predominantly natural vegetation and diverse riparian areas. In some areas of the lake, old-style lawns, cropped short and in close proximity to the shore indicate a need for some educational effort to inform residents about more ecologically friendly waterfront vegetation. Likewise, well-intended activities meant to "clean up" the shoreline or shallow water zone of the lake diminish the habitat quality for invertebrates and fish and could be addressed with some targeted education.

Non-point source pollution – Surface runoff from the land, roadways, parking areas and other surfaces flows into Finger Lake. This runoff can carry with it sediment, nutrients (for example, from fertilizers) and contaminants (for example, herbicides) that can have detrimental effects on the Finger Lake ecosystem. Known as non-point source pollution (because it does not emanate from a discrete point like an effluent pipe from a paper mill), this kind of runoff can come from lawns, agricultural fields, clear-cuts, and impervious surfaces (for example, roads and paved parking lots). Sometimes the impact is physical, such as sediment covering gravel spawning areas. Sometimes it is chemical such as excess phosphorus from lawn fertilizers that might invoke an algal bloom. This type of pollution can be best controlled through education and protection of riparian buffers (natural vegetation near the waterways that absorb the pollutants before they reach the water).

Aquatic invasive species – Non-native plant and animal species have become a grave concern for aquatic, wetland, and terrestrial ecosystems. As more populations of aquatic plant and animal invasive species become established in lakes and streams in the region, the likelihood of AIS coming to Finger Lake increases. When it comes to non-native aquatic plant invaders, the best defense against establishment is a healthy community of native plants. A diverse native plant community presently exists. Effective education and diligent monitoring are important factors in avoiding establishment of aquatic invasive species. For landowners on Finger Lake, an effective approach to minimizing AIS introduction would be to dedicate watercraft and other recreational gear to the lake (in other words, do not use watercraft and gear on other lakes that you use on Finger Lake).

Riparian ecosystem integrity – Healthy riparian areas (the naturally vegetated land near the water) provide numerous important functions and values to Finger Lake. For example, they serve as habitat for many species, contribute important habitat to the lake (e.g., large wood), filter out non-point source pollution from entering the lake, and armors the shores against erosion. Educating riparian owners around Finger Lake as to the importance of riparian areas is crucial to the maintenance of these critical areas. This is one of the most important ecosystem components to protect in terms of long-term health of Finger Lake.

Littoral zone ecosystem quality – Much of the productivity of a lake comes from the shallow water areas known as the littoral zone. This is where plants grow, invertebrates live, fishes spawn, and aquatic birds and mammals spend much of their time. The presence of good aquatic vegetation, diverse substrate, and dead woody material (logs and branches) is crucial to this littoral zone ecosystem. Sometimes the human temptation is to “clean up” these areas, but in fact this process diminishes the habitat quality greatly. It is important to educate landowners and others about how to protect the littoral zone from degradation. Piers and swimming areas impact the littoral zone as well, but can coexist with a quality shallow water habitat if kept to a reasonable level.

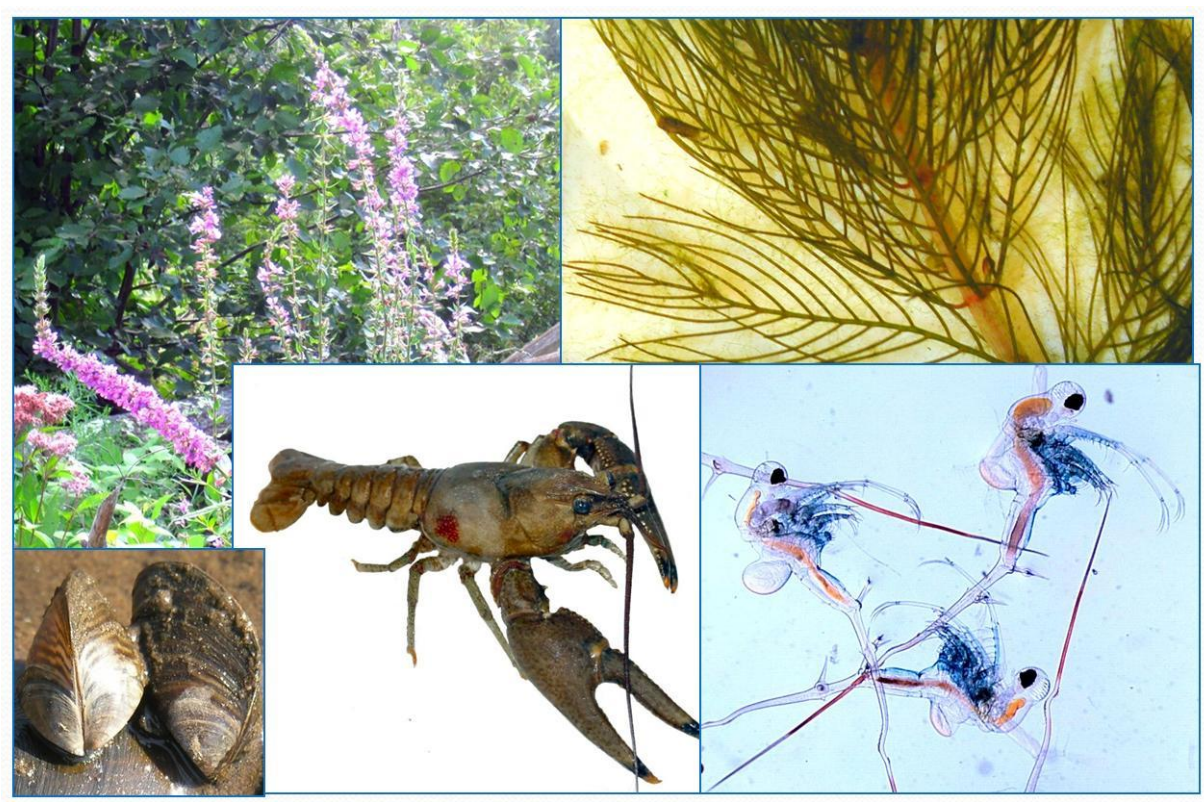
Habitat degradation of nearby aquatic and wetland habitats (ponds, streams) – The wetland habitats, streams, small lakes, and ponds in the vicinity of Finger Lake all potentially contribute to the high quality of the lake. These smaller ecosystems can be overlooked in terms of their importance and therefore deserve some special attention. One of the first protective measures to take is to identify where these features are and characterize their size and ecological composition. This informs future protection and restoration efforts.

Appendix 8

Aquatic Invasive Species Report

Finger Lake
(Vilas County, Wisconsin)

Aquatic Invasive Species Report



WHITE WATER
ASSOCIATES, INC.

Date: 2018

INTRODUCTION

White Water Associates, Inc. has been retained by The Friends of Finger Lake Association, Inc. (FOFL) through an Aquatic Invasive Species (AIS) Grant for Education, Prevention, and Planning on Finger Lake (Vilas County, Wisconsin). As its name implies, this grant focuses on aquatic invasive species. It is intended to increase the understanding of AIS as well as native species in Finger Lake, and prepares the FOFL to undertake and continue stewardship actions that serve lake health. A portion of this project monitored Finger Lake for AIS using the Wisconsin Department of Natural Resources (WDNR) protocol. This approach assesses the lake as to its vulnerability to AIS and documents aquatic invasive plant species as detected. Findings from the survey were entered into the SWIMS database. A core group of lake stewards were trained to recognize AIS so that they provide ongoing AIS monitoring. A broader educational activity was delivered in the form of a *floating workshop* for Finger Lake enthusiasts and interpreted and discusses lake health, riparian ecology, and the impacts that invasive species can have on these important ecosystems.

AQUATIC INVASIVE SPECIES EARLY DETECTION MONITORING

In order to determine presence of AIS in Finger Lake, White Water Associates 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 Finger Lake Survey took place July 22, 2018. A FOFL volunteer (William Abba) provided a boat from which to conduct the survey.

Five sites around the lake shoreline were searched along with a meander search in between sites. Finger Lake has no public boat landing. The five shoreline sites were randomly selected and are identified in Map 1 and Table 1. Snorkeling was not used to search for AIS due to the high water clarity. 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. All shoreline sites (except Site 3) had Chinese mystery snail present. This invasive snail was first observed in Finger Lake in 2013.

Chinese mystery snails are from Southeast Asia and Eastern Russia and were likely released to the Great Lakes from an aquarium (Kipp et al., 2015). The snail does not seem to have a significant impact on native species, but its ecological and anthropological threat comes from its potential to transmit parasites and diseases (Kipp et al., 2015). It is illegal to introduce the Chinese mystery snail into Wisconsin waters.

Spiny water fleas are an aquatic invasive zooplankton species that is found in a few lakes in Wisconsin. They can be monitored by way of plankton tow nets or by an examination of sediment for dead waterflea exoskeleton fragments. In Finger Lake, a Ponar dredge was used to collect a sediment sample in the middle of the lake (Map 1 and Table 2). The sample was brought back to the lab and filtered to look for spiny water flea spines under magnification. No AIS were found.

Meander surveys found no additional invasive species.

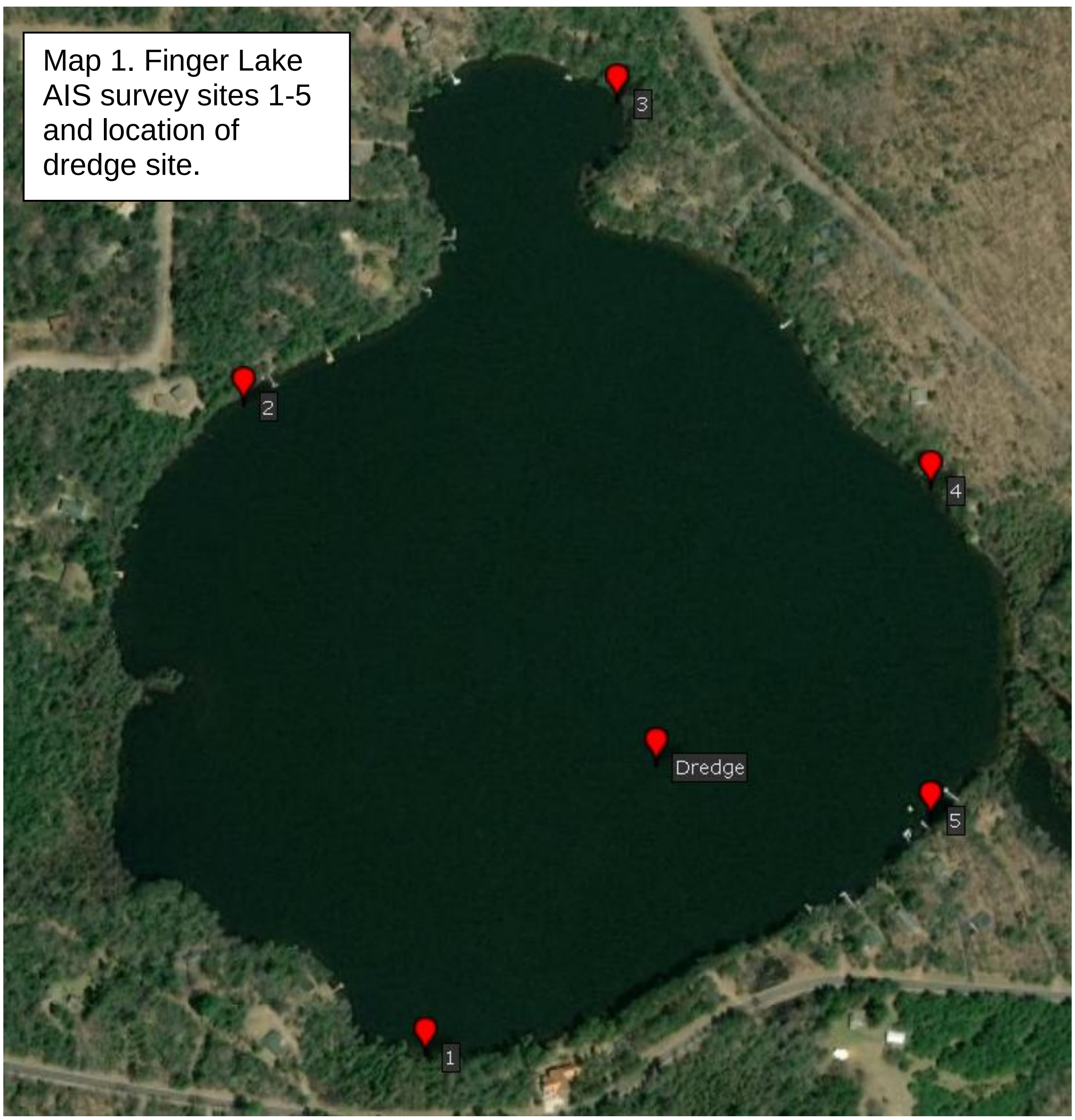


Table 1. AIS Survey on Finger Lake 7/22/2018.			
Site	**Latitude**	**Longitude**	**Species Found**
1	45.96222	-89.18375	Chinese Mystery Snail
2	45.96697	-89.18566	Chinese Mystery Snail
3	45.96918	-89.18173	None
4	45.96636	-89.17844	Chinese Mystery Snail
5	45.96395	-89.17844	Chinese Mystery Snail

Table 2. Spiny Water Flea Sample from Finger Lake			
Date: 7/22/2018	**GPS Coordinates**		**Depth of sample (feet)**
Dredge Site	45.96434	-089.18132	19

FLOATING WORKSHOP

A floating workshop for Finger Lake enthusiasts was conducted by White Water Associates, aquatic biologist, Angie Stine with assistance from Andrea Grosskopf, describing lake and riparian ecology while emphasizing the impacts that invasive species can have on these important ecosystems. The workshop took place July 22, 2018 using two pontoon boats. Highlights were the basic ecology of a lake, what can be monitored in a lake (discussed the historic aquatic plant surveys, shoreline survey, and macroinvertebrates), demonstration of Secchi disk, what is a littoral zone and the riparian area, stressors to a lake, aquatic invasive species, recommendations for good stewardship in the littoral and riparian area. The volunteers were intrigued on how much they learned about Finger Lake and were very susceptible to how they can help the quality of the lake over time.

Floating Workshop on Finger Lake.
Photo by Christina Hilscher.

CITIZEN LAKE MONITORING NETWORK AIS TRAINING

The CLMN AIS Monitoring was held August 18, 2019 at Bill Abba's home. Catherine Higley, Lakes Conservation Specialist from the Vilas County Land and Water Conservation Department, gave the training. Five volunteers were selected that had used Finger Lake frequently. Two of the volunteers have access points to the lake where boats can be put in. These AIS volunteers were educated to keep an eye out for the transport of AIS into Finger Lake. After a briefing on land about AIS they also went out in a pontoon with Catherine and did some sampling to look for AIS. The only invasive that was found was the Chinese mystery snail which is already confirmed in the lake. Catherine mentioned to the team to keep an eye out for Purple Loosestrife, Eurasian water-milfoil, and Curly Leaf Pondweed. She also mentioned the pH not being suitable for the spiny water flea so it may be unlikely that it may take to the lake if brought in. The group was given a binder with many photos of possible AIS to be on the lookout for along with AIS cards for ID. The AIS Team also had interaction with the stakeholders that have 9-10 lots across the road. They have access to the lake. They discussed the importance of not spreading AIS into Finger Lake. The AIS Team plans to go out the end of June each year to search for possible AIS as well as being on the lookout when on the water. The information will be entered into the SWIMS database by volunteer William Abba. Bill Abba also plans to educate on all that has happened at the annual meeting the third Sunday, July 2019.

Literature Cited

Kipp, R.M., A.J. Benson, J. Larson, and A. Fusaro. 2015. *Cipangopaludina chinensis malleata*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved 2017. <http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1045>

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