Shishebogama & Gunlock Lakes

Oneida & Vilas Counties, Wisconsin

Comprehensive Management Plan Update

December 2021

Sponsored by:

Shishebogama & Gunlock Lakes Association
Town of Lac du Flambeau

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Onterra LLC
Lake Management Planning

Shishebogama and Gunlock Lakes

Vilas and Oneida Counties, Wisconsin

Comprehensive Management Plan

December 2021

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1.0 INTRODUCTION

Shishebogama and Gunlock lakes are two interconnected lakes in northern Wisconsin, with portions in both Oneida and Vilas counties as well as the Lac du Flambeau Band of Chippewa Indians Reservation (Map 1). Gunlock Lake is a 267-acre, meso-eutrophic shallow headwater drainage lake with a maximum depth of 26 feet and a mean depth of 12 feet. The Wisconsin Department of Natural Resources (WDNR) uses the 264 acres listed in the DNR Register of Waters database is actually the digitized acreage from the WDNR 24K Hydro Geodatabase.

During this project, based on 2017 aerial imagery from the National Agriculture Imagery Program and the lake's water levels at that time, the lake's surface area was digitized in ArcGIS and was estimated to be 267 acres. The acreage of 267 is utilized for water quality and watershed modeling throughout this report. Gunlock Lake's watershed encompasses an area of just over 1,000 acres. Surveys in 2020 found that coontail (*Ceratophyllum demersum*), small pondweed (*Potamogeton pusillus*), and fern-leaf pondweed (*Potamogeton robbinsii*) were the most frequently encountered aquatic plant species.

Gunlock Lake drains into Shishebogama Lake through a narrow channel on the northwest side of the lake (Map 1). Shishebogama Lake is a 700-acre, mesotrophic deep lowland drainage lake with a maximum depth of 42 feet and a mean depth of 16 feet. Its watershed encompasses approximately 4,254 acres. The lake is drained via Shishebogama Creek which flows into the Tomahawk River. The surveys in 2020 found that coontail, small pondweed, and wild celery (*Vallisneria americana*) were the most frequently encountered aquatic plant species.

Lake at a Glance - Shishebogama & Gunlock Lakes

Morphology	Shishebogama Lake	Gunlock Lake
LakeType	Deep Lowland Drainage	Shallow Headwater Drainage
Surface Area (Acres)	700	267
Max Depth (feet)	42	26
Mean Depth (feet)	16	12
Perimeter (Miles)	10.9	4.8
Shoreline Complexity	8.7	4.5
Watershed Area (Acres)	4,254	1,005
Watershed to Lake Area Ratio	5:1	3:1
Water Quality	**Shishebogama Lake**	**Gunlock Lake**
Trophic State	Mesotrophic	Meso-eutrophic
Limiting Nutrient	Phosphorus	Phosphorus
Avg Summer P (µg/L)	17.0	23.1
Avg Summer Chl-α (µg/L)	5.5	8.5
Avg Summer Secchi Depth (ft)	9.8	8.3
Summer pH	7.8	7.8
Alkalinity (mg/L as $CaCO_3$)	36.5	37.5
Vegetation (2019)	**Shishebogama Lake**	**Gunlock Lake**
Number of Native Species	64	43
NHI-Listed Species	Vasey's pondweed	None
Exotic Species	NLC; PYI; PPL	NLC; PPL
Average Conservatism	6.7	7.0
Floristic Quality	44.1	40.8
Simpson's Diversity (1-D)	0.94	0.92

Descriptions of these parameters can be found within respective report section.
NLC = Narrow-leaved cattail; PYI = Pale-yellow iris; PPL = Purple loosestrife

In 2012, with assistance from a Wisconsin Department of Natural Resources planning grant, the Shishebogama and Gunlock Lakes Association, Inc. (SGLA) completed a comprehensive management plan for Shishebogama and Gunlock lakes. In an effort to continue the conservation of these lakes for future generations, the SGLA was awarded two WDNR lake planning grants in 2018 to reassess the health of these lakes and develop an updated comprehensive management plan.

This project included a comprehensive assessment of these lakes through baseline studies completed by Onterra and Lac du Flambeau Natural Resources Department (LDF NRD) staff in 2019 and 2020. These baseline studies were designed to reevaluate the lakes' water quality, watershed, aquatic plant community, and stakeholder perceptions. In addition, this project also included an evaluation of these lakes' immediate shoreland zone and the collection of sediment cores to determine how water quality may have changed since Euro-American settlement.

The data collected as part of this project were compared against the data collected as part of the first management planning project. The data were also used to determine the current ecological states of Shishebogama and Gunlock lakes and aid in the development of updated management goals to conserve and enhance this important natural resource. A detailed discussion of these study results can be found in sections 2.0 and 3.0 of this report. The study results indicate that both of these lakes remain very healthy – supporting high water quality and diverse native aquatic plant communities. The non-native invasive plants of Eurasian watermilfoil and curly-leaf pondweed were not located, a testament to the efforts of the SGLA and LDF NRD in their efforts to prevent the introduction of invasive species.

Following the completion of the studies on Shishebogama and Gunlock lakes, Onterra ecologists worked with a planning committee comprised of SGLA and LDF NRD representatives to develop short- and long-term management goals using the information collected from the lakes and their stakeholders as a guide. These management goals include the preservation of the lake's water quality and natural shorelands, restoration of developed shorelands, management of shoreland invasive species, and increase awareness of lake stewardship issues among others. These management goals and associated management actions can be found in section 6.0 if this report.

2.0 STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. The objective of this component in the planning process is to accommodate communication between the planners and the stakeholders. The communication is educational in nature, both in terms of the planners educating the stakeholders and vice-versa.

The planners educate the stakeholders about the planning process, the functions of their lake ecosystem, their impact on the lake, and what can realistically be expected regarding the management of the aquatic system. The stakeholders educate the planners by describing how they would like the lake to be, how they use the lake, and how they would like to be involved in managing it. All of this information is communicated through meetings that involve the lake group as a whole or a focus group called a Planning Committee, the completion of a stakeholder survey, and updates within the lake group's newsletter. The highlights of this component are described below. Materials used during the planning process can be found in Appendix A.

General Public Meetings

The general public meetings were used to raise project awareness, gather comments, create the management goals and actions, and deliver the study results. These meetings were open to anyone interested and were generally held during the summer, on a Saturday, to achieve maximum participation.

Kick-off Meeting

While a meeting to introduce the project to the general public is typically held for these planning projects, given this project serves to update the existing lake management plan for Shishebogama and Gunlock Lakes, the SGLA elected to forgo a project kick-off meeting.

Project Wrap-up Meeting

In September 2021, a pre-recorded project wrap-up meeting presentation created by Onterra ecologist Brenton Butterfield was provided to the SGLA and was distributed to lake stakeholders. Mr. Butterfield's presentation covered the results of the surveys completed in 2019, how the lakes have changed since their last assessment, and the updated management goals that were created with the SGLA and LDF planning committee. At the end of the presentation, an email was provided for viewers to provide any comments or questions they had regarding the project.

Committee Level Meetings

A planning committee meeting was used to gather comments, create management goals and actions, and to deliver study results. This meeting was open only to the planning committee and was held during the week on September 11, 2020. The meeting was held following the completion of the draft report sections of the management plan. The planning committee members were supplied with the draft report sections prior to the meeting and much of the meeting time was utilized to detail the results, discuss the conclusions and initial recommendations, and answer committee questions. The objective of the meeting was to fortify a solid understanding of the Shishebogama and Gunlock lakes ecosystem among the committee members and to review and update the management goals and management actions as necessary. The meeting was held virtually via the WebEx platform due to the ongoing covid-19 pandemic.

Stakeholder Survey

As a part of this project, a stakeholder survey was distributed to 1,892 Shishebogama and Gunlock lakes riparian property owners and association members, including members of the Lac du Flambeau Band of Lake Superior Chippewa Indians (LDF Tribe). The survey was designed by Onterra staff, SGLA planning committee members, and LDF Natural Resources Department (NRD) staff. The stakeholder survey was reviewed and approved by a WDNR social scientist. During April 2020, 34-question survey was posted online through Survey Monkey for property owners to answer electronically. If requested, a hard copy was sent to the property owner with a self-addressed stamped envelope for returning the survey anonymously. The returned hardcopy surveys were entered into the online version by a SGLA volunteers and LDF NRD staff.

Of the 1,892 surveys distributed, 272 surveys (14%) were completed. Please note that typically a benchmark of a 60% response rate is required to portray population projections accurately and make conclusions with statistical validity. The data were analyzed and summarized by Onterra for use at the planning meeting and within the management plan. The full survey and results can be found in Appendix B, while discussion of those results is integrated within the appropriate sections of the management plan and a general summary is discussed below.

Approximately 81% of respondents identified as non-tribal members, while 19% identified as a member of LDF Tribe. Approximately 62% of respondents indicates their property was on Shishebogama Lake, 20% was on Gunlock Lake, and 18% were off the lakes. Approximately 92% of respondents indicated that they owned their property while 8% indicated they leased their property.

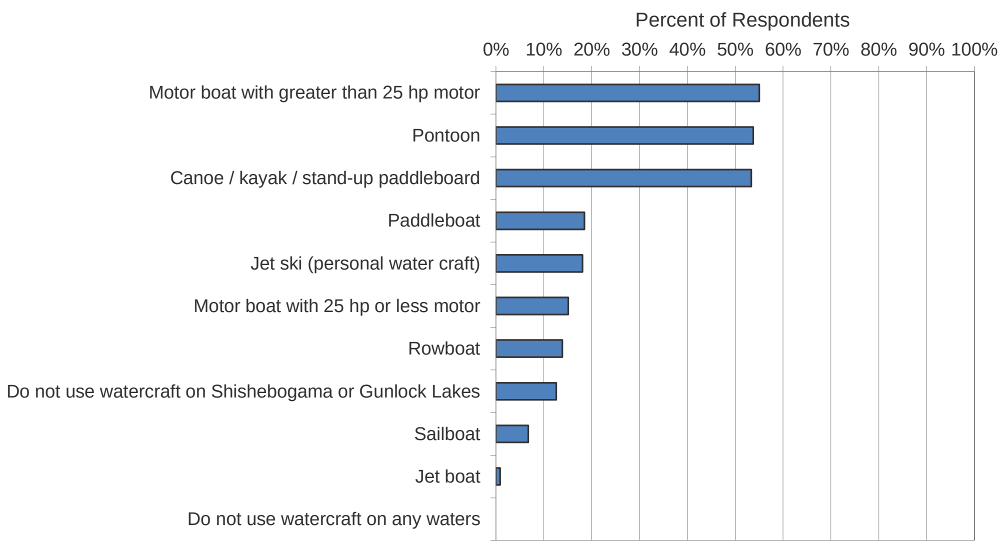
Based upon the results of the stakeholder survey, much was learned about the people that use and care for Shishebogama and Gunlock lakes. Most of the stakeholder respondents (35%) have a seasonal vacation home, 25% have a year-round residence, 21% have a seasonal residence (longer than summer), 4% have undeveloped property, 2% have a summer residence only, 2% indicated tribal treaty use, and less than 1% owned resort property and had rental property, respectively. Approximately 9% indicate they had property designated as “other” (Appendix B Question #4). Thirty-two percent of respondents indicated that have owned their property on Shishebogama or Gunlock lakes for over 25 years, while 28% have owned their property for five years or less (Appendix B Question #6).

The result section 3.0 (Water Quality, Watershed, Paleoecology, Aquatic Plants, and Fisheries Data Integration) discusses the stakeholder survey data with respect to these particular topics. Figures 2.0-1 and 2.0-2 highlight several other questions found within this survey. The survey revealed that the top three types of watercraft used by stakeholder survey respondents are motor boats with greater than 25 horsepower motor, pontoon boats, and canoe, kayaks, or stand-up paddleboards (Figure 2.0-1). Survey respondents listed fishing, relaxing/entertaining, motor boating, and nature viewing as the top four activities on Shishebogama and Gunlock lakes that are important to them (Figure 2.0-1).

When asked to rank their top three concerns regarding Shishebogama and Gunlock lakes, 60% of survey respondents listed water quality degradation and/or aquatic invasive species introduction as one of their top three concerns for these lakes, while 26% listed excessive aquatic plant growth (excluding algae) as one of their top three concerns (Figure 2.0-2). Shoreline erosion, excessive watercraft traffic, and unsafe watercraft practices were also ranked as higher concerns on Shishebogama and Gunlock Lakes.

Survey respondents were also asked which lake-related subjects they would be more interested in learning about. The top three topics respondents wanted to learn more about included how changing water levels impact Shishebogama and Gunlock lakes, aquatic invasive species impacts, means of transport, identification, control options, etc., and how to be a good lake steward (Figure 2.0-1).

Question 17: What types of watercraft do you currently use on Shishebogama and Gunlock Lakes?



Question 20: Please rank up to three activities on or near Shishebogama and Gunlock lakes that are important to you.

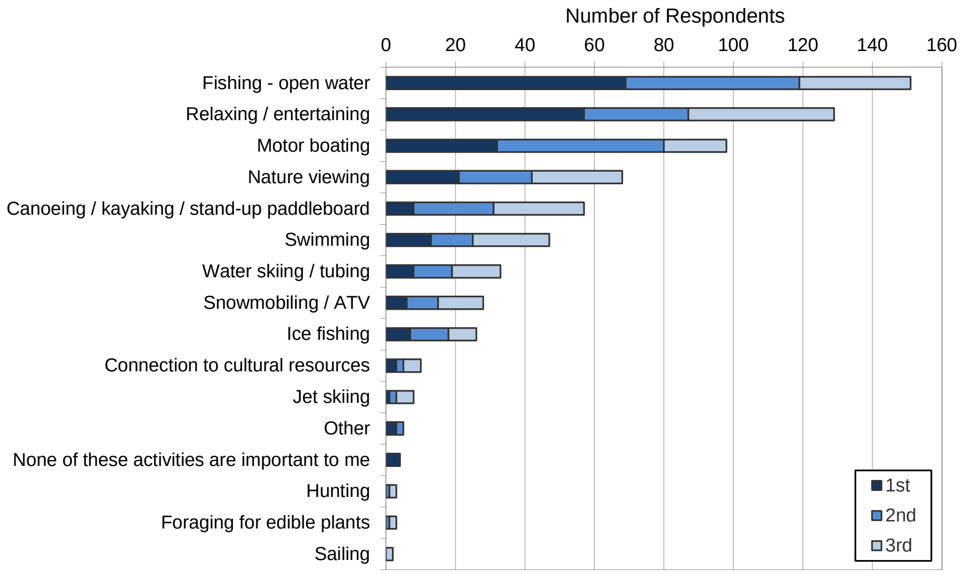
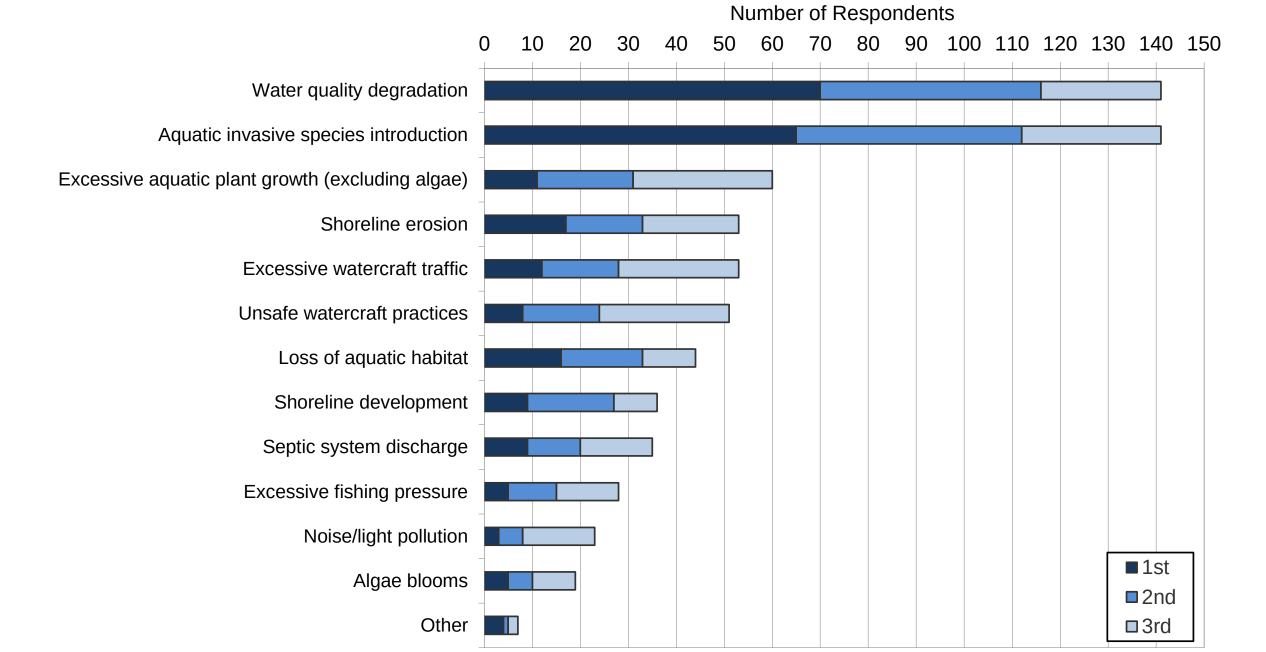


Figure 2.0-1. Select survey responses from the Shishebogama and Gunlock lakes stakeholder survey. Calculated from 272 survey respondents. Additional questions and response charts may be found in Appendix B.

Question 29: Please rank your top three concerns regarding Shishebogama and Gunlock lakes.



Question 32: Which of these subjects would you like to learn more about?

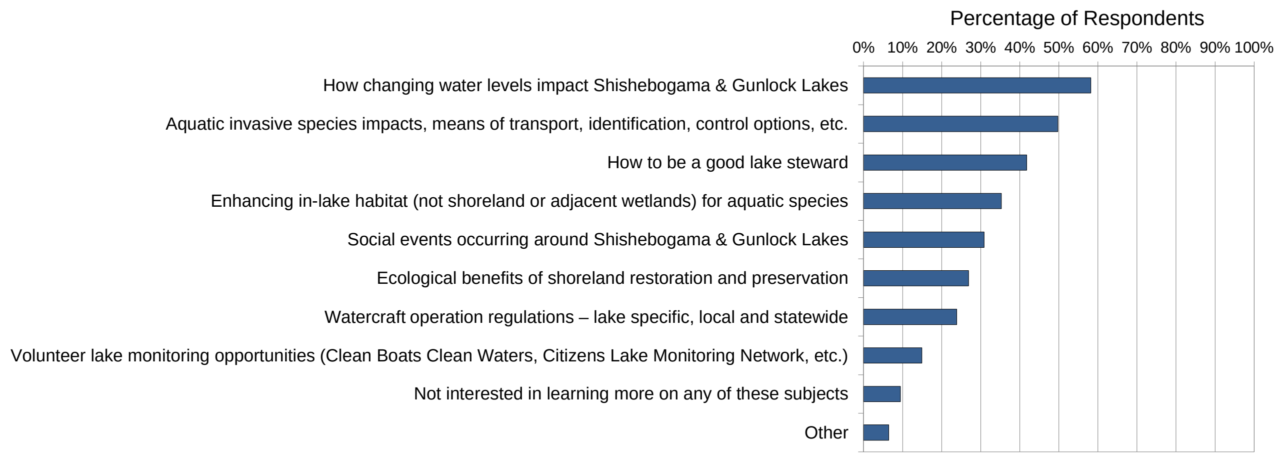


Figure 2.0-2. Select survey responses from the Shishebogama and Gunlock lakes stakeholder survey. Calculated from 272 survey respondents. Additional questions and response charts may be found in Appendix B.

Management Plan Review and Adoption Process

In February 2021, a draft of the Implementation Plan Section (Section 5.0) was provided to the Planning Committee for review. Comments and suggested changes were received from both the SGLA and LDF NRD and these were integrated into the Implementation Plan. In March 2021, the first official draft of the Shishebogama and Gunlock Lakes Comprehensive Management Plan Update was provided to the Planning Committee and the SGLA Board for review. Comments from the planning committee and WDNR were integrated into the report, and the final version was created in December 2021.

3.0 RESULTS & DISCUSSION

3.1 Lake Water Quality

Water Quality Data Analysis and Interpretation

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

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

As mentioned above, chemistry is a large part of water quality analysis. In most cases, listing the values of specific parameters really does not lead to an understanding of a lake's water quality, especially in the minds of non-professionals. A better way of relating the information is to compare it to lakes with similar physical characteristics and lakes within the same regional area. In this document, a portion of the water quality information collected on Shishebogama and Gunlock lakes is compared to other lakes in the state with similar characteristics as well as to lakes within the northern region (Appendix C). In addition, the assessment can also be clarified by limiting the primary analysis to parameters that are important in the lake's ecology and trophic state (see below). Three primary water quality parameters are focused upon in the water quality analysis:

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

These three parameters are often correlated with one another. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water (Canter, Nelson, & Everett, 1994; Dinius, 2007; Smith, Cragg, & Croker, 1991).

Trophic State

Total phosphorus, chlorophyll-*a*, and water clarity values are directly related to the trophic state of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: oligotrophic, mesotrophic, and finally eutrophic. Oligotrophic lakes have the lowest amounts of nutrients and biological productivity, and are generally characterized by having high water clarity and a lower abundance of aquatic plants. Mesotrophic lakes have moderate levels of nutrients and biological productivity and generally support more abundant aquatic plant growth. Eutrophic lakes have higher levels of nutrients and biological productivity, and generally have a high abundance of aquatic plants.

Most lakes will naturally progress through these states under natural conditions (i.e., not influenced by the activities of humans), but this process can take tens of thousands of years. Unfortunately, human development of watersheds and the direct discharge of nutrient-rich effluent has accelerated this natural aging process in many Wisconsin lakes, and this is termed cultural eutrophication. The excessive input of nutrients through cultural eutrophication has resulted in some lakes becoming hypereutrophic. Hypereutrophic lakes have the highest levels of nutrients and biological productivity. These lakes are typically dominated by algae, have very poor water clarity, and little if any aquatic plant growth.

It is important to note that both natural factors and human activity can affect a lake's trophic state, and that some lakes can be naturally eutrophic. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states often does not give clear indication of where a lake really exists in its trophic progression because each trophic state represents a range of productivity. Therefore, two lakes classified in the same trophic state can actually have very different levels of production.

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

Limiting Nutrient

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

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

Temperature and Dissolved Oxygen Profiles

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

Lake stratification occurs when temperature and density gradients are developed with depth in a lake. During stratification, the lake can be broken into three layers: The ***epilimnion*** is the surface layer with the lowest density and has the warmest water in the summer months and the coolest water in the winter months. The ***hypolimnion*** is the bottom layer the highest density and has the coolest water in the summer months and the warmest water in the winter months. The ***metalimnion***, often called the thermocline, is the layer between the epilimnion and hypolimnion where temperature changes most rapidly with depth.

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

Internal Nutrient Loading

In general, lakes tend to act as phosphorus sinks, meaning they tend accumulate phosphorus over time and export less phosphorus than the amount that is loaded to the lake from its watershed. In most lakes, there is a net movement of phosphorus from the water to bottom sediments where it accumulates over time. The retention of this phosphorus within bottom sediments depends on a number of physical, chemical, and biological factors (Wetzel, 2001). If this phosphorus remains bound within bottom sediments, it is largely unavailable for biological use. However, under certain conditions, this phosphorus can be released from bottom sediments into the overlying water where it may become biologically available. This release of phosphorus (and other nutrients) from bottom sediments into the overlying water is termed *internal nutrient loading*. While phosphorus can be released from bottom sediments under a few varying conditions, it occurs most often when the sediment-water interface becomes devoid of oxygen, or anoxic.

When water at the sediment-water interface contains oxygen, phosphorus largely remains bound to ferric iron within the sediment. When the water at the sediment-water interface becomes anoxic, or devoid of oxygen, ferric iron is reduced to ferrous iron and the bond between iron and phosphorus is broken. Under these conditions, iron and phosphorus are now soluble in water and are released from the sediments into the overlying water (Pettersson, 1998). Anoxia at the sediment-water interface typically first develops following thermal stratification, or the formation of distinct layers of water based on temperature and density. As surface water warms in late-spring/early summer, it becomes less dense and floats atop the colder, denser layer of water below. The large density gradient between the upper, warm layer of water (*epilimnion*) and lower, cold layer of water (*hypolimnion*) prevents these layers from mixing together and eliminates atmospheric diffusion of oxygen into bottom waters. If there is a high rate of biological decomposition of organic matter in the bottom sediments, anoxic conditions within the hypolimnion can develop as oxygen is consumed and is not replaced through mixing. The loss of oxygen then results in the release of phosphorus from bottom sediments into the hypolimnion.

The development of an anoxic hypolimnion and subsequent release of phosphorus from bottom sediments occurs in many lakes in Wisconsin. However, in deeper, dimictic lakes which remain stratified during the summer, internal nutrient loading is often not problematic as the majority of the phosphorus released from bottom sediments is confined within the hypolimnion where it is largely inaccessible to phytoplankton. Dimictic lakes are those which remain stratified throughout the summer (and winter) and experience only two complete mixing events (turnover) per year, one in spring and one in fall. In dimictic lakes, phosphorus released from bottom sediments into the hypolimnion during stratification only becomes available to phytoplankton in surface waters during the spring and fall mixing events. While these spring and fall mixing events can stimulate diatom and golden-brown phytoplankton blooms, these mixing events generally to not stimulate cyanobacterial (blue-green algae) blooms because water temperatures are cooler.

Internal nutrient loading can become problematic in lakes when sediment-released phosphorus becomes accessible to phytoplankton during the summer months when surface temperatures are at their warmest. Sediment-released phosphorus can be mobilized to surface waters during the summer in polymictic lakes, or lakes which have the capacity to experience multiple stratification and mixing events over the course of the growing season. Some polymictic lakes tend to straddle the boundary between deep and shallow lakes, and have the capacity to break stratification in summer when sufficient wind energy is generated. Consequently, phosphorus which has accumulated in the anoxic hypolimnion during periods of stratification is mobilized to the surface during partial or full mixing events where it then can spur nuisance phytoplankton blooms at the surface.

Phosphorus from bottom waters can also be mobilized to the surface in polymictic lakes through entrainment, or the continual deepening of the epilimnion and erosion of the metalimnion below (Wetzel, 2001). Wind-driven water generates turbulence across the thermal barrier between the epilimnion and the metalimnion and the metalimnion is eroded, mixing sediment-released nutrients into the epilimnion above. Both periodic mixing and entrainment act as “nutrient pumps” in polymictic lakes, delivering sediment-released nutrients in bottom waters to surface waters (Orihel, et al., 2015). While a continuum exists between dimictic and polymictic lakes, the Osgood

Index (Osgood, 1988) is used to determine the probability that a lake will remain stratified during the summer. This probability is estimated using the ratio of the lake's mean depth to its surface area. Lakes with an Osgood Index of less than 4.0 are deemed polymictic. As is discussed further in this report, Gunlock Lake is classified as polymictic while Shishebogama is classified as intermediate between polymictic and dimictic.

To determine if internal nutrient loading occurs and has a significant effect on Shishebogama and Gunlock lakes' water quality, the dynamics of near-surface phosphorus concentrations over the course of the growing season were examined. In dimictic lakes that experience internal nutrient loading, near-surface concentrations will often be highest in the fall following fall turnover when the phosphorus-rich bottom waters are mixed throughout the water column. In shallower lakes that experience internal loading and periodic mixing throughout the growing season, near-surface phosphorus concentrations will often increase over the course of the growing season as sediment-released phosphorus is periodically mobilized to the surface. In addition, near-bottom phosphorus concentrations are also measured during periods of stratification to determine if significant levels of phosphorus are accumulating in bottom waters.

Finally, watershed modeling was used to determine if measured phosphorus concentrations were similar to those predicted based on watershed size, land cover, and precipitation. If predicted phosphorus concentrations are significantly lower than those measured, this indicates that source(s) of phosphorus are entering the lake that were not accounted for in the model. This unaccounted source of phosphorus is often attributable to the internal loading of phosphorus.

Comparisons with Other Datasets

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

The WDNR classifies Wisconsin's lakes into ten natural communities based on size, hydrology, and depth (Figure 3.1-1). First, the lakes are classified into three main groups: (1) lakes and reservoirs less than 10 acres, (2) lakes and reservoirs greater than or equal to 10 acres, and (3) a classification that addresses special waterbody circumstances. The last two categories have several sub-categories that provide attention to lakes that may be shallow, deep, play host to cold water fish species or have unique hydrologic patterns. Overall, the divisions categorize lakes based upon their size, stratification characteristics, and hydrology. An equation developed by (Lathrop & Lillie, 1980), which incorporates the maximum depth of the lake and the lake's surface area, is used to predict whether the lake is considered a shallow (mixed) lake or a deep (stratified) lake. The lakes are further divided into classifications based on their hydrology and watershed size:

Seepage Lakes have no surface water inflow or outflow in the form of rivers and/or streams.

Drainage Lakes have surface water inflow and/or outflow in the form of rivers and/or streams.

Headwater drainage lakes have a watershed of less than 4 square miles.

Lowland drainage lakes have a watershed of greater than 4 square miles.

Using these criteria, Gunlock Lake is classified as a shallow (mixed) headwater drainage lake (category 2), while Shishebogama Lake is classified as a deep (stratified) lowland drainage lake (category 5). The water quality from each of these lakes will be compared to water quality of the respective lake type in Wisconsin.

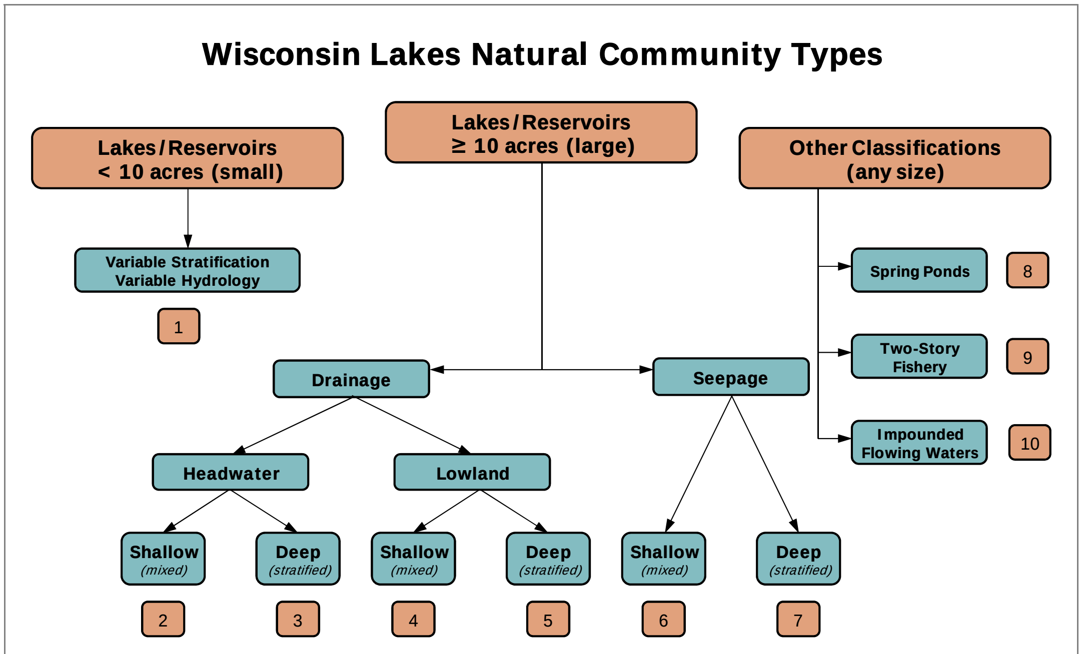


Figure 3.1-1. Wisconsin Lake Natural Communities. Adapted from WDNR 2017.

(Garrison, et al., 2008) developed state-wide median values for total phosphorus, chlorophyll-*a*, and Secchi disk transparency for six of the lake classifications. Though they did not sample sufficient lakes to create median values for each classification within each of the state's ecoregions, they were able to create median values based on all of the lakes sampled within each ecoregion (Figure 3.1-2). Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states. Gunlock and Shishebogama lake are within the Northern Lakes and Forests (NLF) ecoregion of Wisconsin (Figure 3.1-2).

The Wisconsin Consolidated Assessment and Listing Methodology document also helps stakeholders understand the health of their lake compared to other lakes within the state. Looking at pre-settlement diatom population compositions from sediment cores collected from numerous lakes around the state, they were able to infer a reference condition for each lake's water quality prior to human development within their watersheds. Using these reference conditions and current water quality data, the assessors were able to rank phosphorus, chlorophyll-*a*, and Secchi disk transparency values for each lake class into categories ranging from excellent to poor.

Approximately 23% of Gunlock Lake's shoreline and 6% of Shishebogama Lake's shoreline are under ownership by LDF Tribe. The LDF Tribe has adopted Environmental Protection Agency (EPA) water quality standards for lakes within the reservation and they do not use those developed by the State of Wisconsin. The water quality standards utilized by the LDF Tribe are also presented in this section and used to assess the condition of Shishebogama and Gunlock lakes.

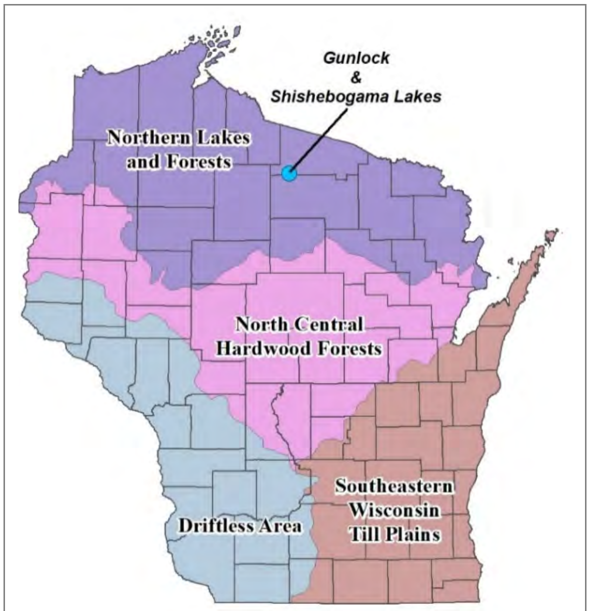


Figure 3.1-2. Location of Shishebogama and Gunlock lakes within the ecoregions of Wisconsin. After Nichols 1999.

These data along with data corresponding to statewide natural lake means, historical, current, and average data from Shishebogama and Gunlock lakes are displayed and discussed in the subsequent section. *Growing season* refers to data collected at any time between April and October, while *summer* refers to data collected in June, July, or August. Most of the data were collected from near-surface samples as these represent the depths at which algae grow.

The historical and current data presented in this section were collected by a combination of SGLA volunteers through the WDNR Citizens Lake Monitoring Network and LDF NRD staff, while Onterra ecologists collected supplemental data in 2009/10 and 2019/20 as part of the lake management planning projects. In Gunlock Lake, all data presented in this section were collected at the lake's deep hole sampling location (Figure 3.1-3). In Shishebogama Lake, all of the nutrient and chemistry data presented in this section were collected at the lake's deep hole sampling location, while water clarity data are available from both the lake's deep hole sampling location and the lake's West Basin sampling location (Figure 3.1-3).

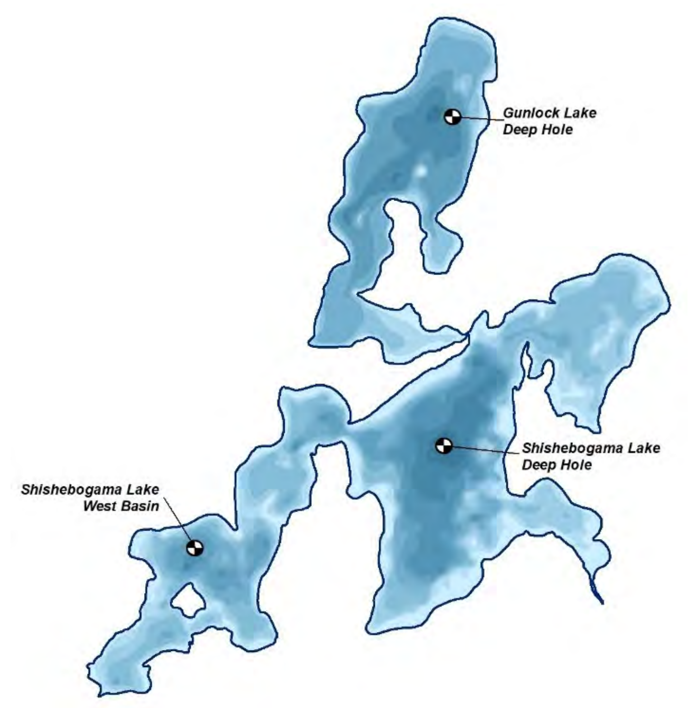


Figure 3.1-3. Shishebogama and Gunlock lakes water quality sampling locations.

Shishebogama and Gunlock Lakes Water Quality Analysis

Shishebogama Lake Long-term Trends

Total Phosphorus

Near-surface total phosphorus (TP) data from Shishebogama Lake are available annually from 2002-2019 (Figure 3.1-4). The weighted summer average TP concentration over this time period is 17.0 µg/L, indicating the lake's TP concentrations are *excellent* for Wisconsin's deep lowland drainage lakes and *good* for LDF Tribe criteria. Summer TP concentrations in 2019 were below average at 13.0 µg/L, falling into the *excellent* category for both Wisconsin's deep lowland drainage lakes and LDF Tribe criteria. Overall, Shishebogama Lake's TP concentrations are lower than the median concentrations for Wisconsin's deep lowland drainage lakes and for all lakes within the NLF ecoregion. Regression analysis indicated that there are no statistically valid trends (positive or negative) in growing season or summer TP concentrations over the period from 2002-2019 in Shishebogama Lake.

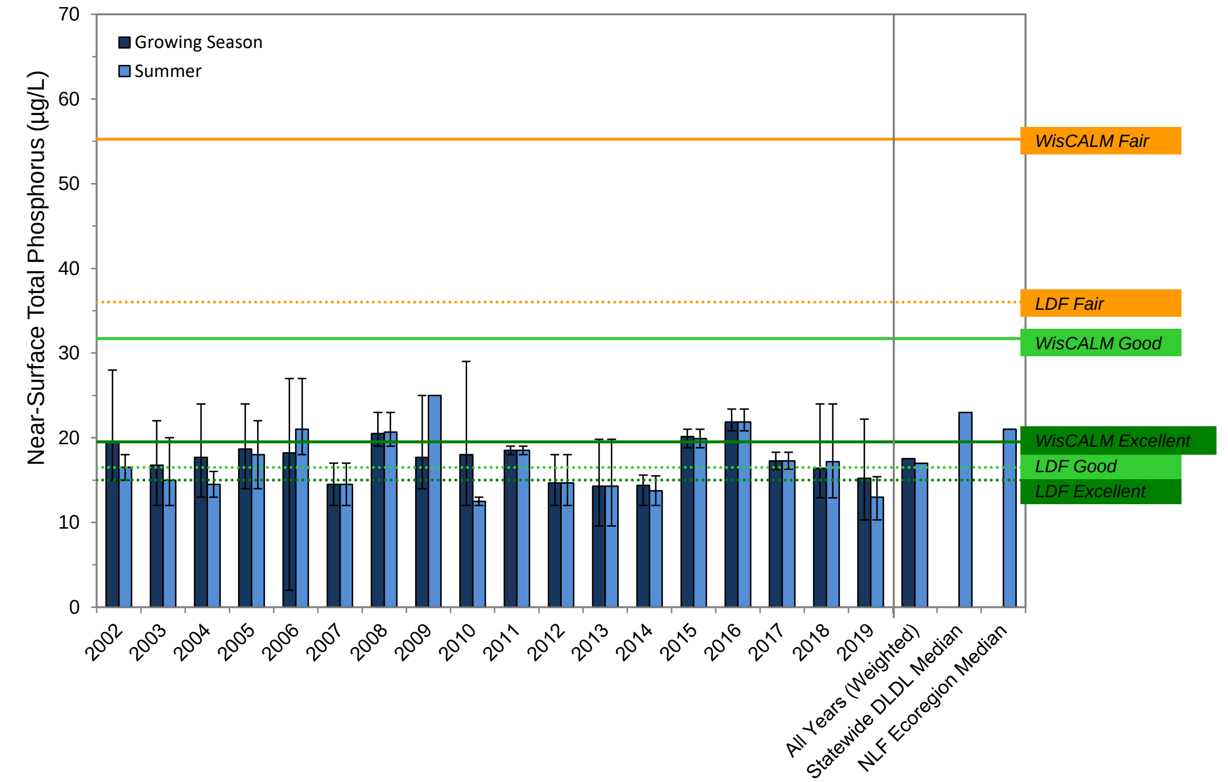


Figure 3.1-4. Shishebogama Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Phosphorus criteria for Wisconsin DLDL lakes (WisCALM) and LDF Tribe criteria displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Examination of Shishebogama Lake's average near-surface TP concentrations by month shows that concentrations are relatively similar in May, June, and July, but tend to increase slightly in August, September, and October (Figure 3.1-5). As is discussed in the previous section, increasing phosphorus concentrations during the growing season often indicate that internal nutrient loading is occurring and sediment-released phosphorus is being mobilized from bottom waters to the surface. Phosphorus concentrations were measured from bottom waters in Shishebogama Lake in

July of 2019. During this sampling event, dissolved oxygen data indicated that the lake had developed an anoxic hypolimnion starting at approximately 24 feet. The TP concentration measured near the bottom was 41.1 µg/L, approximately three times higher than concentrations at the surface. While this near-bottom TP concentration is not considered high by internal nutrient loading standards, it does indicate that TP concentrations become somewhat elevated during summer stratification in Shishebogama Lake.

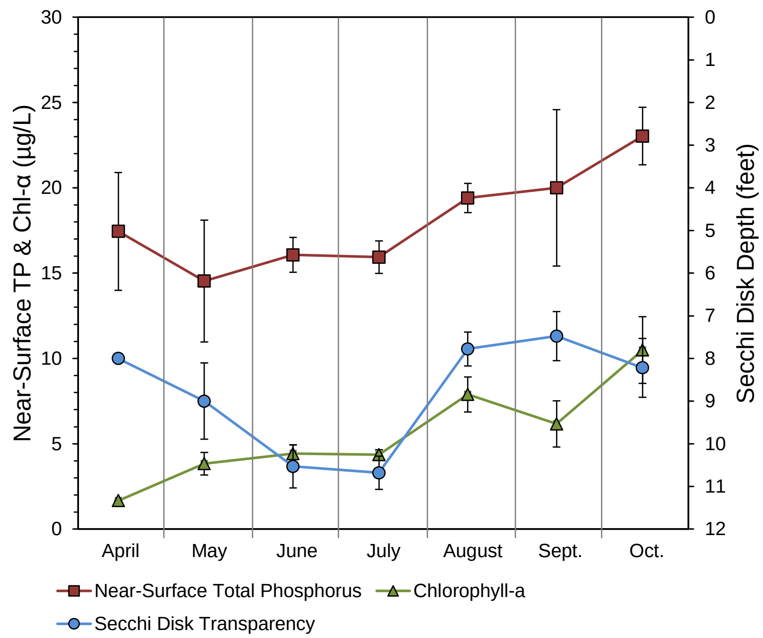


Figure 3.1-5. Shishebogama Lake average monthly near-surface total phosphorus, chlorophyll-α, and Secchi disk depth. Monthly averages calculated using data from 2002-2019. Error bars represent standard error.

Current and historical temperature and dissolved oxygen profiles collected from Shishebogama Lake's deep hole sampling locations were examined to determine if and how phosphorus from bottom waters may be mobilized to the surface in late summer. These data indicate the Shishebogama Lake remains stratified throughout the summer (dimictic lake); however, the lake's warmer surface layer of water, the epilimnion, extends to a deeper depth later in the summer. As discussed previously, wind-driven water can generate turbulence across the thermal barrier between the epilimnion and the metalimnion. The metalimnion is eroded, and hypolimnetic phosphorus can mix into surface waters. This process is known as entrainment. This process is likely why phosphorus concentrations in Shishebogama Lake tend to increase slightly in August.

On average, Shishebogama Lake's near-surface TP concentrations are highest in October following fall turnover. During fall turnover, the phosphorus that had accumulated in bottom waters is mixed throughout the water column, increasing concentrations at the surface. Data collected through the ice in the winter of 2020 show that Shishebogama Lake develops an anoxic hypolimnion in winter as well. Near-bottom concentrations in winter were approximately two times higher than those measured at the surface, indicating accumulation of phosphorus in bottom waters. During spring turnover, phosphorus in bottom waters is mixed throughout the water column, causing a slight increase in concentrations measured at the surface in early spring.

Using the average near-surface TP concentration at spring and fall turnover and Shishebogama Lake's estimated water volume, it is estimated that on average approximately 100 pounds of phosphorus originate from internal loading during the growing season. While this may seem significant, only a portion of this phosphorus is mobilized to surface waters in late summer while most of this phosphorus is mobilized to surface waters in the fall. While internal nutrient loading occurs in Shishebogama Lake, it's impact on the lake's water quality is not significant, and it is not a concern at this time.

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Shishebogama Lake for the same time period as TP, from 2000-2019 (Figure 3.1-6). The weighted summer average chlorophyll-*a* concentration over this period is 5.5 µg/L, indicating the lake's chlorophyll-*a* concentrations straddle the threshold between *excellent* and *good* for Wisconsin's deep lowland drainage lakes and are considered *good* for LDF Tribe criteria. Summer chlorophyll-*a* concentrations in 2019 were below average with a concentration of 4.5 µg/L, falling into the *excellent* category for Wisconsin's deep lowland drainage lakes and the *good* category for LDF Tribal lakes.

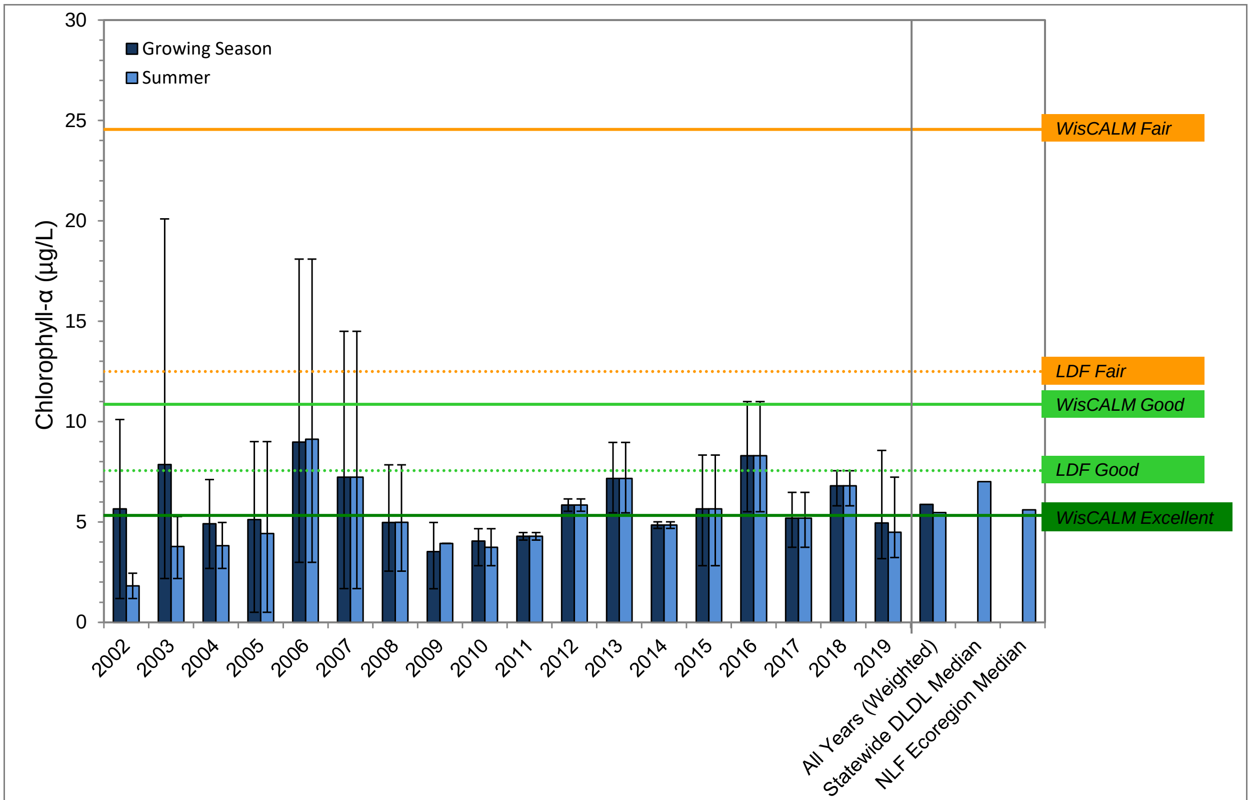


Figure 3.1-6. Shishebogama Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Chlorophyll-α criteria for Wisconsin DLDL lakes (WisCALM) and LDF Tribe criteria displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Overall, Shishebogama Lake's chlorophyll-*a* concentrations are lower than the median concentration for Wisconsin's deep lowland drainage lakes and similar to the median concentration for all lake types within the NLF ecoregion. Regression analysis indicated that there are no statistically valid trends (positive or negative) in growing season or summer chlorophyll-*a* concentrations over the period from 2002-2019 in Shishebogama Lake. As discussed earlier, chlorophyll-*a* concentrations are often positively correlated with TP concentrations. Like TP, chlorophyll-*a* concentrations in Shishebogama Lake tend to increase in August, September, and October as phosphorus from bottom waters is mobilized to the surface (Figure 3.1-5).

Water clarity monitoring using Secchi disk depths has been conducted at Shishebogama Lake's deep hole sampling location in 1990-1991, 1999-2010, and 2012-2019 (Figure 3.1-7). Average summer Secchi disk depths have ranged from 12.5 feet in 2004 and 2010 to 6.7 feet in 2016. The weighted summer average Secchi disk depth over this time period is 9.8 feet, indicating Shishebogama Lake's water clarity is *excellent* for Wisconsin's deep lowland drainage lakes. The LDF Tribe does not currently have criteria developed for water clarity. Summer Secchi disk depths in 2019 were above average at 10.2 feet. On average, Shishebogama Lake's Secchi disk depths are higher than median depths for other deep lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

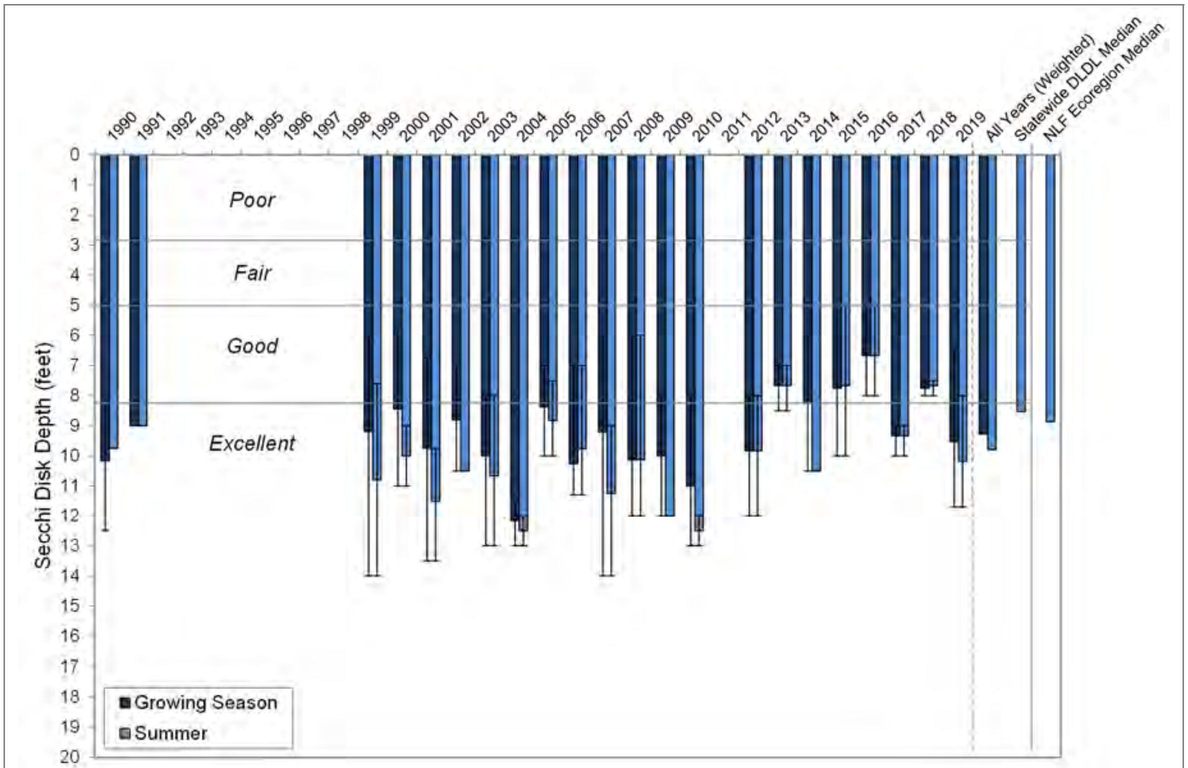


Figure 3.1-7. Shishebogama Lake average annual Secchi disk depth measured at the deep hole sampling location and median Secchi disk depth for state-wide deep lowland drainage lakes (DLDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Examination of monthly average Secchi disk depths shows that water clarity in Shishebogama Lake is highest in June and July, with average depths near 10-11 feet (Figure 3.1-5). Water clarity declines to an average depth of approximately 8.0 feet in August corresponding with the increase in chlorophyll-*a* concentrations. The phosphorus which is mobilized from bottom waters to the surface in late summer causes an increase in phytoplankton production (chlorophyll-*a*), and the increased level of phytoplankton production reduces light penetration and water clarity.

Unlike TP and chlorophyll-*a* concentrations which have seen no statistically valid trends over the period from 2002-2019, there has been a statistically valid decreasing trend in summer Secchi disk depths over this period in Shishebogama Lake ($R^2 = 0.23$; p-value = 0.014). A t-test (two-sample assuming equal variances) showed that there is a statistically valid difference in average Secchi disk depth from 2002-2010 (10.9 feet) and 2012-2019 (8.7 feet). This decline in average Secchi disk depth has occurred despite no statistically valid increase in chlorophyll-*a* concentrations over this same period. This indicates that a factor other than algal abundance is causing reduced water clarity in Shishebogama Lake in recent years.

The two most important factors affecting water clarity in Wisconsin's lakes are algal abundance and water color, or true color. True color is a measure of water clarity once all particulates (i.e., algae, sediments, etc.) have been filtered out and only dissolved compounds remain. Dissolved organic matter (DOM) causes the water in lakes, particularly in northern Wisconsin, to be brown in color, or stained. This DOM originates from decaying plant matter in forests and wetlands in the lake's watershed. Studies have been showing that DOM has been increasing in lakes across North America as the result of increases in precipitation and increases in extreme precipitation events (North American Lake Management Society 2020). Higher rates of precipitation cause increases in DOM in a couple of ways: first, higher precipitation saturates soils which creates anoxic conditions which increases the production of DOM, and second, higher precipitation increases the amount of water and DOM flowing into the lake.

Annual precipitation data obtained from nearby Minocqua (NWS US Cooperative Network 475516) shows that annual precipitation has increased from an average of 30.2 inches from 2002-2011 to 39.5 inches from 2012-2019. Annual precipitation records from Minocqua are available nearly every year since 1904. These data indicate that precipitation has been above the annual average of 31.8 inches every year from 2013-2019. Regression analysis shows that summer water clarity in Shishebogama Lake has been negatively correlated with average annual precipitation (Figure 3.1-8). True color measurements made in 2019 indicated Shishebogama Lake's water was *slightly tea-colored*, indicating some influence on water clarity by DOM. True color measurements are not available prior to 2019, but given the relationship between water clarity and precipitation, it is likely that the recent decline in water clarity is likely due to increases in precipitation and DOM concentrations. This decline in water clarity in recent years despite no measured increase in chlorophyll-*a* concentrations has been observed on other regional lakes (Onterra 2018 and Onterra 2019).

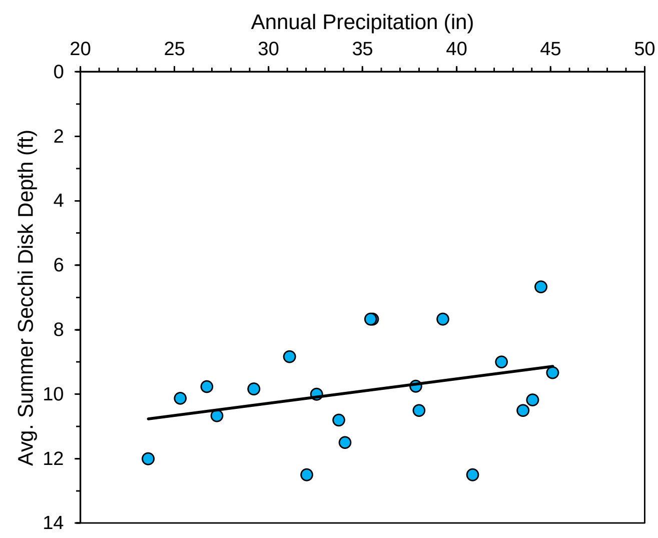


Figure 3.1-8. Shishebogama Lake average summer Secchi disk depth plotted against annual precipitation using available data from 1990-1991 and 1999-2019. Analysis shows that summer water clarity declines with increasing annual precipitation. This is believed to be the result of higher inputs of dissolved organic matter (DOM) which cause a 'browning' of the lake water.

The SGLA has also been monitoring water clarity in Shishebogama Lake's west basin using Secchi disk depths. On its own, the lake's west basin is classified as a deep headwater drainage lake. Secchi disk depths from the west basin are available from 1999-2001 and 2011-2019 (Figure 3.1-9). A t-test (two-sample assuming equal variances) showed that average summer Secchi disk depth was not statistically different between the west basin sampling location (9.1 feet) and the deep hole sampling location (9.3 feet) in years when measurements were taken in the same year. Overall, the west basin's water clarity is excellent for Wisconsin's deep headwater drainage lakes. A decline in water clarity like that observed at the deep hole sampling location has also been observed in recent years within the west basin.

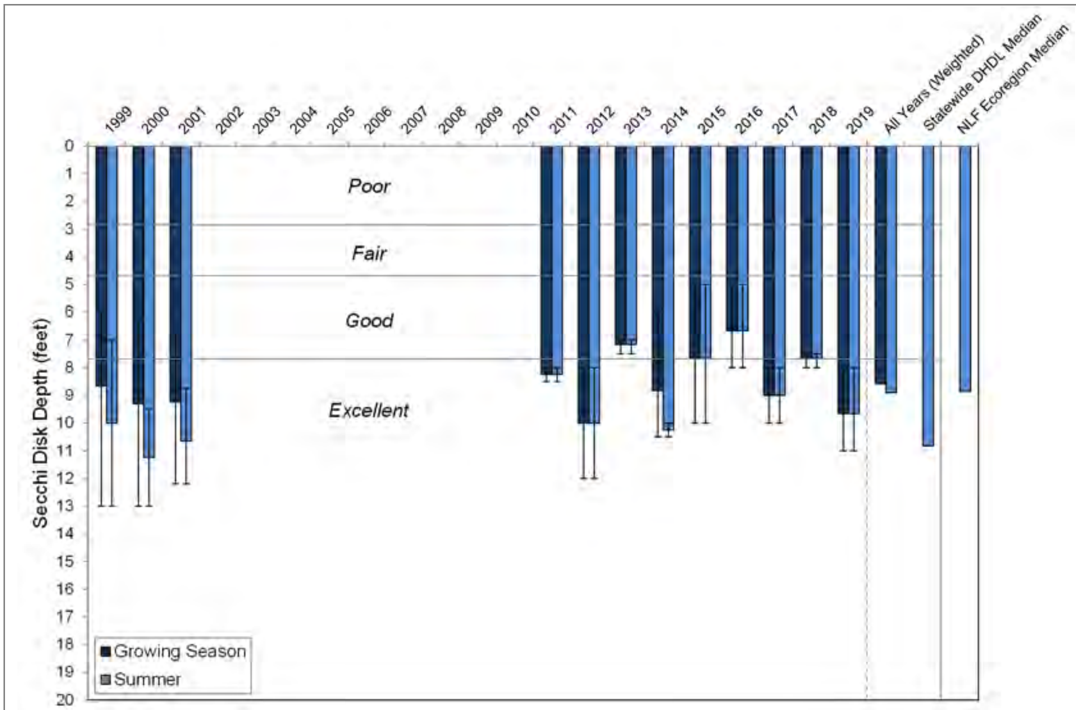


Figure 3.1-9. Shishebogama Lake average annual Secchi disk depth measured at the west basin sampling location and median Secchi disk depth for state-wide deep headwater drainage lakes (DHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values. Water clarity in the west basin is not statistically different from water clarity measured at the deep hole sampling location.

Gunlock Lake Long-term Trends

Total Phosphorus

Near-surface total phosphorus (TP) data from Gunlock Lake are available from 1979, 2000, 2005, 2009, and 2011-2019 (Figure 3.1-10). The weighted summer average TP concentration over this time period is 23.0 µg/L, indicating the lake's TP concentrations are *excellent* for Wisconsin's shallow headwater drainage lakes and *fair* for LDF Tribe criteria. Summer TP concentrations in 2019 were below average and the lowest measured on record at 15.3 µg/L, falling into the *excellent* category for Wisconsin's shallow headwater drainage lakes and *good* category for LDF Tribe criteria. Overall, Gunlock Lake's TP concentrations are lower than the median concentrations for Wisconsin's shallow headwater drainage lakes and slightly higher than the median concentration for all lakes within the NLF ecoregion. Regression analysis indicated that there are no statistically valid trends (positive or negative) in growing season or summer TP concentrations over the period from 2000-2019 in Gunlock Lake. However, there has been a noticeable decreasing trend in TP concentrations from 2015-2019.

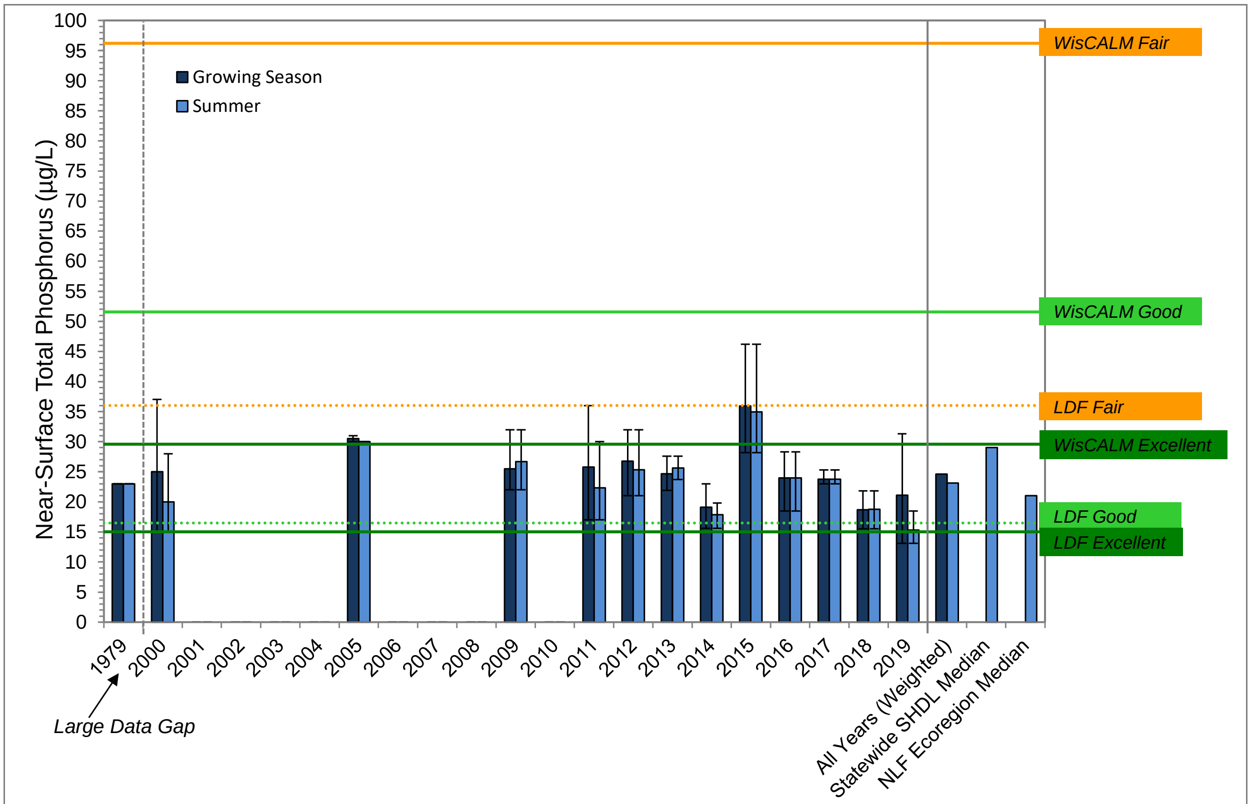


Figure 3.1-10. Gunlock Lake average annual near-surface total phosphorus concentrations and median near-surface total phosphorus concentrations for statewide shallow headwater drainage lakes (SHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Phosphorus criteria for Wisconsin SHDL lakes (WisCALM) and LDF Tribe criteria displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Examination of Gunlock Lake's average near-surface TP concentrations by month shows that concentrations are higher in spring, decline in May, June, and July, and increase in August and into fall (Figure 3.1-11). Like in Shishebogama Lake, this indicates that Gunlock Lake likely experiences internal nutrient loading and the mobilization of phosphorus from bottom waters to the surface. Phosphorus concentrations were measured from bottom waters in Gunlock Lake in

July of 2019. During this sampling event, dissolved oxygen data indicated that the lake had developed an anoxic hypolimnion starting at approximately 15 feet. The TP concentration measured near the bottom was 122.0 µg/L, approximately eight times higher than the concentration of 15.2 µg/L at the surface. This higher near-bottom TP concentration indicates that internal nutrient loading occurs in Gunlock Lake during stratification and the development of an anoxic hypolimnion.

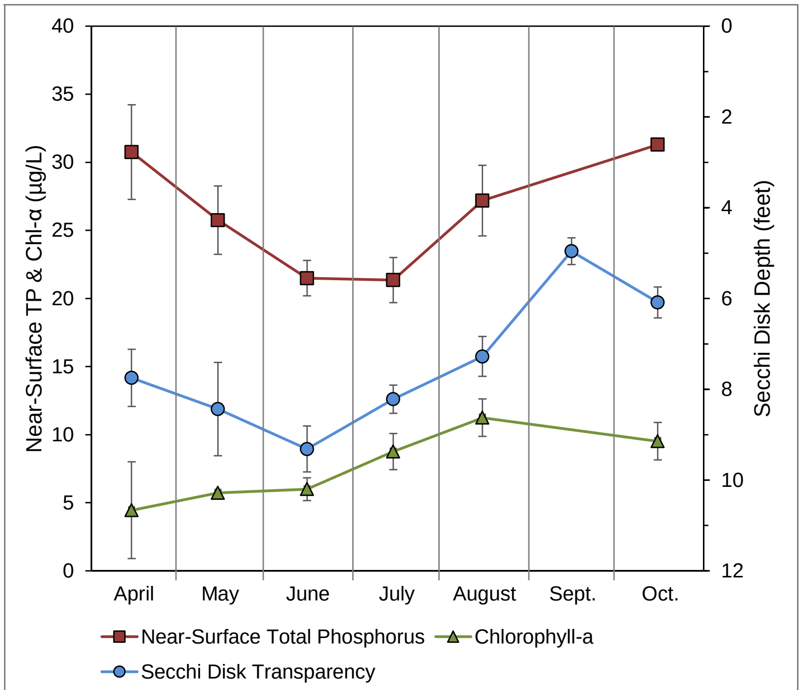


Figure 3.1-11. Gunlock Lake average monthly near-surface total phosphorus, chlorophyll-α, and Secchi disk depth. Monthly averages calculated using available data between 1979 and 2019. Error bars represent standard error.

Current and historical temperature and dissolved oxygen profiles collected from Gunlock Lake's deep hole sampling locations were examined to determine if and how phosphorus from bottom waters may be mobilized to the surface in late summer. These data indicate that like Shishebogama Lake, Gunlock Lake remains stratified throughout the summer (dimictic lake); however, the lake's warmer surface layer of water, the epilimnion, extends to a deeper depth later in the summer. Like in Shishebogama Lake, the erosion of warm surface waters into anoxic bottom waters later in summer mobilizes phosphorus from bottom waters to the surface, and is known as entrainment.

Annual phosphorus concentrations are more variable in Gunlock Lake when compared to those in Shishebogama Lake. This likely has to do with variations in the amount of phosphorus released from bottom sediments and the amount mobilized to surface waters in a given year. This is likely going to be dependent upon the strength and duration of thermal stratification. The longer the lake is thermally stratified with an anoxic hypolimnion, the more phosphorus can be released from bottom sediments and accumulated in bottom waters. The highest phosphorus concentrations on record for Gunlock Lake occurred in 2015. Temperature and dissolved oxygen profiles collected by SGLA volunteers in 2015 indicate the lake had already developed an anoxic hypolimnion in June that is of similar size to what is normally observed in July. Profiles collected in August of

2015 show the epilimnion was then driven deeper, cutting into waters that were anoxic in July. This caused near-surface TP concentrations to increase by 1.5 times between July and August.

Cooler temperatures in the spring of 2019 reduced the onset of thermal stratification and the development of an anoxic hypolimnion in Gunlock Lake. While phosphorus concentrations increased slightly in August due to a deepening of the epilimnion, near-surface concentrations did not increase significantly until fall turnover in October when phosphorus in bottom waters was mixed throughout the water column. Data collected through the ice in the winter of 2020 show that Gunlock Lake develops an anoxic hypolimnion in winter as well. Near-bottom concentrations in winter were approximately two times higher than those measured at the surface, indicating accumulation of phosphorus in bottom waters. During spring turnover, phosphorus in bottom waters is mixed throughout the water column, causing an increase in concentrations measured at the surface in early spring.

It is estimated that on average approximately 130 pounds of phosphorus originate from internal loading during the growing season in Gunlock Lake. While internal loading does not have a significant impact on Shishebogama Lake's water quality, internal loading does appear to affect Gunlock Lake's water quality in years where there is a longer period of thermal stratification and anoxia. The effects of internal nutrient loading appear to be primarily realized in late summer, and in some years, surface TP concentrations are elevated enough to fuel algal growth that is likely visible to lake users. At present, internal nutrient loading is not creating conditions that would result in Gunlock Lake being considered impaired for phosphorus and algae. However, continued monitoring will indicate if the impact of internal nutrient loading on the lake's water quality increases, especially since the duration of thermal stratification is expected to increase in the future with climate change (Kraemer et al. 2015).

Chlorophyll-*a* concentrations, a measure of phytoplankton abundance, are available from Gunlock Lake for the same time period as TP (Figure 3.1-12). The weighted summer average chlorophyll-*a* concentration over this period is 8.5 µg/L, indicating the lake's chlorophyll-*a* concentrations are *excellent* for Wisconsin's shallow headwater drainage lakes and *fair* for LDF Tribe lakes criteria. Summer chlorophyll-*a* concentrations in 2019 were below average with a concentration of 5.9 µg/L, falling into the *excellent* category for Wisconsin's deep lowland drainage lakes and the *good* category for LDF Tribal lakes.

Overall, Gunlock Lake's chlorophyll-*a* concentrations are higher than median concentrations for Wisconsin's shallow headwater drainage lakes and all lake types within the NLF ecoregion. Regression analysis indicated that there are no statistically valid trends (positive or negative) in growing season or summer chlorophyll-*a* concentrations over the period from 2000-2019 in Gunlock Lake. As discussed earlier, chlorophyll-*a* concentrations are often positively correlated with TP concentrations. Like TP, chlorophyll-*a* concentrations in Gunlock Lake tend to increase later in the summer and are highest in August as phosphorus from bottom waters is mobilized to the surface (Figure 3.1-11).

Water clarity monitoring using Secchi disk depths has been conducted at Gunlock Lake's deep hole sampling location in 1979, 1990-1994, and 2008-2019 (Figure 3.1-13). Average summer Secchi disk depths have ranged from 12.0 feet in 2014 to 5.7 feet in 2015. The weighted summer average Secchi disk depth over this time period is 8.3 feet, indicating Gunlock Lake's water clarity is *excellent* for Wisconsin's shallow headwater drainage lakes. On average, Gunlock Lake's average summer Secchi disk depth is 1.5 times lower when compared to Shishebogama Lake. Summer Secchi disk depths in 2019 were the same as the long-term average at 8.3 feet. Overall, Gunlock Lake's Secchi disk depths are higher than median depths for other shallow headwater drainage lakes in Wisconsin and slightly lower than the median depth for all lake types within the NLF ecoregion.

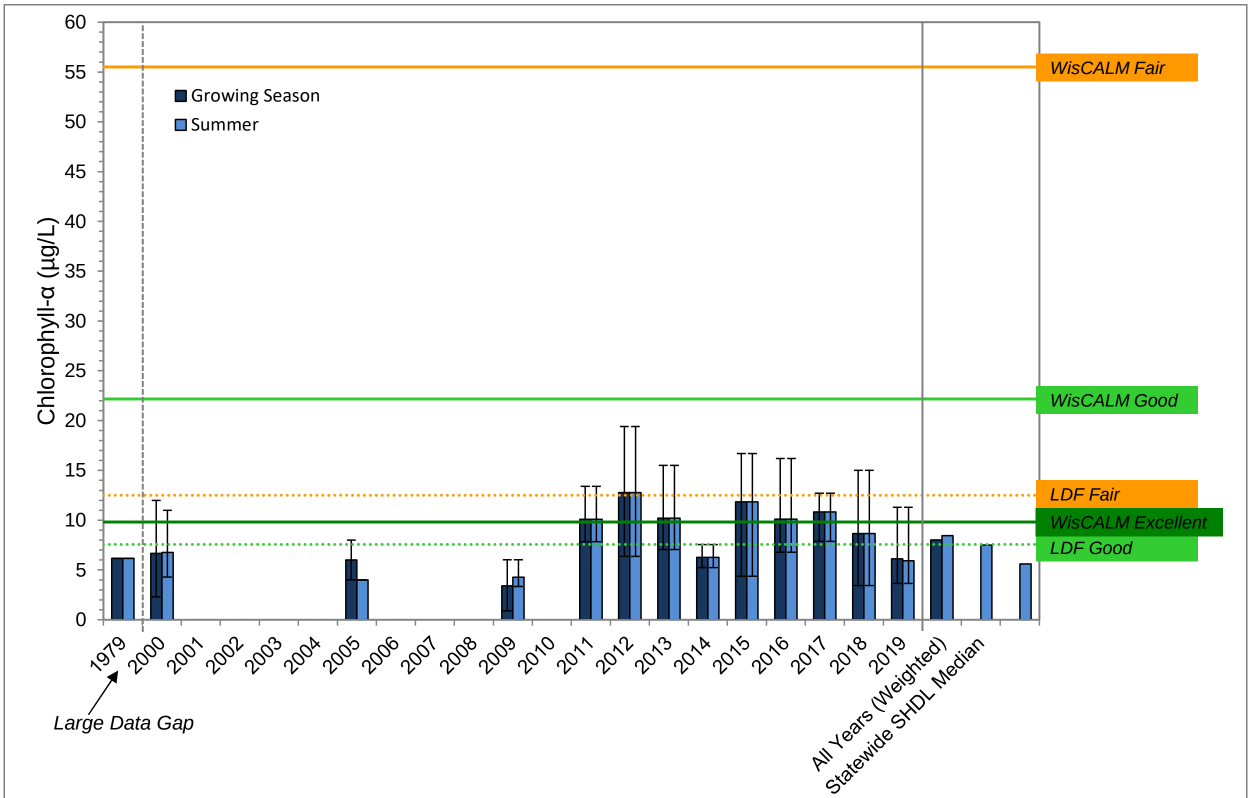


Figure 3.1-12. Gunlock Lake average annual chlorophyll-α concentrations and median chlorophyll-α concentrations for statewide shallow headwater drainage lakes (SHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Chlorophyll-α criteria for Wisconsin SHDL lakes (WisCALM) and LDF Tribe criteria displayed at right. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Examination of Secchi disk depths by month over the course of the growing season shows that Gunlock Lake's water clarity fluctuates on average by over four feet (Figure 3.1-11). In spring, average Secchi disk depth is around 8.0 feet and increases to a maximum of 9.3 feet in June. Water clarity then declines by approximately 4.0 feet from July to September, corresponding with increases in algal abundance. The phosphorus which is mobilized from bottom waters to the surface in late summer and early fall causes an increase in phytoplankton production (chlorophyll-*a*), and the increased level of phytoplankton production reduces light penetration and water clarity.

While Shishebogama Lake has seen a decreasing trend in water clarity from 2002-2019, Secchi disk transparency data are not available from Gunlock Lake between 2002-2007. The data that are available indicate that average summer Secchi disk depth from 1990-1994 was 9.1 feet compared to 7.9 feet from 2008-2019, indicating lower water clarity in the most recent decade. Chlorophyll-*a* concentrations are not available from 1990-1994, so it cannot be said if chlorophyll-*a* concentrations have changed over this time period. However, as discussed with Shishebogama Lake, it is likely that dissolved organic materials (DOM) have also increased in Gunlock Lake as a result of higher precipitation, decreasing water clarity. True color measurements made in 2019 indicated Gunlock Lake's water was *slightly tea-colored*, indicating some influence on water clarity by DOM.

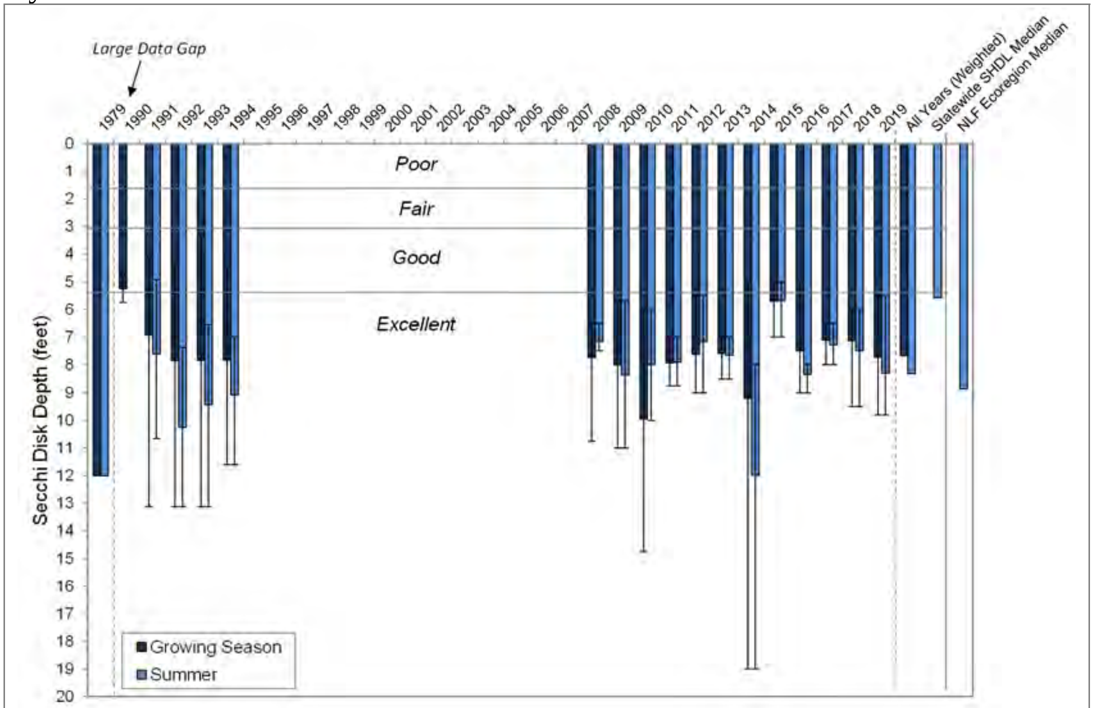


Figure 3.1-13. Gunlock Lake average annual Secchi disk depth measured at the deep hole sampling location and median Secchi disk depth for state-wide shallow headwater drainage lakes (SHDL) and Northern Lakes and Forests (NLF) ecoregion lakes. Water Quality Index values adapted from WDNR PUB WT-913. Error bars represent maximum and minimum values.

Limiting Plant Nutrient of Shishebogama and Gunlock Lakes

Using mid-summer nitrogen and phosphorus concentrations from Shishebogama and Gunlock Lakes, a nitrogen:phosphorus ratios of 25:1 and 22:1 were calculated, respectively. This indicates that both Shishebogama and Gunlock lakes are phosphorus limited, as are the majority of Wisconsin's lakes. In general, this means that phosphorus is the primary nutrient regulating algal growth within the lake, and increases in phosphorus will likely result in increased algal production and lower water clarity. Conservation of the water quality of these lakes means limiting anthropogenic sources of phosphorus to these lakes (i.e., shoreland development, septic systems, etc.).

Shishebogama and Gunlock Lakes Trophic State

The Trophic State Index (TSI) values for Shishebogama and Gunlock lakes were calculated using summer near-surface total phosphorus, chlorophyll-*a*, and Secchi disk transparency data collected as part of this project along with historical data (Figures 3.1-14). In general, the best values to use in judging a lake's trophic state are the biological parameters of total phosphorus and chlorophyll-*a* as Secchi disk transparency can be influenced by factors (e.g., DOM) other than algae. The data indicate that Shishebogama Lake has fluctuated between lower mesotrophic and lower eutrophic states. The weighted average indicates that Shishebogama Lake can be classified as a mesotrophic system. Shishebogama Lake has lower productivity when compared to other deep lowland drainage lakes in Wisconsin and all lake types within the NLF ecoregion.

The TSI analysis for Gunlock Lake indicates that it has fluctuated between mesotrophic and lower eutrophic states. The weighted average indicates Gunlock Lake can be classified as a lower eutrophic or upper mesotrophic system. Gunlock Lake is of similar productivity when compared to other shallow headwater drainage lakes in Wisconsin and of higher productivity when compared to all lake types within the NLF ecoregion.

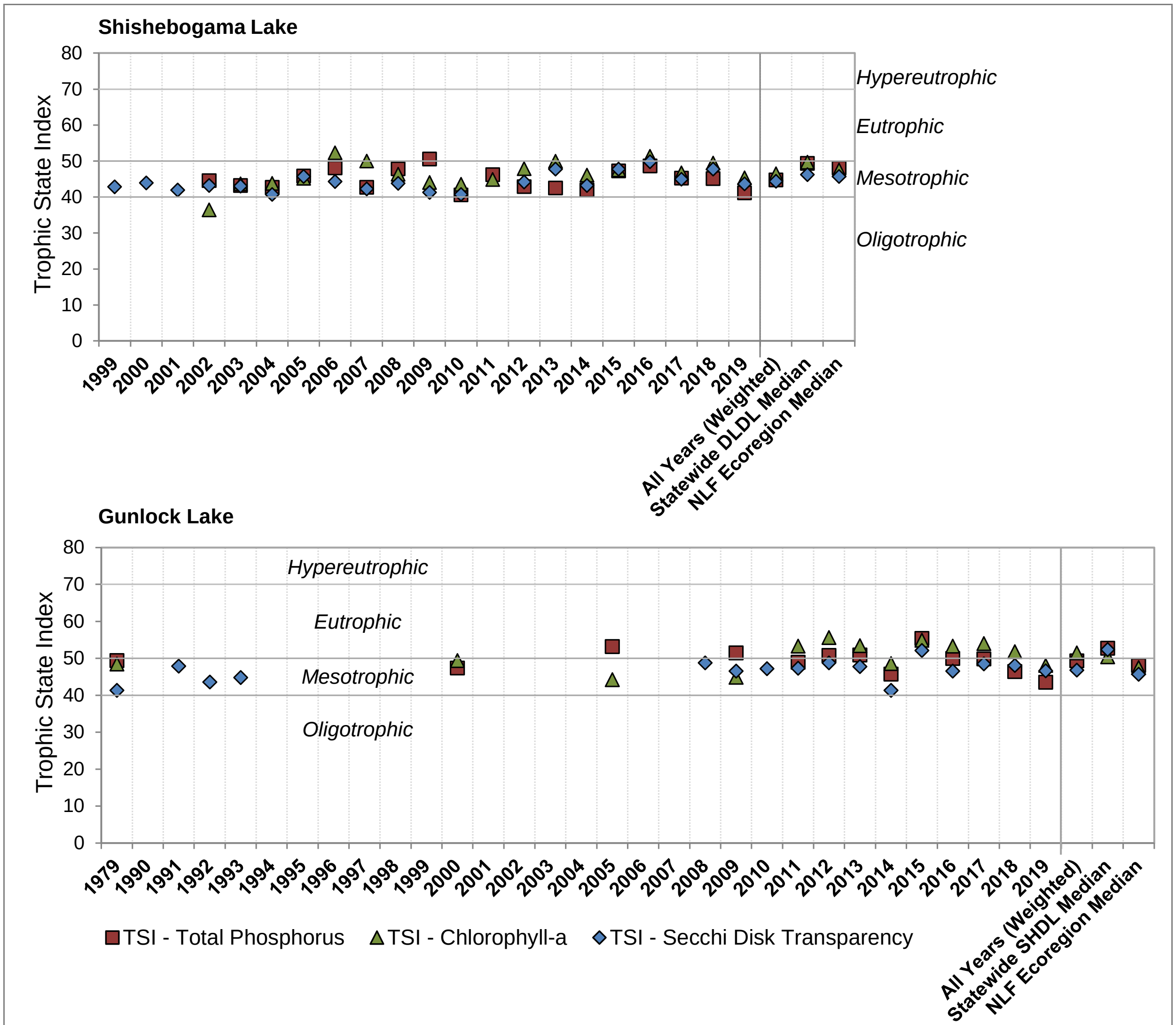


Figure 3.1-14. Shishebogama and Gunlock lakes Trophic State Index (TSI). Values calculated with summer month surface sample data using WDNR PUB-WT-193.

Dissolved Oxygen and Temperature in Shishebogama Lake

Dissolved oxygen and temperature profiles were collected by a combination of Onterra ecologists and SGLA volunteers on a monthly basis during the growing season of 2019 and in February 2020 (Figure 3.1-15). These profiles show that both Shishebogama and Gunlock lakes are dimictic, meaning they remain stratified during the summer (and winter) and completely mix, or turn over, two times per year – once in spring and once in fall. Temperature profiles collected in May of 2019 show both lakes were beginning to thermally stratify with an epilimnion and a large metalimnion extending to the bottom. By June, both lakes had developed defined epilimnion, metalimnion, and hypolimnion layers. In July, both lakes had developed anoxic conditions within the hypolimnion. In August, the epilimnions of both lakes had deepened, cutting into the metalimnion and hypolimnion below.

In the fall, as surface temperatures cool, the entire water column is again able to mix, which re-oxygenates the hypolimnion. Both lakes experienced fall turnover by October as indicated by uniform temperatures and dissolved oxygen from the surface to the bottom. During the winter, the coldest temperatures are found just under the overlying ice as water is densest at 39°F, while oxygen gradually declines once again towards the bottom of the lake. In February under the ice, both lakes were inversely stratified with the coldest water with a temperature of near freezing closest to the surface and the warmest water near 40°F near the bottom. Shishebogama Lake had anoxic conditions between 30-40 feet, while Gunlock Lake had anoxic conditions between 13-25 feet. Both lakes support sufficient oxygen throughout the water column in winter, and the probability of winter fish kills in these lakes due to anoxia is likely very low.

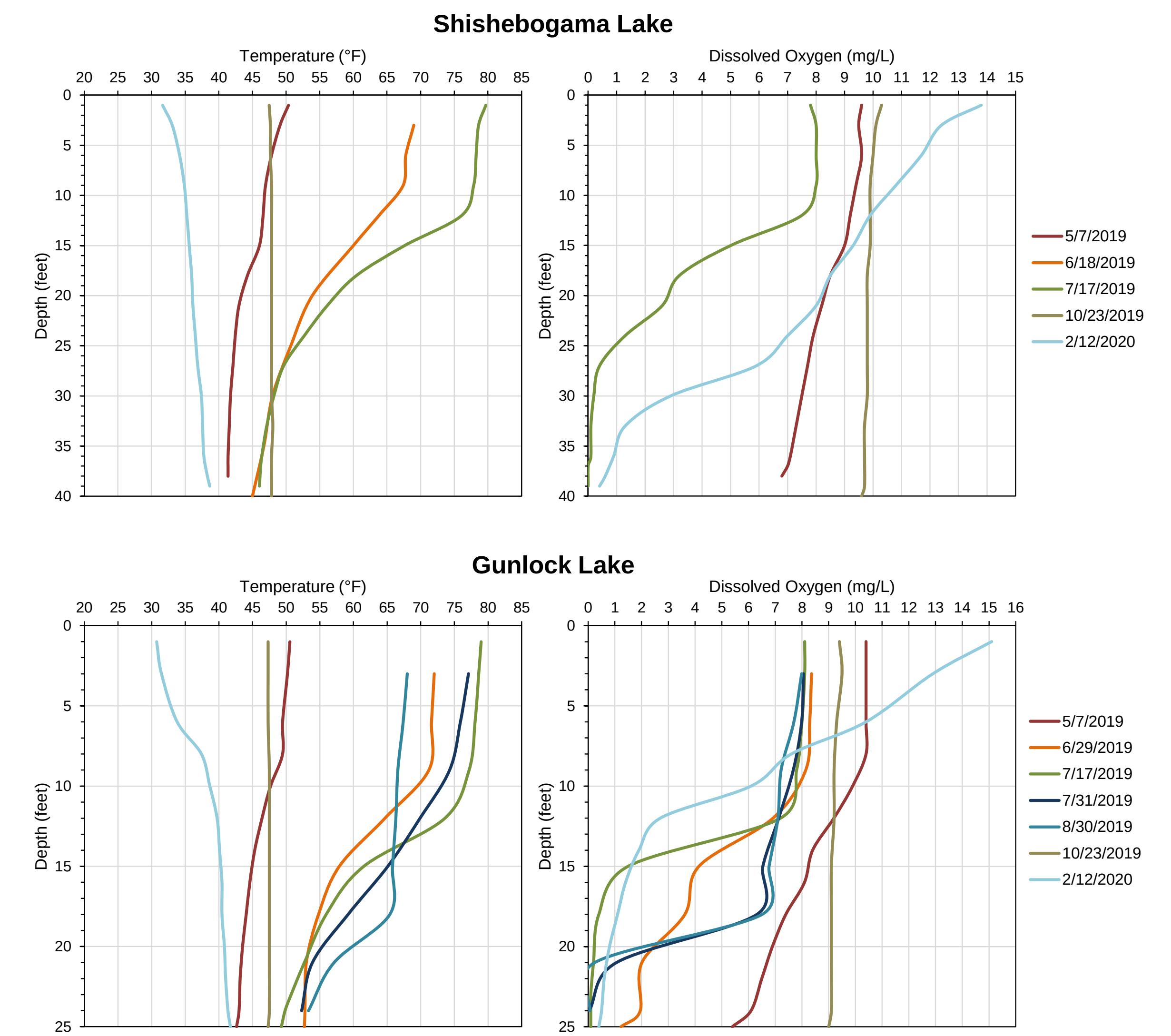


Figure 3.1-15. Shishebogama and Gunlock lakes 2019/20 temperature and dissolved oxygen profiles. Data were collected from each lakes' deep hole sampling location. Data collected by SGLA volunteers and Onterra ecologists.

Additional Water Quality Data Collected at Shishebogama Lake

The water quality section is centered on lake eutrophication. However, parameters other than water clarity, nutrients, and chlorophyll-*a* were collected as part of the project. These other parameters were collected to increase the understanding of Shishebogama Lake's water quality and are recommended as a part of the WDNR long-term lake trends monitoring protocol. These parameters include pH, alkalinity, and calcium.

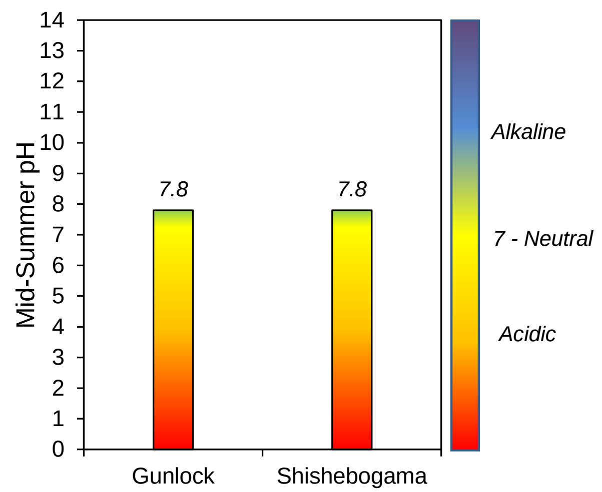


Figure 3.1-16. Shishebogama and Gunlock lakes 2019 mid-summer near-surface pH values.

The pH scale ranges from 0 to 14 and indicates the concentration of hydrogen ions (H^+) within the lake's water and is an index of the lake's acidity. Water with a pH value of 7 has equal amounts of hydrogen ions and hydroxide ions (OH^-) and is considered to be neutral. Water with a pH of less than 7 has higher concentrations of hydrogen ions and is considered to be acidic, while values greater than 7 have lower hydrogen ion concentrations and are considered basic or alkaline. The pH scale is logarithmic; meaning that for every 1.0 pH unit the hydrogen ion concentration changes tenfold. The normal range for lake water pH in Wisconsin is about 5.2 to 8.4, though values lower than 5.2 can be observed in some acid bog lakes and higher than 8.4 in some marl lakes. In lakes with a pH of 6.5 and lower, the spawning of certain fish species such as walleye becomes inhibited (Shaw & Nimphius, 1985). The mid-summer pH of the water in Shishebogama and Gunlock lakes was found to be slightly alkaline with a value of 7.8 and falls within the normal range for Wisconsin Lakes (Figure 3.1-16).

Alkalinity is a lake's capacity to resist fluctuations in pH by neutralizing or buffering against inputs such as acid rain. The main compounds that contribute to a lake's alkalinity in Wisconsin are bicarbonate (HCO_3^-) and carbonate (CO_3^-), which neutralize hydrogen ions from acidic inputs. These compounds are present in a lake if the groundwater entering it comes into contact with minerals such as calcite ($CaCO_3$) and/or dolomite ($CaMgCO_3$). A lake's pH is primarily determined by the amount of alkalinity. Rainwater in northern Wisconsin is slightly acidic naturally due to dissolved carbon dioxide from the atmosphere with a pH of around 5.0. Consequently, lakes with low alkalinity have lower pH due to their inability to buffer against acid inputs. The alkalinity in Shishebogama and Gunlock lakes was measured at 37.5 and 36.5 (mg/L as $CaCO_3$), respectively, indicating that both lakes have sufficient buffering capacity to resist fluctuations in pH and are not sensitive to acid rain (Figure 3.1-17). Like most lakes in northern Wisconsin, Shishebogama and Gunlock lakes are considered softwater lakes.

Like associated pH and alkalinity, the concentration of calcium within a lake's water depends on the geology of the lake's watershed. Recently, the combination of calcium concentration and pH has been used to determine what lakes can support zebra mussel populations if they are introduced. The commonly accepted pH range for zebra mussels is 7.0 to 9.0, so Shishebogama and Gunlock lakes' pH of 7.8 falls within this range. Lakes with calcium concentrations of less than 12 mg/L are considered to have very low susceptibility to zebra mussel establishment. The calcium concentration of Shishebogama and Gunlock lakes was found to be 11.8 and 11.4 mg/L, respectively, indicating both lakes have very low susceptibility to zebra mussel establishment (Figure 3.1-17).

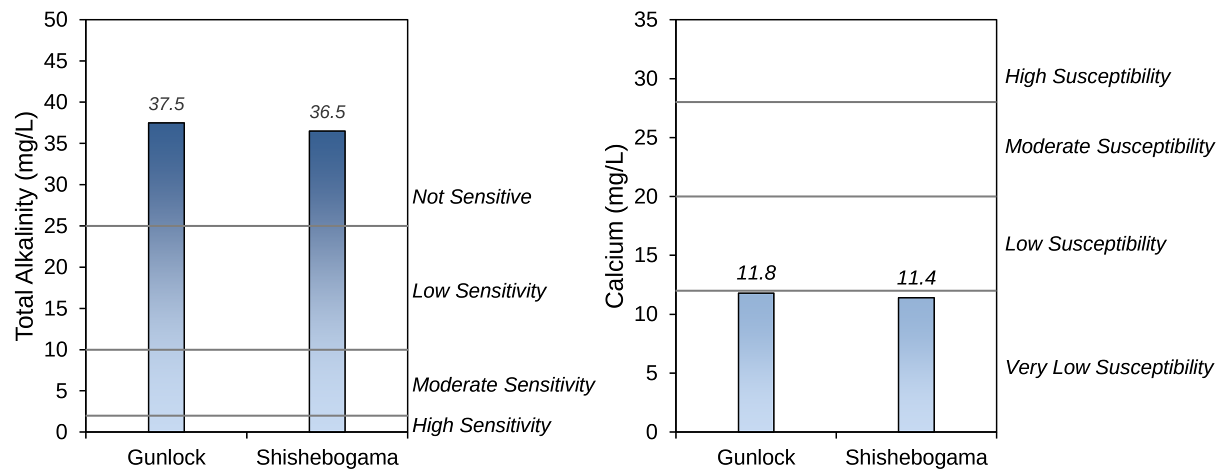


Figure 3.1-17. Shishebogama and Gunlock lakes 2019 total alkalinity and sensitivity to acid rain (left), and calcium concentrations and susceptibility to zebra mussel establishment (right). Samples collected from the near-surface deep hole sampling locations.

Zebra mussels (*Dreissena polymorpha*) are small bottom dwelling mussels, native to Europe and Asia, that found their way to the Great Lakes region in the mid-1980s. They are thought to have come into the region through ballast water of ocean-going ships entering the Great Lakes, and they have the capacity to spread rapidly. Zebra mussels can attach themselves to boats, boat lifts, and docks, and can live for up to five days after being taken out of the water. These mussels can be identified by their small size, D-shaped shell and yellow-brown striped coloring.

Once zebra mussels have entered and established in a waterway, they are nearly impossible to eradicate. Best practice methods for cleaning boats that have been in zebra mussel infested waters is inspecting and removing any attached mussels, spraying your boat down with diluted bleach, power-washing, and letting the watercraft dry for at least five days. Plankton tows were completed by Onterra ecologists in Shishebogama and Gunlock lakes in 2019 that underwent analysis for the presence of zebra mussel veligers, their planktonic larval stage. Analysis of these samples were negative for zebra mussel veligers, and Onterra ecologists did not observe any adult zebra mussels during the 2019 surveys. Samples were also collected from Gunlock Lake in 2009 and Shishebogama Lake in 2009 and 2010 for zebra mussel veligers, and samples from both lakes were negative.

As previously discussed, a measure of water clarity once all of the suspended material (i.e., phytoplankton and sediments) have been removed, is termed *true color*, and measures how the clarity of the water is influenced by dissolved components. True color was measured at 20 and 15 SU in Shishebogama and Gunlock lakes in 2019, indicating their water is *slightly* to *lightly tea-colored* (Figure 3.1-18). It is important to note that the brown coloring in these lakes is natural and common in drainage lakes in northern Wisconsin and is not an indication of degraded conditions. The concentration of these humic substances and resulting water clarity will fluctuate with changes in precipitation.

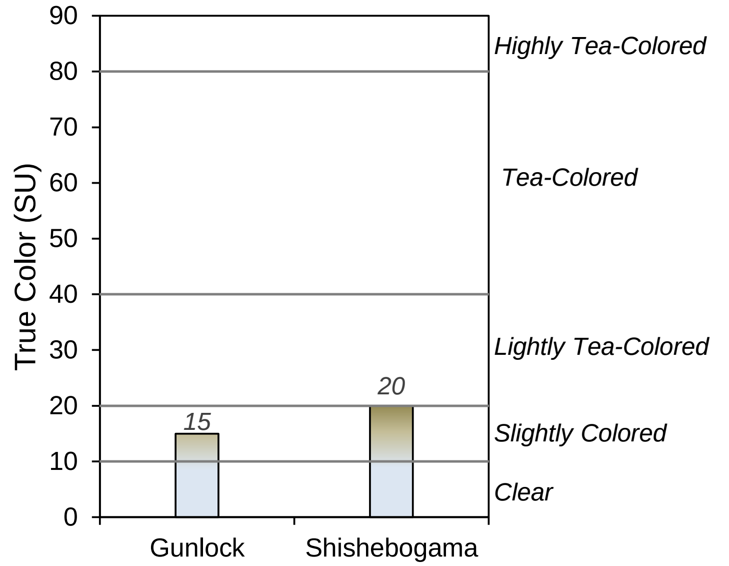


Figure 3.1-18. Shishebogama and Gunlock lakes 2019 true color values.

Stakeholder Survey Responses to Shishebogama and Gunlock Lakes Water Quality

In 2020, a stakeholder survey was sent to 1,892 Shishebogama and Gunlock lake riparian property owners and LDF Tribe members. Fourteen percent (272) of these surveys were completed and returned. Given the low response rate, the results of the stakeholder survey cannot be interpreted as being statistically representative of the population sampled. At best, the results may indicate possible trends and opinions about the stakeholder perceptions of these lakes but cannot be stated with statistical confidence. The full survey and results can be found in Appendix B.

When asked about Shishebogama and Gunlock lakes' current water quality, 75% of the respondents indicated the water quality is good or excellent, 11% indicated the water quality is fair, 3% indicated water quality is poor, and 11% were unsure (Figure 3.1-19). Stakeholder perceptions of these lakes having excellent to good water quality at present aligns with the water quality data discussed previously.

When asked how the water quality of Shishebogama and Gunlock lakes has changed since they first visited the lake, 51% indicated water quality has remained the same, 22% indicated water quality has somewhat degraded, 9% indicated water quality has somewhat improved, 3% indicated it has severely degraded, and 15% were unsure (Figure 3.1-20). These stakeholder responses also align with the trends that have been observed within the available water quality dataset. The water quality on both of these lakes has largely remained the same; however, water clarity has seen measurable declines in recent years, likely due to increases in dissolved organic matter.

The stakeholder survey indicated that 89% of respondents think of water clarity first when describing water quality. The larger proportion of respondents who indicated water quality has gotten somewhat worse have likely noticed the recent decline in water clarity. While this change may be perceived as degradation of water quality, as is discussed further in this section, these changes in water quality are believed to be largely driven by increases in precipitation in recent years and not the result of anthropogenic activity in the watershed.

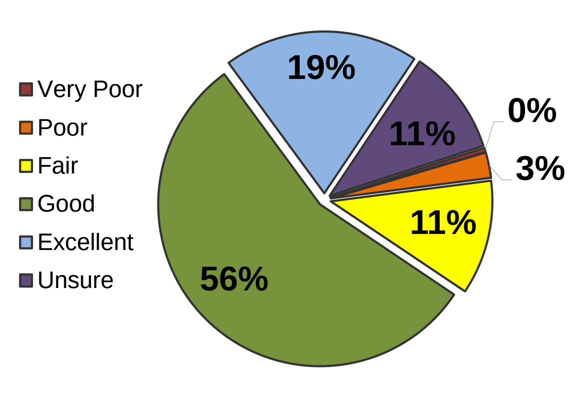


Figure 3.1-19. Stakeholder survey response Question #21. How would you describe the current water quality of Shishebogama and Gunlock Lakes?

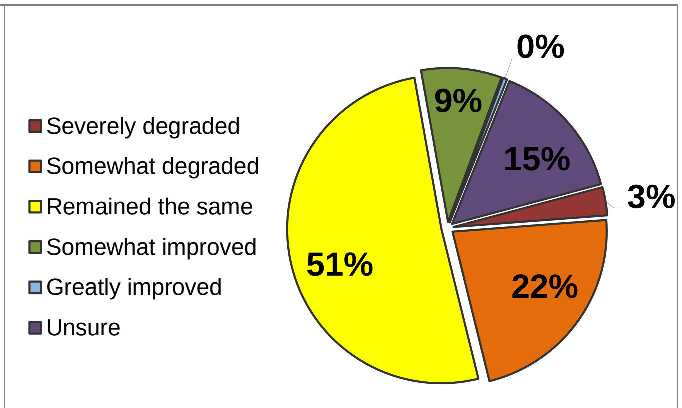


Figure 3.1-20. Stakeholder survey response Question #22. How as the water quality changed in Shishebogama and Gunlock Lakes since you first visited the lake?

3.2 Watershed Assessment

Two aspects of a lake's watershed are the key factors in determining the amount of phosphorus the watershed exports to the lake: 1) the land cover (land use) within the watershed and 2) the size of the watershed. The type of land cover and the amount of that land cover that exists in the watershed is largely going to determine the amount of phosphorus (and sediment) that runs off the land and eventually makes its way to the lake. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Areas within a lake's watershed that are naturally vegetated (e.g., forests, grasslands, and wetlands) strongly influence the way water behaves on the land surface after it falls as precipitation or is released by the melting of snow (Silk & Ciruna, 2005).

Runoff is slowed down in areas with denser vegetation and increases the time it takes for precipitation from a storm event to reach the lake. This allows more water to soak into the soil and reduces the potential for flooding. Intact wetlands within a lake's watershed have been likened to the "kidneys of the landscape" as they filter out nutrients, sediments, and other pollutants from water which passes through them (Silk & Ciruna, 2005). The water quality within a lake is largely a reflection of the health of its watershed, and maintaining natural land cover within a lake's watershed is essential for maintaining good water quality.

Among the largest threats to a lake's water quality is the conversion of natural areas to agriculture and urban development. Conversion of natural areas to agriculture disrupts the hydrologic regime and increases surface runoff due to increased soil compaction and reduced water infiltration. Wetlands which were drained and converted to farmland were shown to increase runoff by 200-400% (Silk & Ciruna, 2005). Agriculture accounts for 60% of the pollutants in lakes and rivers in the United States due to increased runoff in combination with the application of fertilizers, pesticides, and manure.

Similar to agriculture, urban development can significantly alter the hydrologic regime within a watershed, primarily through the installation of impervious surfaces (e.g., roads, driveways, roof-tops) which decrease water infiltration and increase runoff. As impervious surface cover increases, the time it takes water from a storm event to reach the lake decreases. With the increase in water velocity and volume entering the water body, nutrient and sediment input also increase, degrading water quality. Nutrient input can also increase from urban areas as the result of fertilizer application, wastewater treatment facilities, and other industrial activities.

As is discussed further in this section, Shishebogama and Gunlock lakes' watersheds are largely comprised of intact forests and wetlands with minimal amounts of human development. In the forested watersheds of northern Wisconsin where soils and climate are not as conducive for farming, apart from shoreland development (discussed in the next section) forestry or timber harvest likely represents the largest man-made disturbance occurring in these watersheds. While timber harvest has the potential to increase sediment erosion through the removal of vegetation and construction of access roads and bridges, the impacts of timber harvest to a lake's water quality are going to be highly dependent upon harvest rates and methods, vegetation management, and the location and size of these activities within the watershed (Silk & Ciruna, 2005). Wisconsin is required by federal law to develop and implement a program of best management practices (BMPs) to reduce nonpoint source pollution, including from timber harvesting activities (WDNR PUB FR-

093 2010). In summary, any forestry activities within the watersheds of these lakes are being implemented under this framework and should not impart significant impacts to these lakes.

In addition to land cover within the watershed, the size of the watershed relative to the water volume within the lake also influences water quality. The watershed to lake area ratio (WS:LA) defines how many acres of watershed drain to each surface-acre of the lake. Larger ratios result in the watershed having a greater role in the lake's annual water budget and phosphorus load. In systems with lower WS:LA ratios, land cover type plays a very important role in how much phosphorus is loaded to the lake from the watershed. In these systems, the occurrence of agriculture or urban development in even a small percentage of the watershed (less than 10%) can unnaturally elevate phosphorus inputs to the lake. If these land cover types are converted to a cover that does not export as much phosphorus, such as converting row crop areas to grasslands or forested areas, the phosphorus load and its impacts to the lake may be decreased. In fact, if the phosphorus load is reduced greatly, changes in lake water quality may be noticeable, (e.g., reduced algal abundance and better water clarity) and may even be enough to cause a shift in the lake's trophic state.

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

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

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

Watershed Modeling

A reliable and cost-efficient method of creating a general picture of a watershed's effect on a lake can be obtained through modeling. The WDNR created a useful suite of modeling tools called the Wisconsin Lake Modeling Suite (WiLMS). Certain morphological attributes of a lake and its watershed are entered into WiLMS along with the acreages of different types of land cover within the watershed to produce useful information about the lake ecosystem. This information includes an estimate of annual phosphorus load and the partitioning of those loads between the watershed's different land cover types and atmospheric fallout entering through the lake's water surface.

WiLMS also calculates the lake's flushing rate and residence times using county-specific average precipitation/evaporation values or values entered by the user. Predictive models are also included within WiLMS that are valuable in validating modeled phosphorus loads to the lake in question and modeling alternate land cover scenarios within the watershed. Finally, if specific information is available, WiLMS will also estimate the significance of internal nutrient loading within a lake and the impact of shoreland septic systems.

Shishebogama and Gunlock Lakes Watershed Assessment

The watershed for the entire Shishebogama-Gunlock lakes system encompasses approximately 4,254 acres or 6.6 square miles across Oneida and Vilas counties (Figure 3.2-1 and Map 2), and is considered a headwater system within the Upper Wisconsin River Watershed. Gunlock Lake's watershed, which is a subwatershed of Shishebogama Lake's watershed, encompasses approximately 1,005 acres or 1.5 square miles in Vilas County. Water from Gunlock Lake flows south into Shishebogama Lake. Water from Shishebogama Lake flows south via Shishebogama Creek and into the Tomahawk River, which ultimately flows into the Wisconsin River.

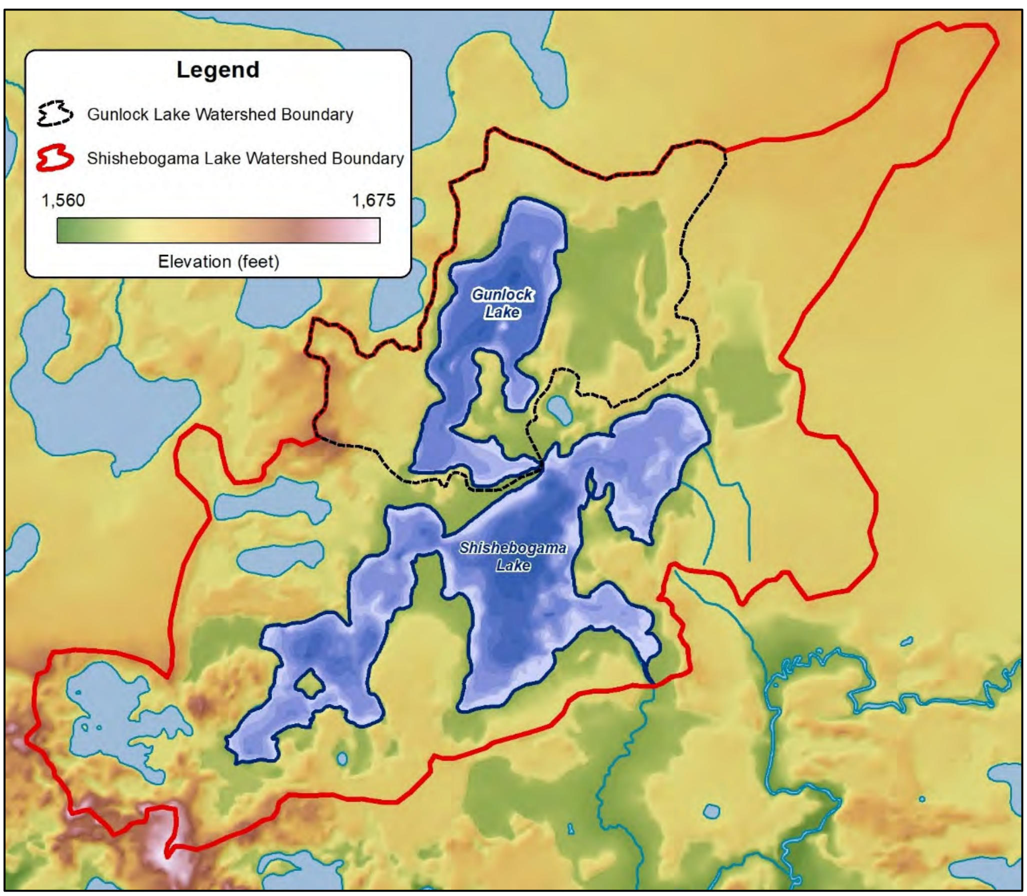


Figure 3.2-1. Shishebogama and Gunlock lakes watershed and land elevation.

Wisconsin Lakes Modeling Suite (WiLMS) estimated that Shishebogama Lake has a water residence time of 2.6 years, while Gunlock Lake has an estimated water residence time of 3.3 years. In other words, the water is completely replaced on average in Shishebogama Lake once every 2.6 years and once every 3.3 years in Gunlock Lake.

Shishebogama Lake's watershed is comprised of wetlands (30%), the Gunlock Lake subwatershed (24%), upland forests (22%), the lake's surface itself (16%), pasture/grass/rural open space (6%), and rural residential areas (2%) (Figures 3.2-2 and 3.2-3). Gunlock Lake's watershed is comprised of upland forests (34%), wetlands (29%), the lake's surface itself (26%), pasture/grass/rural open space (8%), and rural residential areas (3%) (Figures 3.2-2 and 3.2-3).

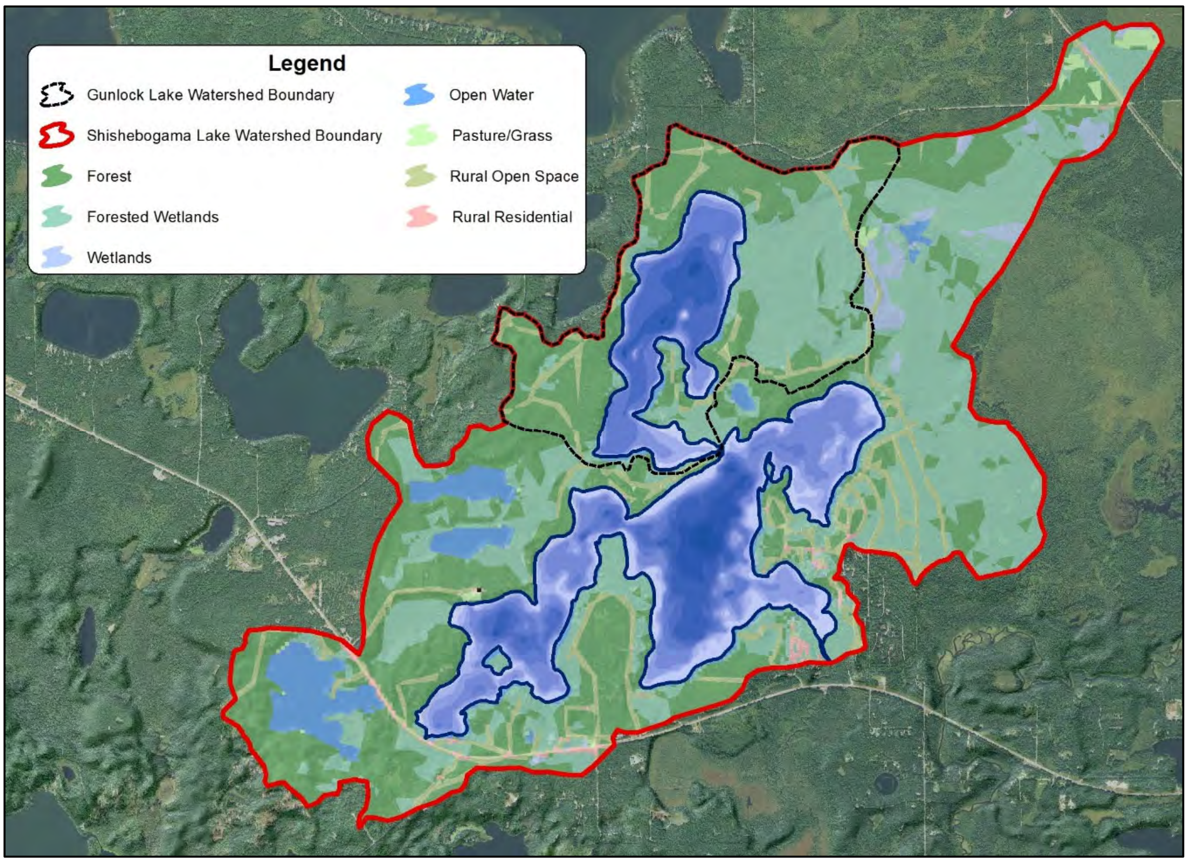


Figure 3.2-2. Shishebogama and Gunlock lakes watershed and land cover types. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

Using the land cover types and their acreages within the Shishebogama and Gunlock lakes watersheds, WiLMS was utilized to estimate the annual potential phosphorus load delivered to each lake. In addition, data obtained from a stakeholder survey distributed in 2020 was also used to estimate the potential phosphorus loading to the lake from riparian septic systems. The model estimated that approximately 123 pounds of phosphorus are loaded to Gunlock Lake on an annual basis from its watershed (Figure 3.2-4). Based on this estimated annual loading of phosphorus, WiLMS predicted that the in-lake average growing season total phosphorus concentrations should be 16.6 µg/L. However, the average measured growing season total phosphorus concentration in Gunlock Lake is 24.7 µg/L, nearly 50% higher than predicted. This indicates that there is a significant source of phosphorus being loaded to Gunlock Lake that was not accounted for in the model.

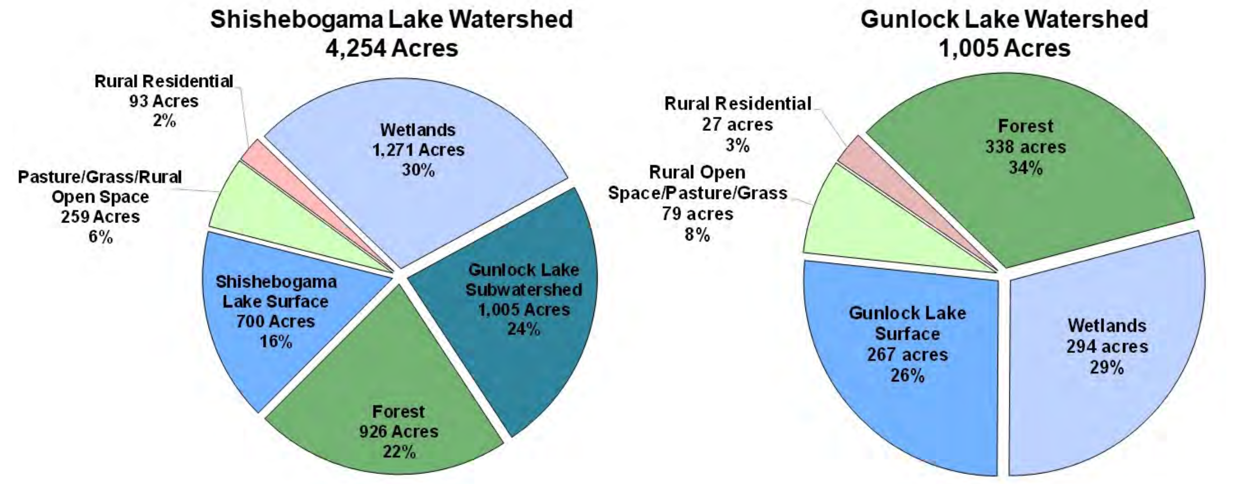


Figure 3.2-3. Proportion of land cover types within Shishebogama and Gunlock lakes' watersheds. Based upon National Land Cover Database (NLCD – Fry et. al 2011).

As is discussed in the previous Lake Water Quality Section (Section 3.1), this unaccounted source of phosphorus in Gunlock Lake is believed to be from internal phosphorus loading, or the release of phosphorus from anoxic bottom sediments. To achieve the measured growing season total phosphorus concentration of 24.7 µg/L, WiLMS estimates that approximately 100 pounds of additional phosphorus are being loaded to Gunlock Lake annually. This estimate aligns well with the estimated 130 pounds of phosphorus that originate from internal nutrient loading using the water quality data. In total, it is estimated that over 200 pounds of phosphorus are loaded to Gunlock Lake annually from internal and external sources. However, the amount of phosphorus originating from internal nutrient loading can vary from year to year depending on the strength and duration of thermal stratification.

WiLMS estimates that 44% of the annual phosphorus load in Gunlock Lake originates from internal nutrient loading, 19% from direct atmospheric deposition onto the lake's surface, 12% from wetlands, 12% from upland forests, 10% from rural open space/pasture/grasslands, 2% from riparian septic systems, and 1% from rural residential areas (Figure 3.2-4).

For Shishebogama Lake, Gunlock Lake was loaded in the WiLMS model as a point-source given that actual phosphorus measurements were collected from the lake. The "Water and Nutrient Outflow" feature in WiLMS was used to estimate how much phosphorus was exported from Gunlock Lake to Shishebogama Lake on an annual basis (based on measured phosphorus and predicted outflow). Modeling Gunlock Lake in this way would account for phosphorus that was internally loaded in Gunlock Lake and delivered to Shishebogama Lake.

WiLMS estimated that Shishebogama Lake receives an estimated 466 pounds of phosphorus from its watershed on an annual basis (Figure 3.2-4). Based on this estimated phosphorus load, WiLMS predicted an in-lake average growing season total phosphorus concentration of 16.1 µg/L, slightly under the measured 17.6 µg/L. To achieve an estimated growing season concentration of 17.6 µg/L, WiLMS estimates that 60 pounds of additional phosphorus need to be loaded to

Shishebogama Lake annually. Like with Gunlock Lake, this additional phosphorus is believed to be originating from internal nutrient loading. With external and internal loading together, it is estimated that 526 pounds of phosphorus are loaded to Shishebogama Lake on average every year.

Of the 526 pounds, 21% is estimated to originate from wetlands, 21% from atmospheric deposition onto the lake's surface, 14% from upland forests, 13% from rural open space/pasture/grass, 12% from the Gunlock Lake subwatershed, 11% from internal nutrient loading, 6% from riparian septic systems, and 2% from rural residential areas (Figure 3.2-4).

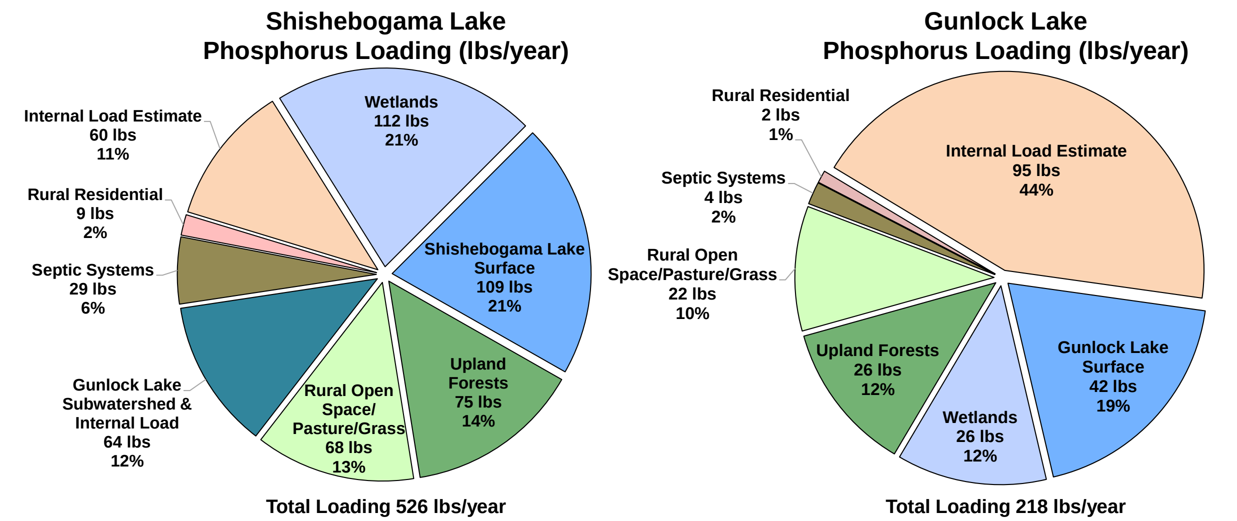


Figure 3.2-4. Shishebogama and Gunlock lakes estimated annual phosphorus loading. Based upon Wisconsin Lake Modeling Suite (WiLMS) estimates.

It is important to note that a failing septic system may not necessarily be impacting the lake if it is located in an area where groundwater is leaving the lake, while a properly functioning septic system may impact the lake if groundwater is passing through it and into the lake. The septic estimates for Shishebogama and Gunlock lakes did not take into account the location of the septic systems and flow of groundwater into and out of these lakes. While it is important that riparians with septic systems conduct routine maintenance and inspections, this analysis indicates that septic systems around these lakes are likely not having a detectable impact on water quality at this time.

Using the WiLMS models, hypothetical changes can be made to the watersheds of these lakes to determine how their water quality would be predicted to change. For example, if 25% of the forests within Shishebogama Lake's watershed were converted to pasture/grassland, WiLMS estimates that phosphorus loading would increase by over 60 pounds. This would result in an increase in phosphorus concentrations to around 19 µg/L, causing an increase in algae and a predicted reduction in average water clarity of almost 1.0 feet. Similarly, if 25% of the forests in Gunlock Lake were converted to pasture/grassland, phosphorus loading would increase by an estimated 44 pounds. Phosphorus concentrations would increase to 28 µg/L, causing a reduction in water clarity of nearly 1.0 feet over current conditions.

As is discussed in the subsequent Paleoecology Section (Section 3.3), aerial photography from 1937 indicates that approximately 190 acres (4.5%) of Shishebogama Lake's watershed contained row crop agricultural fields, some of which were immediately adjacent to the lake's shoreline.

While these areas are no longer farmed, WiLMS can be used to estimate what phosphorus loading may have been during this period. WiLMS estimates that annual phosphorus loading was likely around 635 pounds per year, or 20% higher than today. This likely would have resulted in an in-lake average phosphorus concentration of around 20 µg/L, and water clarity that would be 1.2 feet lower than today on average.

As of 2019, approximately 66% of the land within the Shishebogama-Gunlock lakes' watershed is in private ownership, 34% is owned by the LDF Tribe, and less than 1% is owned by the Minocqua Township (Figure 3.2-5). The SGLA should periodically communicate with LDF NRD staff the local WDNR, and county conservation staff to learn about ongoing land management within the Shishebogama-Gunlock lakes' watershed.

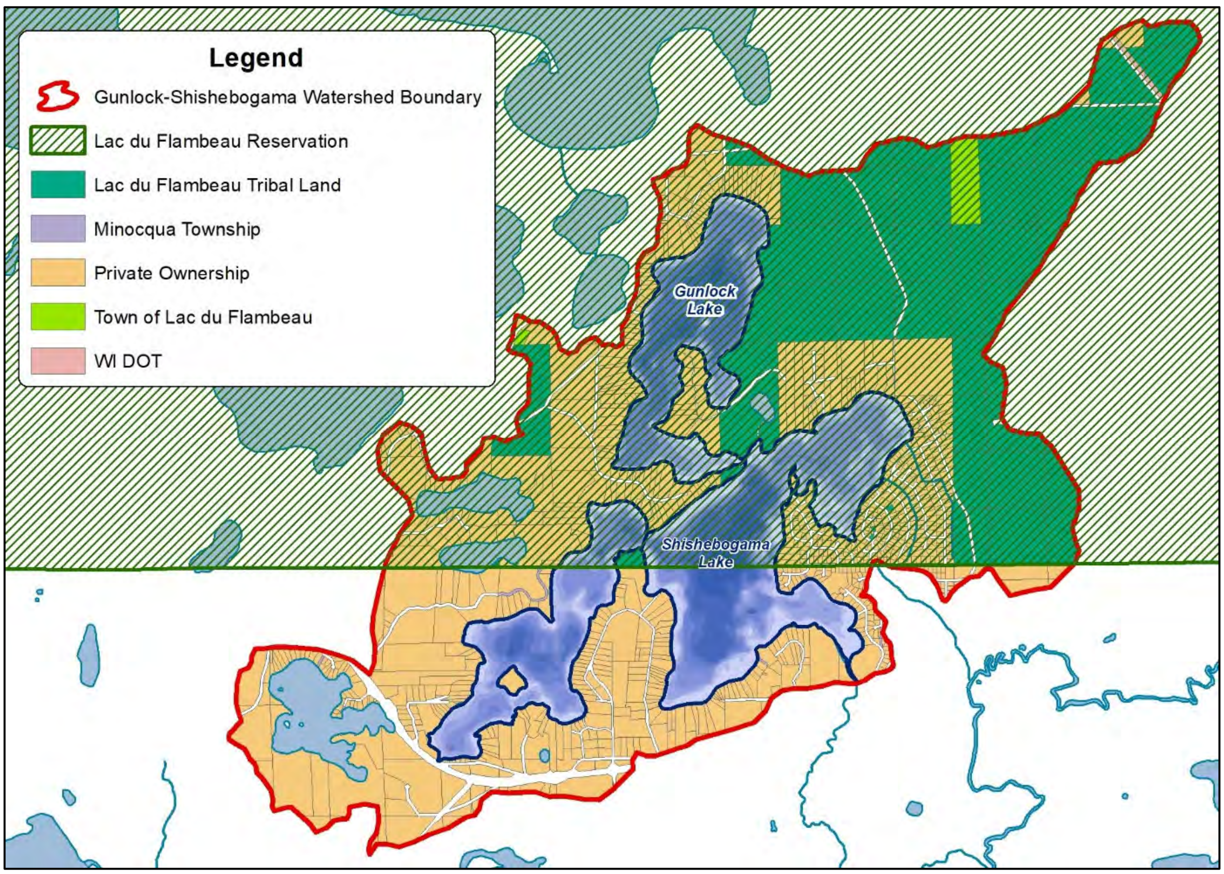


Figure 3.2-5. Land ownership in the Gunlock-Shishebogama watershed. Created using parcel data from Oneida and Vilas counties (2019).

3.3 Paleoecology

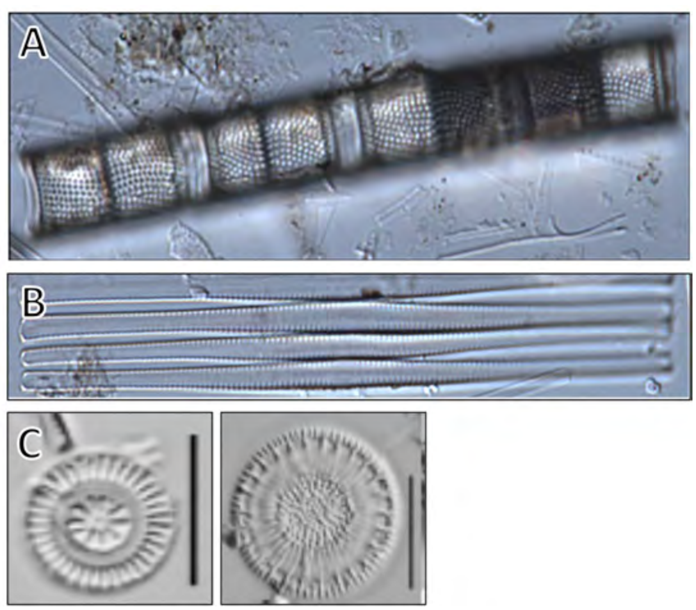
Primer on Paleoecology and Interpretation

Questions often arise concerning how a lake's water quality has changed through time as a result of watershed disturbances. In most cases, there is little or no reliable long-term data. They also want to understand when the changes occurred and what the lake was like before the transformations began. Paleoecology offers a way to address these issues. The paleoecological approach depends upon the fact that lakes act as partial sediment traps for particles that are created within the lake or delivered from the watershed. The sediments of the lake entomb a selection of fossil remains that are more or less resistant to bacterial decay or chemical dissolution.

These remains include frustules (silica-based cell walls) of a specific algal group called diatoms, cell walls of certain algal species, and subfossils from aquatic plants. The diatom community is especially useful in reconstructing a lake's ecological history as they are highly resistant to degradation and are ecologically diverse. Diatom species have unique features as shown in Photograph 3.3-1, which enable them to be readily identified. Certain taxa are usually found under nutrient poor conditions while others are more common under elevated nutrient levels. Some species float in the open water areas while others grow attached to substrates such as aquatic plants or the lake bottom.

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

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



Photograph 3.3-1. Photographmicrographs of the diatoms commonly found in the sediment cores from Shishebogama and Gunlock lakes. The top diatom (A) is *Aulacoseira ambigua* which is common in many Wisconsin lakes with low to moderate phosphorus concentrations. *Fragilaria crotonensis (B)* is more common with moderate phosphorus levels but also indicates higher nitrogen concentrations. This diatom is most common in the top samples. *Discostella stelligera* (C left) and *Cyclotella bodanica* var. *lemanica* (C right) indicate lower nutrient levels and were more common in the bottom samples.

Shishebogama and Gunlock Lakes Paleoecological Results

Top/bottom sediment cores were collected from the deep hole areas in Shishebogama and Gunlock lakes by Onterra staff on August 19, 2019 (Photograph 3.3-1). The total length of these cores was 29 cm for Shishebogama Lake and 36 cm for Gunlock Lake. Both cores were dark brown in color throughout. In both cores, the top 1 cm was kept for diatom analysis and assumed to represent present day water quality conditions in the lakes. In Shishebogama Lake, the bottom section from 26 to 28 cm was kept for analysis, and the bottom section from 33-35 cm in Gunlock Lake was kept for analysis. The bottom sections are assumed to represent conditions before the arrival Euro-American settlers in the nineteenth century.

Photograph 3.3-1. Photograph of sediment cores collected from Shishebogama Lake (left) and Gunlock Lake (right).

Diatom Community Changes

Multivariate Statistical Analysis

In order to make a comparison of environmental conditions between the bottom and top samples of the core from Shishebogama and Gunlock lakes, an exploratory detrended correspondence analysis (DCA) was performed (CANOCO 5 software) (Ter Braak & Smilauer, 2012). The DCA analysis has been done on many Wisconsin lakes to examine the similarities of the diatom communities between the top and bottom samples of the same lake. These lakes are those that are relatively deep and stratify during the summer, much as Shishebogama and Gunlock lakes do.

The results revealed two clear axes of variation in the diatom data, with 39% and 25% of the variance explained by axis 1 and axis 2, respectively (Figure 3.3-1). Sites with similar sample scores occur in close proximity reflecting similar diatom composition. The arrows symbolize the trend from the bottom to the top samples. The bottom samples of Shishebogama and Gunlock lakes cluster together indicating their diatoms communities were historically very similar prior to Euro-American settlement. The position of the top samples is farther apart from one another, indicating that the lakes' current diatom communities are more dissimilar than they were historically. The distance between the top and bottom samples in Shishebogama Lake is larger when compared to Gunlock Lake, indicating the composition of Shishebogama Lake's diatom community has changed to a greater extent than Gunlock Lake's since Euro-American settlement.

While it is not possible to determine which were the most important environmental variables ordering the diatom communities, one trend is apparent. Axis 1 likely represents the alkalinity of the lakes. Other studies on Wisconsin and Vermont lakes indicate that the most important variable ordering the diatom communities is alkalinity. Lakes on the right side of the DCA graph tend to have the lowest alkalinity values while the highest are on the left side. A study by (Eilers, Glass, Pollack, & Sorenson, 1989) of 149 lakes in north central Wisconsin found that as a consequence of lake shore development, alkalinity and conductivity concentrations increase. This is because of the sediment that enters the lake during cottage and road construction. The direction of the arrow in both Shishebogama and Gunlock lakes indicates slightly higher alkalinity at present than compared to pre-Euro-American settlement, most likely the result of shoreland development.

Top and Bottom Diatom Communities

In the bottom section of the core collected from Shishebogama Lake, planktonic (floating) diatoms dominated the diatom community (Figure 3.3-2). The most common diatom was *Aulacoseira ambigua* which is frequently the dominant diatom in deep, low nutrient lakes in northern Wisconsin, Michigan, and Minnesota prior to the arrival of Euro-American settlers (Camburn & Kingston, 1986) (Kingston, et al., 1990) (Garrison & Fitzgerald, 2005). In fact, in Shishebogama Lake this diatom comprised over 55% of the historical diatom community. In the top section of the core collected from Shishebogama Lake, the presence of *A. ambigua* was reduced to 16%, and all of the planktonic diatoms together constituted less than one half of the diatom community (Figure 3.3-2). In the top sample, *A. ambigua* was replaced by diatoms that prefer higher nutrient levels (e.g., *Fragilaria crotonensis* and *Asterionella formosa*) as well as those diatoms that grow attached to aquatic plants.

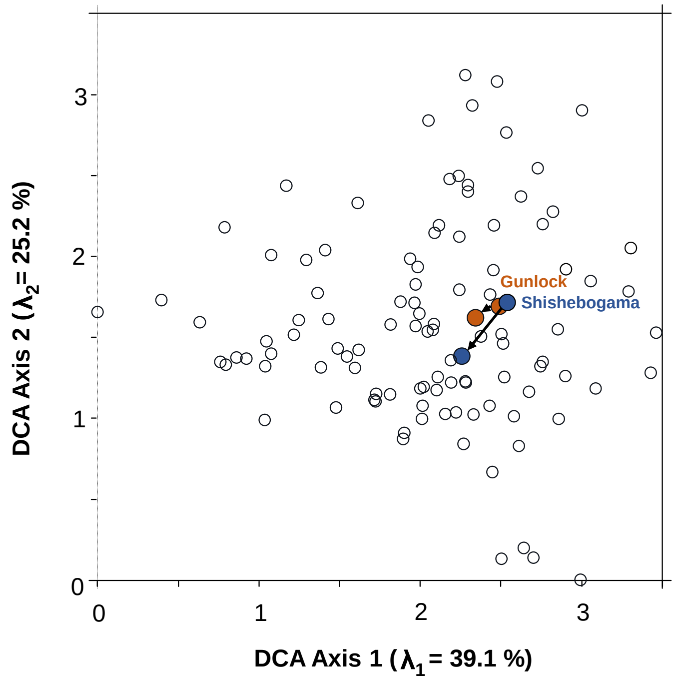


Figure 3.3-1. Detrended Correspondence Analysis (DCA) plot of top/bottom samples from Shishebogama and Gunlock lakes. The arrows connect bottom to top samples in the same lake. The open circles are other Wisconsin lakes where top/bottom samples have been analyzed. The composition of Shishebogama Lake's diatom community has changed to a greater extent than Gunlock Lake's over the past ~150 years.

Benthic *Fragilaria* often grow attached to submerged aquatic plants under moderate to high nutrient levels. In Shishebogama Lake, their numbers in both the top and bottom samples were low indicating that nutrient levels have not changed significantly since Euro-American settlement. However, the decline in planktonic diatoms between the bottom and top core sections (69% to 47%) indicates that aquatic plant coverage has likely increased in Shishebogama Lake since Euro-American settlement.

Studies have found that the littoral zone of the lake, the area where aquatic plants grow, is often is the first area of a lake to respond to when nutrient input from the watershed increases. This early response is due to the fact that the littoral zone is at the interface between the watershed and the main body of the lake. In a study of seepage lakes in northwestern Wisconsin, (Borman, 2007) found that aquatic plant communities often shifted from a community dominated by small, low-growing species to one dominated by larger, tall-growing species in response to increasing shoreland development. Construction around the immediate shoreland zone caused an increase in sediment runoff, particularly more fine-grained sediment. The increased sediment input resulted in increased alkalinity and suitable substrates for the establishment of larger aquatic plants. Larger aquatic plants provide more surface area for diatoms to attach to and grow, and thus, their abundance increases with increasing aquatic plant abundance.

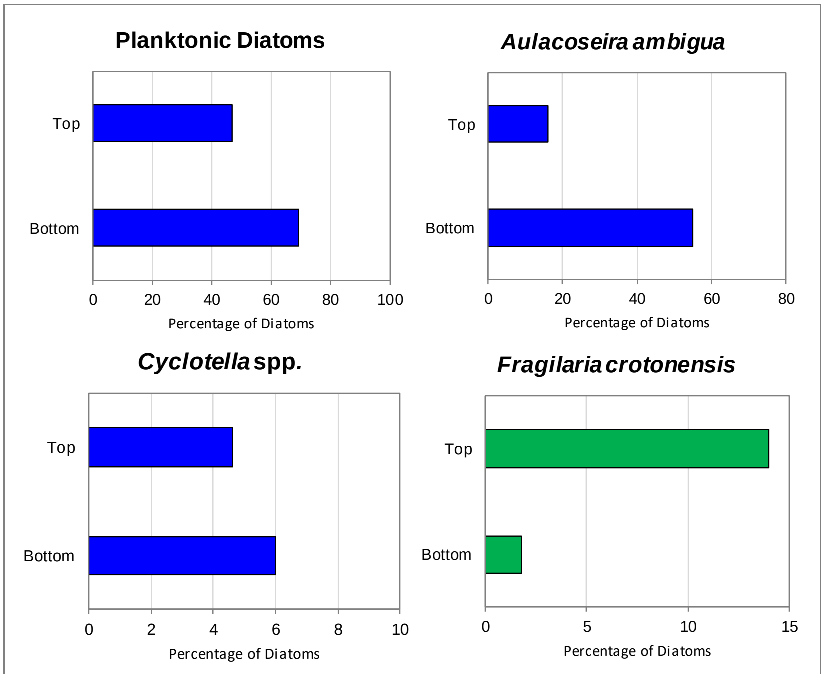


Figure 3.3-2. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Shishebogama Lake. The diatom community at the bottom of the core was dominated by *Aulacoseira ambigua* which are generally found in low phosphorus concentrations. The increase in *F. crotonensis* the top sample indicates a small increase in nutrients, especially nitrogen.

In northern Wisconsin, the earliest impacts to the lakes were from wide-spread logging operations. This activity generally had a short-term impact upon the lakes' ecology. Following the early logging, agriculture was attempted in northern Wisconsin but was largely abandoned due to short growing seasons and nonarable soils. Aerial Photography from 1937 shows that row crop farming was attempted in portions of Shishebogama Lake's watershed (Figure 3.3-3). In some areas, these agricultural fields were immediately adjacent to the lake. These agricultural practices likely resulted in increased sediment and nutrient runoff into Shishebogama Lake during this period.

With the failure of the agricultural experiment following the early logging in the late nineteenth and early twentieth centuries, tourism increased resulting in the addition of cottages around many lakes after the late 1920s (Davis, 1995). Beginning around the 1970s, lake shore homes began to become larger and lawn maintenance more common. This increased urbanization resulted in increased delivery of sediment and nutrients to the lakes. This often resulted in large impacts on shoreland habitat as well as nearshore habitat. The analysis on Shishebogama Lake's sediment core indicates that the most significant impact of Euro-American settlement has been increased aquatic plant growth, likely due to increased sediment and nutrient runoff from agriculture and near-shore home construction.

The two most *Cyclotella* species, *Discostella stelligera* and *Cyclotella bodanica* var. *lemanica* abundance is similar in the top and bottom samples (Figure 3.3-2). This suggests that the diatom community has not been significantly influenced by climate modification.

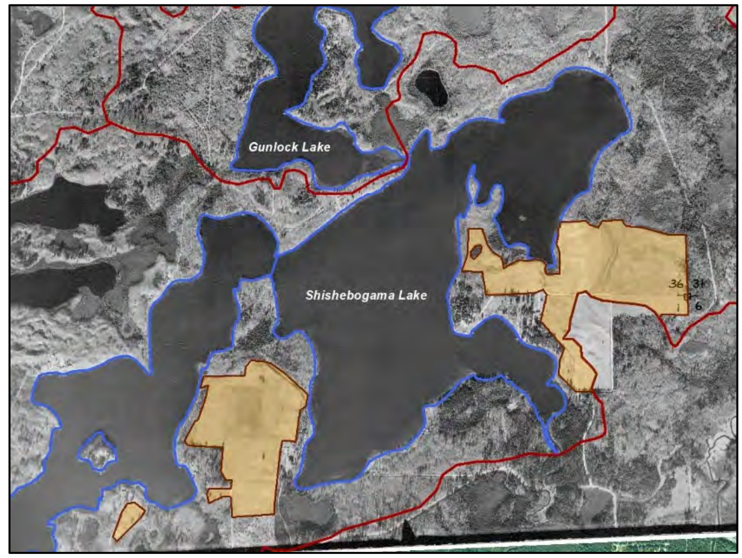


Figure 3.3-3. Aerial imagery from 1937 showing row crop agricultural fields (orange) within Shishebogama Lake's watershed. Red line represents Shishebogama-Gunlock lakes watershed boundary. Aerial photograph obtained from UW-Madison State Cartographer's Office.

The shift in diatom community composition observed in Shishebogama Lake was relatively similar in Gunlock Lake. The bottom section of the sediment core from Gunlock Lake was dominated by planktonic diatoms, especially *A. ambigua* (Figure 3.3-4). In the top section of the core, *A. ambigua* was replaced by *F. crotonensis*, a diatom which prefers slightly higher nutrient levels and grows attached to aquatic plants. Like Shishebogama Lake, this indicates that there is currently greater coverage of aquatic plants in Gunlock Lake when compared to pre-Euro-American settlement. As discussed previously, this is a common occurrence in lakes in northern Wisconsin that have experienced shoreland development.

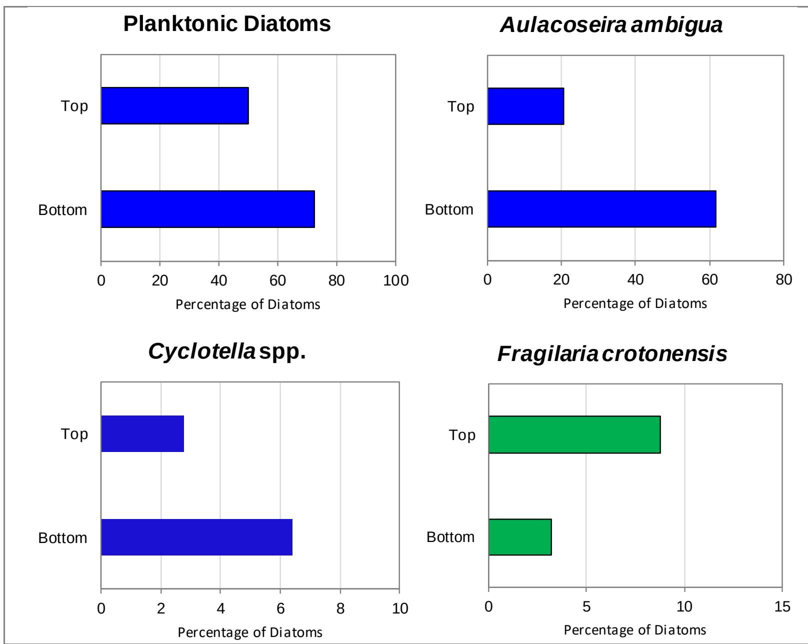


Figure 3.3-4. Changes in abundance of important diatoms found in the top and bottom of the sediment core from Gunlock Lake. The diatom community at the bottom of the core was dominated by *Aulacoseira ambigua* which are generally found in low phosphorus concentrations. The increase in *F. crotonensis* the top sample indicates a small increase in nutrients, especially nitrogen.

Lake Diatom Condition Index

The Lake Diatom Condition Index (LDCI) was developed by Dr. Jan Stevenson, Michigan State University (Stevenson, Zalack, & Wolin, 2013). The LDCI uses diatoms to assess the ecological condition of lakes. The LDCI ranges from 0 to 100 with a higher score representing better ecological integrity. The index is weighted towards nutrients, but also incorporates ecological integrity by examining species diversity where higher diversity indicates better ecological condition. The index also incorporates taxa that are commonly found in undisturbed and disturbed conditions. The breakpoints (poor, fair, good) were determined by the 25th and 5th percentiles for reference lakes in the Upper Midwest. The LDCI was used in the 2007 National Lakes Assessment to determine the biological integrity of the nation's lakes.

The LDCI in the top and bottom samples from both Shishebogama and Gunlock lakes place them the good category (Figure 3.3-5). Although the LDCI is better in the top samples of both lakes, this is largely because of the increased taxa richness and diversity in the top samples. This often happens in lakes with relatively good water quality that experience increased habitat for diatom growth with the expansion of aquatic plant coverage. As discussed above, both lakes contain high aquatic plant coverage at the present time compared with prior to the arrival of Euro-Americans.

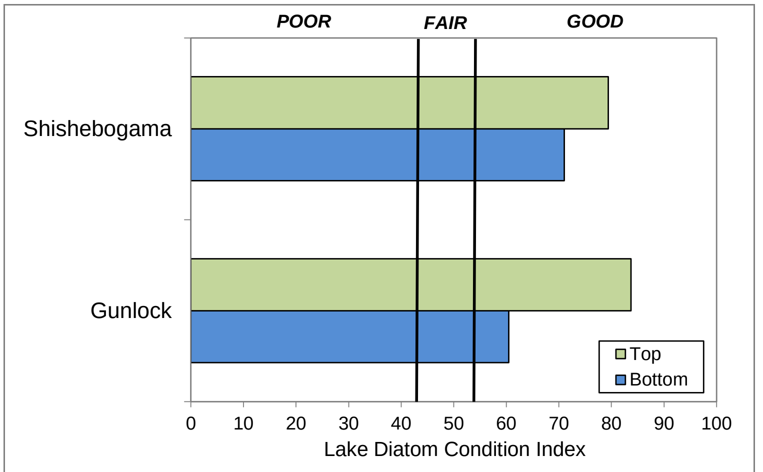


Figure 3.3-4. The Lake Diatom Condition Index (LDCI) for Shishebogama and Gunlock lakes. The biotic integrity is good in the top and bottom samples.

Inference models

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

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

The diatom inferred phosphorus concentration in the top sections of the core samples collected from Shishebogama and Gunlock lakes is similar to the average summer phosphorus concentration for the last few years of 19 µg/L in Shishebogama Lake and 26 µg/L in Gunlock Lake. This suggests that the estimated historical phosphorus concentration is reliable. The estimated phosphorus concentrations in the top and bottom sample of Shishebogama Lake are the same at 23 µg/L (Table 3.3-1). In Gunlock Lake the phosphorus concentrations in the top and bottom samples are nearly the same at 22 and 23 µg/L, respectively. Although the changes in the diatom community between the bottom and top samples suggest an increase in nutrients, it likely is primarily an increase in nitrogen.

Table 3.3-1. Diatom inferred phosphorus concentrations in core samples (µg/L).

Lakes	Phosphorus
Shishebogama Top	23
Shishebogama Bottom	23
Gunlock Top	22
Gunlock Bottom	23

The sediment cores from the lakes indicate that at the present time there are more macrophytes in the lakes than there were 100 years ago. There likely has been a small increase in nutrients, especially nitrogen. Shoreland development results in more nutrient input to the lake but with increased macrophyte coverage, more surfaces are provided for diatom growth. The attached algae remove much of the increased phosphorus input from shoreland development. This means that phosphorus levels in the open water remain unchanged. If phosphorus input increases enough, the attached algae are not able to take up all the phosphorus and concentrations in the open water increase. This has not happened yet in either lake but continued input of phosphorus from the nearshore could eventually result in higher phosphorus levels in the lake.

3.4 Shoreland Condition

Lake Shoreland Zone and its Importance

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

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

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

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

Shoreland Zone Regulations

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

Wisconsin-NR 115: Wisconsin's Shoreland Protection Program

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

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

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

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

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

Wisconsin Act 31

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

Shoreland Research

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

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

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

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

Photograph 3.4-1. Example of coarse woody habitat in a lake.

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

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

National Lakes Assessment

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

Through the National Lakes Assessment, a number of potential stressors were examined, including nutrient impairment, algal toxins, fish tissue contaminants, physical habitat, and others. The 2007 NLA report states that "*of the stressors examined, poor lakeshore habitat is the biggest problem in the nations lakes; over one-third exhibit poor shoreline habitat condition*" (USEPA 2009). Furthermore, the report states that "*poor biological health is three times more likely in lakes with poor lakeshore habitat.*" These results indicate that stronger management of shoreline development is absolutely necessary to preserve, protect, and restore lakes. Shoreland protection will become increasingly important as development pressure on lakes continues to grow.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects (Jennings et al. 2003).

The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreland. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreland sediments vulnerable to wave action caused by boating and wind (Jennings et al. 2003) (Radmoski and Goeman 2001) (Elias and Meyer 2003). Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife (Scheuerell and Schindler 2004).

Photograph 3.4-2. Example of a bio-log restoration site.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a shoreland buffer zone. The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some of the shoreland's natural function. Enhancement activities also include additions of submergent, emergent, and floating-leaf plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Wisconsin's Healthy Lakes & Rivers Action Plan

Starting in 2014, a program was enacted by the WDNR and UW-Extension to promote riparian landowners to implement relatively straight-forward shoreland restoration activities. This program provides education, guidance, and grant funding to promote installation of best management practices aimed to protect and restore lakes and rivers in Wisconsin. The program has identified five best practices aimed at improving habitat and water quality (Figure 3.4-1).

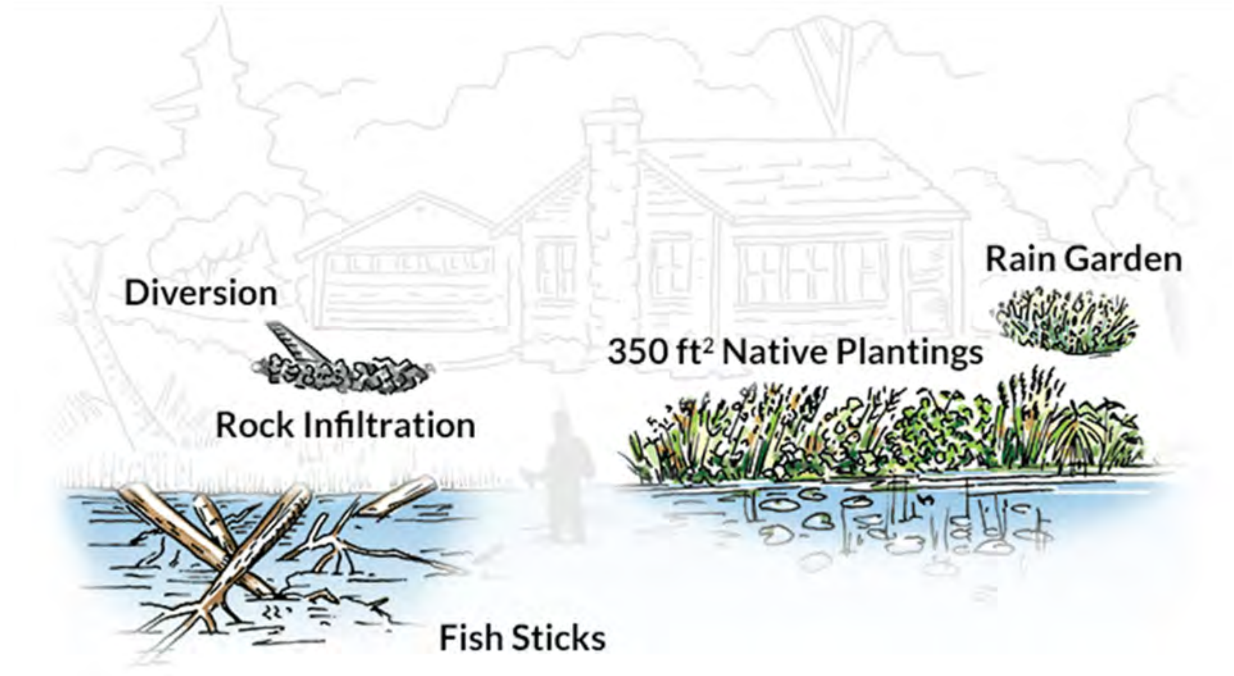


Figure 3.4-1. Healthy Lakes & Rivers 5 Best Practices. Illustration by Karen Engelbretson, extracted from healthylakeswi.com.

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

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

https://healthylakeswi.com/

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

Shishebogama and Gunlock Lakes Shoreland Zone Condition

Shoreland Development

Shishebogama and Gunlock lakes' shoreland zone can be classified in terms of its degree of development. In general, more developed shorelands are more stressful on a lake ecosystem, while definite benefits occur from shorelands that are left in their natural state. Figure 3.4-2 displays a diagram of shoreland categories, from "Urbanized", meaning the shoreland zone is completely disturbed by human influence, to "Natural/Undeveloped", meaning the shoreland has been left in its original state.

On Shishebogama and Gunlock lakes, the development stage of the entire shoreland was surveyed during Fall of 2019 using a GPS unit to map the shoreland. Onterra staff only considered the area of shoreland 35 feet inland from the water's edge, and did not assess the shoreland on a property-by-property basis. During the survey, Onterra staff examined the shoreland for signs of development and assigned areas of the shoreland one of the five descriptive categories in Figure 3.4-2.

Shishebogama and Gunlock lakes have stretches of shoreland that fit all of the five shoreland assessment categories (Figure 3.4-3). Of Shishebogama Lake's 10.9 miles of shoreline, approximately 7.8 miles (72%) contained little to no development, delineated as natural/undeveloped and developed-natural. Similarly, of Gunlock Lake's 4.8 miles of shoreline, 3.6 miles (75%) was delineated as natural/undeveloped and developed-natural. These areas have intact natural habitat and provide the most benefit to the lake in terms of habitat and water quality protection. Conservation of these areas should be a priority to prevent future development.

Approximately 2.0 miles (18%) of Shishebogama Lake's shoreline and 0.9 miles (19%) of Gunlock Lake's shoreline were designated as developed-unnatural or urbanized indicating most if not all of the natural habitat has been developed and lost. These developed areas lack natural habitat and currently provide little benefit to these lakes, and may actually be negatively impacting the ecosystems of these lakes. If shoreline restoration is to take place, these should be primary focus areas for restoration. The location of these developed shorelands can be found on maps 3 and 4.

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

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

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

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

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

Figure 3.4-2. Shoreland assessment category descriptions.

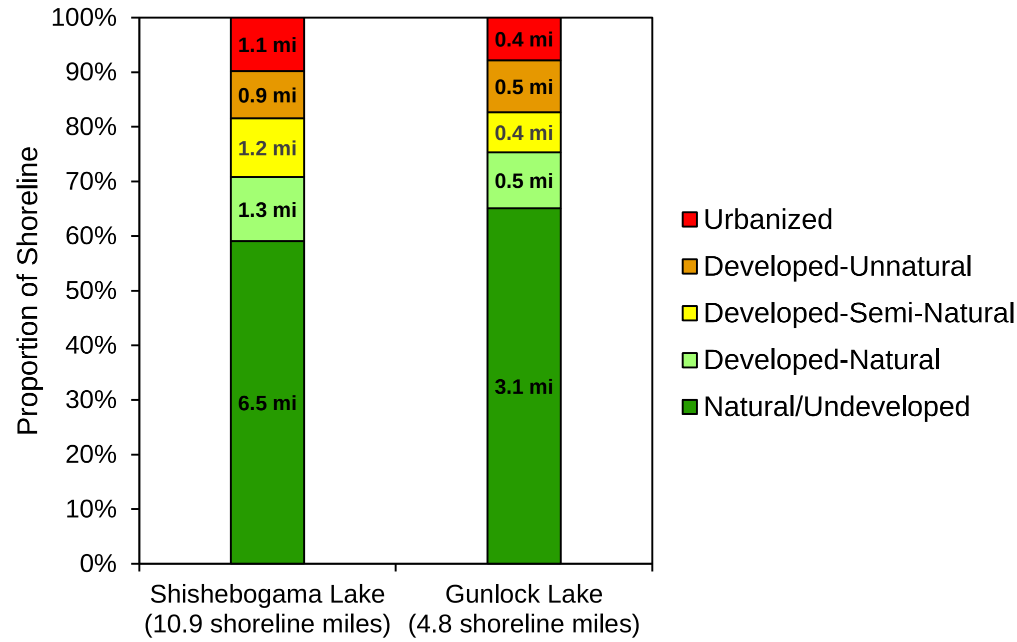


Figure 3.4-3. Shishebogama and Gunlock lakes shoreland categories and total lengths. Based upon a Fall 2019 survey. Locations of these categorized shorelands can be found on maps 3 and 4.

Coarse Woody Habitat

As part of the shoreland condition assessment, Shishebogama and Gunlock lakes were also surveyed to determine the extent of their coarse woody habitat. Coarse woody habitat was identified, and classified in three size categories (cluster of pieces, 2-8 inches in diameter, and 8+ inches in diameter) as well as four branching categories: no branches, minimal branches, moderate branches, and full canopy. Pictures descriptions of these categories can be found in Figure 3.4-4. As discussed earlier, research indicates that fish species prefer some branching as opposed to no branching on coarse woody habitat, and increasing complexity is positively correlated with higher fish species richness, diversity and abundance (Newbrey, Bozek, Jennings, & Cook, 2005).

During the survey on Shishebogama Lake, 280 total pieces of coarse woody habitat along 10.9 miles of shoreline were observed (Map 5), yielding a course woody habitat to shoreline mile ratio of 26:1 (Figure 3.4-5). On Gunlock Lake, a total of 69 pieces of coarse woody habitat were located along 4.8 miles of shoreline (Map 6), yielding a coarse woody habitat to shoreline mile ratio of 14:1 (Figure 3.4-4). Only instances where emergent coarse woody habitat extended from shore into the water were recorded during the survey.

To put this into perspective, Wisconsin researchers have found that in completely undeveloped lakes, an average of 345 coarse woody habitat structures may be found per mile (Christensen, Herwig, Schindler, & Carpenter, 1996). Please note the methodologies between the surveys done on Shishebogama and Gunlock lakes and those cited in this literature comparison are much different, but still provide a valuable insight into what undisturbed shorelines may have in terms of coarse woody habitat. Onterra has completed coarse woody habitat surveys on 111 lakes throughout Wisconsin since 2012, with the majority occurring in the NLF ecoregion on lakes with public access. The number of coarse woody habitat pieces per shoreline mile found on

Shishebogama and Gunlock lakes in 2019 fall in the 50th and 18th percentile, respectively (Figure 3.4-4).

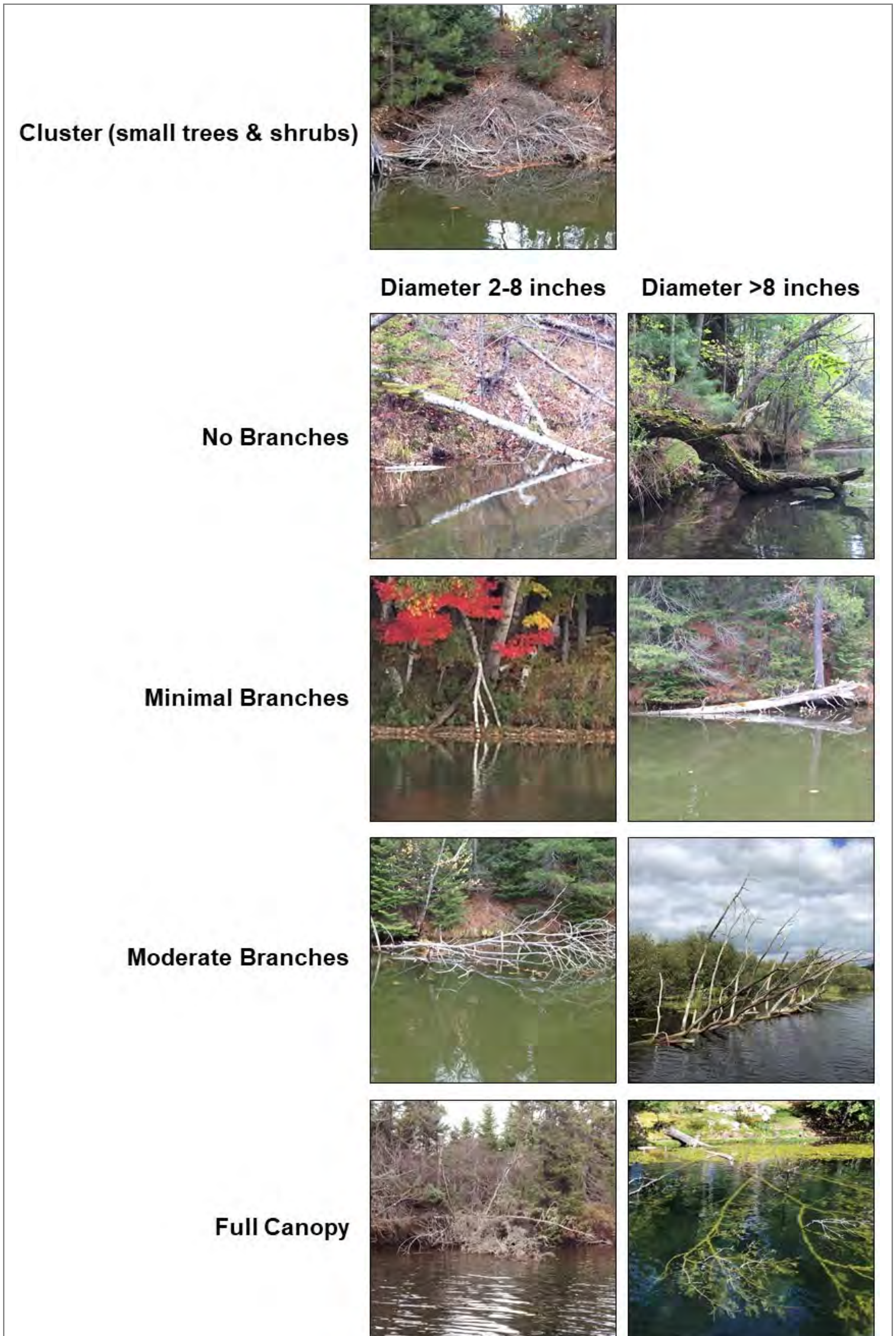


Figure 3.4-4. Coarse woody habitat classifications used during 2019 survey on Shishebogama and Gunlock Lakes. Photograph credit Onterra.

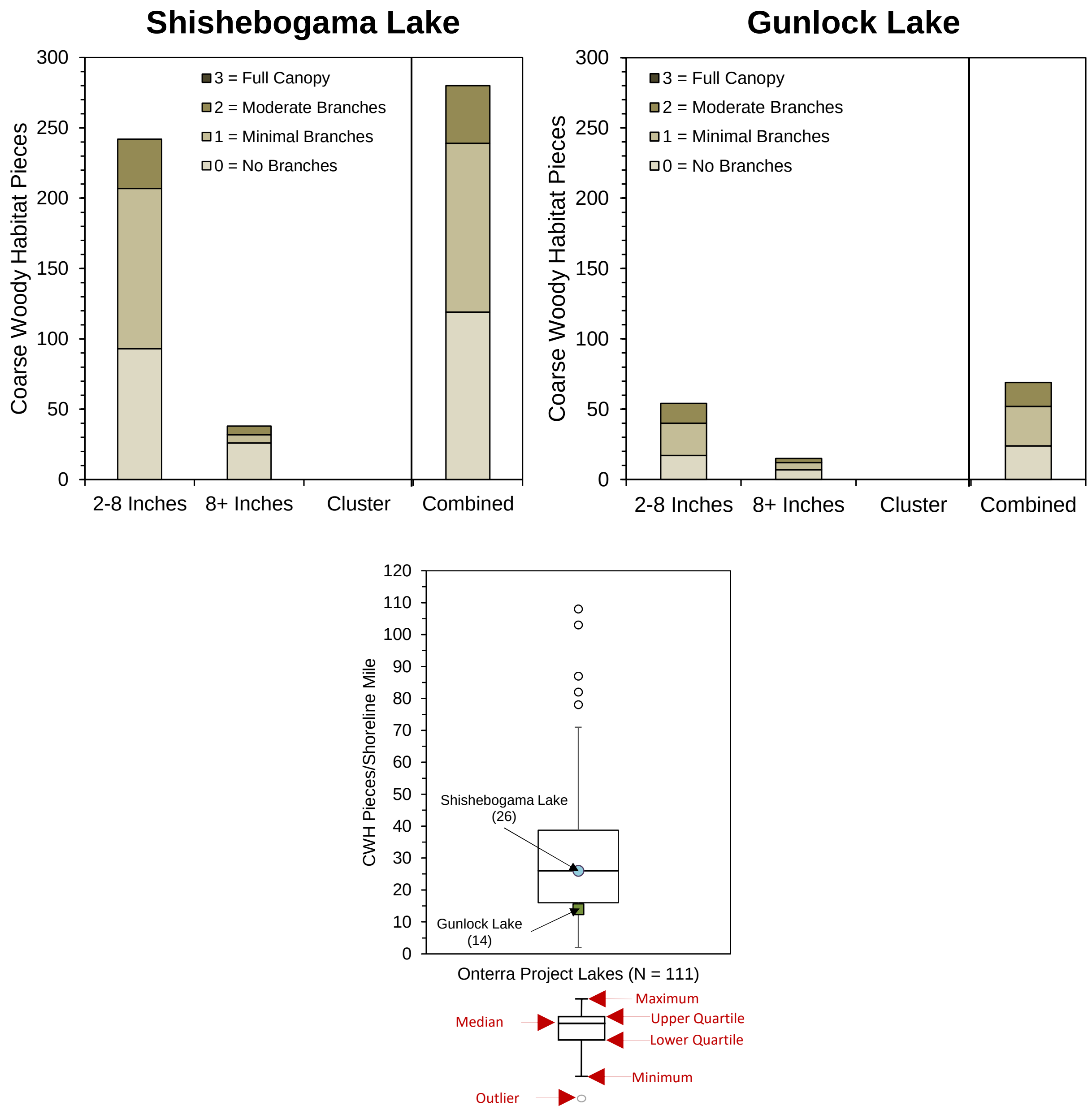


Figure 3.4-5. Shishebogama and Gunlock lakes 2019 coarse woody habitat survey results. Based upon a Fall of 2019 survey. Coarse woody habitat locations can be found on Maps 5 and 6.

3.5 Aquatic Plants

Introduction

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

Photograph 3.5-1. Example of emergent and floating-leaf plant community.

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

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

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

Aquatic Plant Management and Protection

An aquatic plant management plan is often aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community.

> **Important Note:**
> Even though most of these techniques are not applicable to Shishebogama and Gunlock lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why particular methods are or are not applicable in their lake. The techniques applicable to Shishebogama and Gunlock lakes are discussed in Summary and Conclusions section and the Implementation Plan found near the end of this document.

Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that 30 feet. This action can be conducted up to 150 feet from shore. Please note that a permit is needed in all instances if wild rice is to be removed. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR.

Permits are required for chemical and mechanical manipulation of native and non-native plant communities. Large-scale protocols have been established for chemical treatment projects covering >10 acres or areas greater than 10% of the lake littoral zone and more than 150 feet from shore. Different protocols are to be followed for whole-lake scale treatments (≥160 acres or ≥50% of the lake littoral area). Additionally, it is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Manual Removal (Hand-Harvesting & DASH)

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however, Wisconsin law states that all plant fragments must be removed.

Photograph 3.5-2. Example of aquatic plants that have been removed manually.

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

Cost

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

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

Bottom Screens

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

Cost

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

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

Mechanical Harvesting

Photograph 3.5-3. Aquatic plant mechanical harvester.

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

Cost

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

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

Herbicide Treatment

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

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

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

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

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

Contact herbicides act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but in some plants does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.

Systemic herbicides act slower than contact herbicides, being transported throughout the entire plant and disrupting biochemical pathways which often result in complete mortality.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

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

Table 3.4-1. Common herbicides used for aquatic plant management.

	General Mode of Action	Compound	Specific Mode of Action	Most Common Target Species in Wisconsin
Contact		Copper	plant cell toxicant	Algae, including macro-algae (i.e. muskgrasses & stoneworts)
		Endothall	Inhibits respiration & protein synthesis	Submersed species, largely for curly-leaf pondweed; invasive watermilfoil control when mixed with auxin herbicides
		Diquat	Inhibits photosynthesis & destroys cell membranes	Nusiance species including duckweeds, targeted AIS control when exposure times are low
		Flumioxazin	Inhibits photosynthesis & destroys cell membranes	Nusiance species, targeted AIS control when exposure times are low
Systemic	Auxin Mimics	2,4-D	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Triclopyr	auxin mimic, plant growth regulator	Submersed species, largely for invasive watermilfoil
		Florpyrauxifen -benzyl	arylpicolinate auxin mimic, growth regulator, different binding afinity than 2,4-D or triclopyr	Submersed species, largely for invasive watermilfoil
	In Water Use Only	Fluridone	Inhibits plant specific enzyme, new growth bleached	Submersed species, largely for invasive watermilfoil
	Enzyme Specific (ALS)	Penoxsulam	Inhibits plant-specific enzyme (ALS), new growth stunted	Emergent species with potential for submergent and floating-leaf species
		Imazamox	Inhibits plant-specific enzyme (ALS), new growth stunted	New to WI, potential for submergent and floating-leaf species
	Enzyme Specific (foliar use only)	Glyphosate	Inhibits plant-specific enzyme (ALS)	Emergent species, including purple loosestrife
		Imazapyr	Inhibits plant-specific enzyme (EPSP)	Hardy emergent species, including common reed

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

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

Cost

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

Advantages	Disadvantages
• Herbicides are easily applied in restricted areas, like around docks and boatlifts. • Herbicides can target large areas all at once. • Herbicides can be economical at certain scales compared with other management options. • Herbicide type and application timing can increase selectivity towards target species. • Most herbicides are designed to target plant physiology and in general, have low toxicological effects on non-plant organisms (e.g., mammals, insects)	• All herbicide use carries some degree of human health and ecological risk due to toxicity. • Fast-acting herbicides may cause fish kills due to rapid plant decomposition if not applied correctly. • Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them. • Many aquatic herbicides are nonselective. • Some herbicides have a combination of use restrictions that must be followed after their application. • Overuse of same herbicide may lead to plant resistance to that herbicide.

Biological Controls

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

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

Cost

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

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

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

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

Cost

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

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

Analysis of Current Aquatic Plant Data

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

As described in more detail in the methods section, multiple aquatic plant surveys were completed on Shishebogama and Gunlock lakes; the first looked strictly for the exotic plant, curly-leaf pondweed, while the others that followed assessed both native and non-native species. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the aquatic plant species, both native and non-native, that were located during the surveys completed in Shishebogama and Gunlock lakes in 2019. The list also contains the growth-form of each plant found (e.g., submergent, emergent, etc.), its scientific name, common name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and losses of individual species, or changes in growth forms that are present, can be an early indicator of changes in the ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain aquatic plant species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of the whole-lake point-intercept survey completed on Shishebogama and Gunlock lakes, plant samples were collected from plots laid out on a grid that covered the lake. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. The occurrence of aquatic plant species is displayed as the *littoral frequency of occurrence*. Littoral frequency of occurrence is used to describe how often each species occurred in the plots that are within the maximum depth of plant growth (littoral zone), and is displayed as a percentage.

Floristic Quality Assessment

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

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

On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality. The floristic quality is calculated using the species richness and average conservatism value of the aquatic plant species that were solely encountered on the rake during the point-intercept surveys (equation shown below). This assessment allows the aquatic plant community of Shishebogama and Gunlock lakes to be compared to other lakes within the region and state.

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

Species Diversity

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

An aquatic system with high species diversity is more stable than a system with a low diversity. This is analogous to a diverse financial portfolio in that a diverse aquatic plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. A lake with a diverse plant community is also better suited to compete against exotic infestations than a lake with a lower diversity. The diversity of a lake's aquatic plant community is determined using the Simpson's Diversity Index (1-D):

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

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

If a lake has a diversity index value of 0.90, it means that if two plants were randomly sampled from the lake there is a 90% probability that the two individuals would be of a different species. The Simpson's Diversity Index value from Shishebogama and Gunlock lakes is compared to data collected by Onterra and the WDNR Science Services on 212 lakes withn the Northern Lakes and Forests ecoregion and on 392 lakes throughout Wisconsin.

Community Mapping

A key component of any aquatic plant community assessment is the delineation of the emergent and floating-leaf aquatic plant communities within each lake as these plants are often underrepresented during the point-intercept survey. This survey creates a snapshot of these important communities within each lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. Examples of emergent plants include cattails, rushes, sedges, grasses, bur-reeds, and arrowheads, while examples of floating-leaf species include the water lilies. The emergent and floating-leaf aquatic plant communities in Shishebogama and Gunlock lakes were mapped using a Trimble Global Positioning System (GPS) with sub-meter accuracy.

Exotic Plants

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

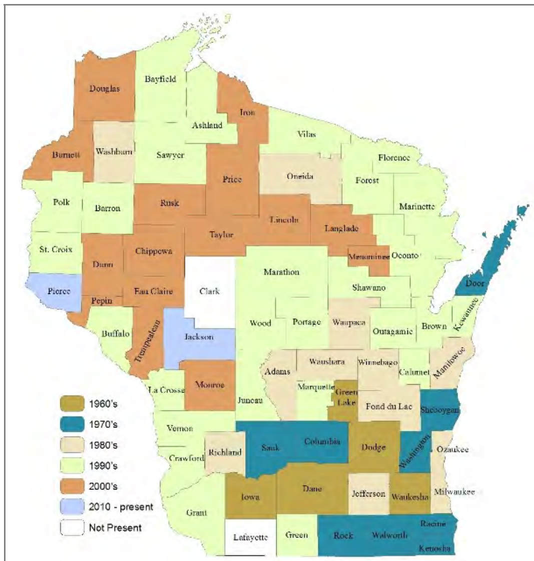


Figure 3.5-1. Spread of Eurasian watermilfoil within WI counties. WDNR Data 2015 mapped by Onterra.

Eurasian watermilfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 3.5-1). Eurasian watermilfoil is unique in that its primary mode of propagation is not by seed. It actually spreads by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian watermilfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian watermilfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

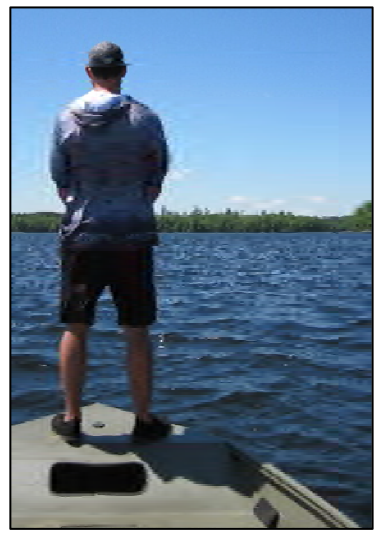
Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it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

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

Aquatic Plant Survey Results

Shishebogama Lake

The first survey completed on Shishebogama Lake was an early-season aquatic invasive species (ESAIS) survey completed on June 26, 2019 (Photograph 3.5-1). The goal of this survey was to identify and assess any new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists did not observe any occurrences of curly-leaf pondweed or Eurasian watermilfoil; however, numerous occurrences of pale-yellow iris were located along the lake's southeastern shore.



Photograph 3.5-1 Onterra ecologists during the spring early season AIS meander survey on Shishebogama Lake.

Pale-yellow iris is an invasive wetland plant that is readily identified in early summer by its large, showy yellow flowers. Without flowering or fruiting bodies, there are no widely accepted ways to distinguish between pale-yellow iris and the two native blue-flag iris species. The occurrence and potential management strategies for controlling pale-yellow iris are discussed in detail in the subsequent Non-Native Aquatic Plants Section.

The whole-lake point-intercept survey was conducted on Shishebogama Lake on July 24 and 25, 2019, while the emergent and floating-leaf community mapping survey was completed on August 14, 2019. During the 2019 surveys, a total of 67 aquatic plant species were located in Shishebogama Lake, three of which are considered to be non-native, invasive species: pale-yellow iris, purple loosestrife, and narrow-leaved cattail (Table 3.5-1 and Table 3.5-2). These non-native plants are discussed in the Non-Native Aquatic Plants Section. Tables 3.5-1 and 3.5-2 also contain the list of the 65 aquatic plant species that were recorded during the 2009 surveys completed by Onterra. Taking both survey years together, a total of 77 aquatic plant species have been identified from Shishebogama Lake, with 55 of these species being recorded in both 2009 and 2019.

Table 3.5-1. Emergent and floating-leaf aquatic plant species located in Shishebogama Lake during the 2009 and 2019 aquatic plant surveys by Onterra.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2009	2019
Emergent	*Calla palustris*	Water arum	Native	9	I	I
	Carex comosa	Bristly sedge	Native	5	I	I
	Carex lasiocarpa	Narrow-leaved woolly sedge	Native	9	I	I
	Carex utriculata	Common yellow lake sedge	Native	7		I
	Carex vesicaria	Blister sedge	Native	7	I	
	Decodon verticillatus	Water-willow	Native	7		I
	Dulichium arundinaceum	Three-way sedge	Native	9	X	I
	Eleocharis palustris	Creeping spikerush	Native	6	X	X
	Equisetum fluviatile	Water horsetail	Native	7	X	
	Iris pseudacorus	Pale-yellow iris	Non-Native - Invasive	N/A		I
	Juncus effusus	Soft rush	Native	4	I	I
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	I	I
	Phragmites australis subsp. *americanus*	Common reed	Native	5	I	
	Pontederia cordata	Pickerelweed	Native	9	X	X
	Sagittaria latifolia	Common arrowhead	Native	3	I	I
	Schoenoplectus acutus	Hardstem bulrush	Native	5	X	X
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4	X	X
	Scirpus cyperinus	Wool grass	Native	4		I
	Sparganium americanum	American bur-reed	Native	8		I
	Sparganium eurycarpum	Common bur-reed	Native	5	X	I
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A		I
	Typha latifolia	Broad-leaved cattail	Native	1	I	I
FL	*Brasenia schreberi*	Watershield	Native	7	X	X
	Nuphar variegata	Spatterdock	Native	6	X	X
	Nymphaea odorata	White water lily	Native	6	X	X
	Persicaria amphibia	Water smartweed	Native	5		I
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	X	I
	Sparganium fluctuans	Floating-leaf bur-reed	Native	10	X	X
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	Native	8	I	I

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

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the 2019 point-intercept survey on Shishebogama Lake, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 69% of the point-intercept locations in 15 feet of water or less contained organic sediments, 24% contained sand, and 7% contained rock (Map 7). Sampling locations with sand and/or rock were primarily located in near-shore areas of the lake. The combination of both soft and hard substrates in Shishebogama Lake creates habitat types which support different aquatic plant community assemblages.

Table 3.5-2. Submergent and free-floating aquatic plant species located in Shishebogama Lake during the 2009 and 2019 aquatic plant surveys by Onterra.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2009	2019
Submergent	*Bidens beckii*	Water marigold	Native	8	X	X
	Ceratophyllum demersum	Coontail	Native	3	X	X
	Chara spp.	Muskgrasses	Native	7	X	X
	Elatine minima	Waterwort	Native	9	X	I
	Elodea canadensis	Common waterweed	Native	3	X	X
	Eriocaulon aquaticum	Pipewort	Native	9	X	X
	Gratiola aurea	Golden pert	Native	10		I
	Heteranthera dubia	Water stargrass	Native	6	X	X
	Isoetes spp.	Quillwort spp.	Native	8	X	X
	Lobelia dortmanna	Water lobelia	Native	10	X	I
	Myriophyllum alterniflorum	Alternate-flowered watermilfoil	Native	10	X	I
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X
	Myriophyllum verticillatum	Whorled watermilfoil	Native	8	X	
	Najas flexilis	Slender naiad	Native	6	X	X
	Nitella spp.	Stoneworts	Native	7	X	X
	Potamogeton alpinus	Alpine pondweed	Native	9		I
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X
	Potamogeton berchtoldii	Slender pondweed	Native	7		X
	Potamogeton epihydrus	Ribbon-leaf pondweed	Native	8	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6		X
	Potamogeton friesii	Fries' pondweed	Native	8	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X
	Potamogeton praelongus x *P. richardsonii*	White-stem x Clasping-leaf pondweed	Native	N/A	X	X
	Potamogeton pusillus	Small pondweed	Native	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X
	Potamogeton spirillus	Spiral-fruited pondweed	Native	8	X	X
	*Potamogeton vaseyi**	Vasey's pondweed	Native - Special Concern	10	X	X
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8	X	X
	Ranunculus flammula	Creeping spearwort	Native	9	X	I
	Sagittaria sp. (rosette)	Arrowhead sp. (rosette)	Native	N/A	X	X
	Stuckenia pectinata	Sago pondweed	Native	3	X	X
	Utricularia intermedia	Flat-leaf bladderwort	Native	9	X	
	Utricularia vulgaris	Common bladderwort	Native	7	X	X
	Vallisneria americana	Wild celery	Native	6	X	X
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	X	X
	Juncus pelocarpus	Brown-fruited rush	Native	8	X	X
	Sagittaria cristata	Crested arrowhead	Native	9	X	
	Sagittaria graminea	Grass-leaved arrowhead	Native	9	I	
	Schoenoplectus subterminalis	Water bulrush	Native	9	X	X
FF	*Lemna minor*	Lesser duckweed	Native	5	X	
	Lemna trisulca	Forked duckweed	Native	6	X	X
	Lemna turionifera	Turion duckweed	Native	2		X
	Spirodela polyrhiza	Greater duckweed	Native	5	X	

S/E = Submergent and Emergent; FF = Free Floating

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey

** = Species listed as special concern by WI Natural Heritage inventory*

The maximum depth of aquatic plant growth in Shishebogama Lake in 2019 was 19 feet, slightly deeper than the maximum depth of 17 feet recorded in 2009. The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. Shishebogama Lake's mean Secchi disk depth in 2019 was 9.5 feet and 10.7 feet in 2009. As is discussed in the Water Quality Section (3.1), Shishebogama Lake's Secchi disk depth from 2015-2019 of 8.2 feet was 1.4 feet lower when compared to the average from 1999-2014. Despite this decline in water clarity, the maximum depth of aquatic plant growth was not reduced in 2019. However, the 2019 survey did reveal that the overall occurrence of aquatic plants in Shishebogama Lake, particularly in deeper areas of the littoral zone, declined markedly between the 2009 and 2019 surveys.

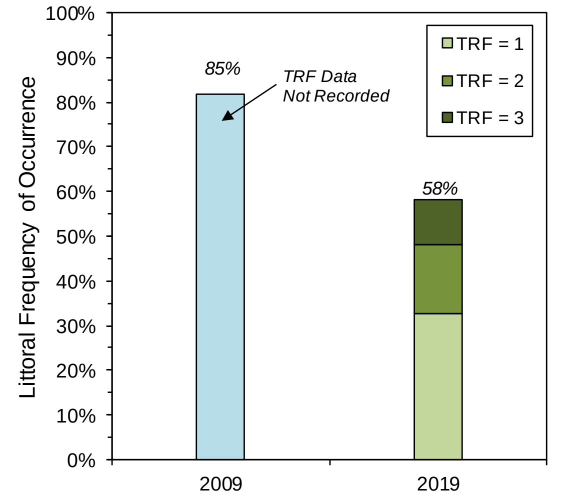


Figure 3.5-2 Shishebogama Lake littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings.

In 2009, 85% of the point-intercept survey sampling locations that fell within the littoral zone contained aquatic vegetation (Figure 3.5-2 and Map 8). In 2019, this percentage declined to 58%, indicating that the littoral frequency of occurrence of aquatic plants in Shishebogama Lake had declined by 32%. While total rake fullness (TRF) ratings had not been part of the standard point-intercept survey protocol in 2009, the higher proportion of TRF ratings of 1 in 2019 indicate that the overall biomass of aquatic plants in Shishebogama Lake was relatively low. Figure 3.5-3 illustrates that the majority of the vegetation loss in Shishebogama Lake between 2009 and 2019 has been in the deepest areas of the littoral zone, between 12 and 17 feet.

The reduction in the occurrence of aquatic plant growth in deeper areas of Shishebogama Lake's littoral zone likely indicates reduced light availability at these depths in 2019 when compared to 2009. As discussed in the Water Quality Section (3.1), recent reductions in the lake's water clarity are believed to be due to increases in dissolved organic matter (DOM) which decrease light penetration. Water levels on area lakes have also increased in recent years, and while water level data are not available from Shishebogama Lake, it is possible increases in water levels have also resulted in decreased light availability in deeper areas of the littoral zone. While aquatic plant occurrence has declined in Shishebogama Lake between 2009 and 2019, these declines are believed to be driven by natural environmental factors and are not the result of human activity.

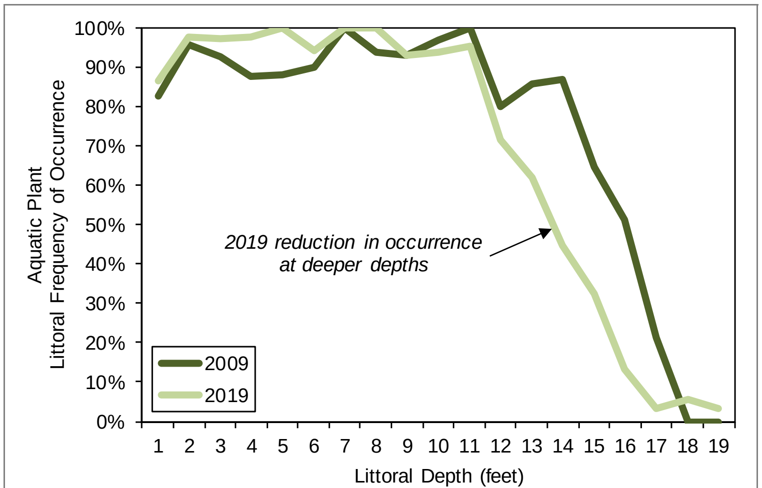


Figure 3.5-3 Shishebogama Lake aquatic plant littoral frequency of occurrence across littoral water depth. This figure illustrates the reduction in aquatic plant occurrence in deeper areas of Shishebogama Lake's littoral zone between 2009 and 2019.

The data collected in the 2009 and 2019 point-intercept surveys can also be used to compare how the occurrence of individual species have changed between these two years. Species that had a littoral frequency of occurrence of approximately 5% or higher in at least one of the survey years are included in this analysis (Figure 3.5-3). Some species data may be combined for analysis due to similar morphology making accurate field identification difficult. This decision is made on a case-by-case basis and can vary by lake. For Shishebogama

Lake, slender pondweed (*Potamogeton berchtoldii*) and small pondweed (*P. pusillus)* data were combined for analysis because of their morphological similarity.

Of the 20 aquatic plant species in Shishebogama Lake that had a littoral frequency of occurrence of approximately 5% or greater, 11 exhibited statistically valid declines in their occurrence between the 2009 and 2019 surveys (Figure 3.5-4).These include coontail (35% decrease), fern-leaf pondweed (44% decrease), stoneworts (65% decrease), flat-stem pondweed (63% decrease), northern watermilfoil (55% decrease), variable-leaf pondweed (34% decrease), clasping-leaf pondweed (38% decrease), spatterdock (75% decrease), watershield (51% decrease), pickerelweed (49% decrease), and Fries' pondweed (89% decrease). One species, common waterweed, exhibited a statistically valid increase of 104% in its occurrence between 2009 and 2019, while the occurrences of the remaining eight species were not statistically different.

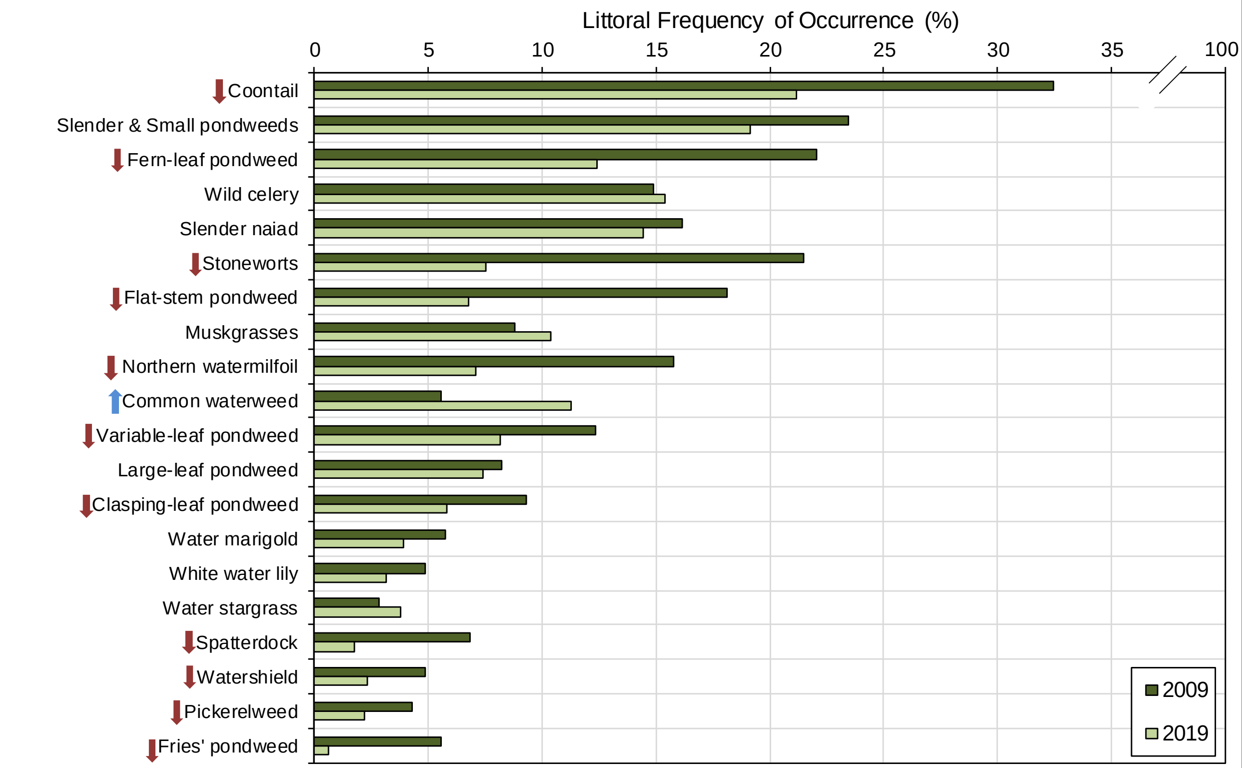


Figure 3.5-4. Littoral frequency of occurrence of most prevalent aquatic plant species in the 2009 and 2019 surveys of Shishebogama Lake. Red arrow indicates statistically valid reduction in occurrence, blue arrow indicates statistically valid increase in occurrence, and no arrow indicates occurrence is not statistically different. Chi-square analysis (α = 0.05) used to determine statistical validity.

In 2009, the majority of the coontail and stonewort populations were in deeper areas of Shishebogama Lake's littoral zone, and the occurrence of both of these species declined in these deeper areas in 2019. Populations of fern-leaf pondweed, flat-stem pondweed, northern watermilfoil, variable-leaf pondweed, and clasping-leaf pondweed were all found at moderate depths of the littoral zone in 2009, and these species decreased across all depths in 2019. The populations of common waterweed, which increased in occurrence in 2019, and wild celery, slender naiad, and muskgrasses, which did not change in 2019, are found in shallower areas of the littoral zone where light availability likely remained high. Populations of spatterdock, watershield, and pickerelweed are found in the shallowest areas of the lake's littoral zone, and these species declined in their occurrence in 2019. As is discussed later in this section, the 2019 surveys found that emergent and floating-leaf plant communities in Shishebogama Lake have contracted slightly when compared to 2009. This contraction could be associated with higher water levels in recent years.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul & Freedman, 2006).

Prior to the 2019 surveys, concern was expressed by the SGLA to Onterra ecologists about the excessive growth and surface matting of small pondweed (*Potamogeton pusillus*) in certain areas of Shishebogama Lake and the navigation challenges it was causing (Figure 3.5-5). During the 2019 point-intercept survey, Onterra crews paid particular attention to this species and did observe some large colonies and at least one area where it was matting on the surface.

The point-intercept survey data indicates that the overall lake-wide occurrence of small pondweed was not statistically different from 2009 to 2019, with a littoral frequency of occurrence of 24% and 19%, respectively (Figure 3.5-5). The rake fullness ratings for small pondweed also do not indicate an increase in biomass, at least on a lake-wide level (Figure 3.5-5). These data are on a lake-wide scale and may not capture the changes in biomass on the scale observed by SGLA members.

Map 12 displays locations of small pondweed and the corresponding rake fullness rating. In 2019, no specific bay or shoreline was found to harbor a higher biomass of small pondweed, and in general small pondweed is fairly evenly distributed around the lake. These data indicate that any presence of nuisance level abundance of small pondweed on Shishebogama Lake in 2019 was occurring on a small, isolated scale that was not captured by the whole-lake point-intercept survey.

Onterra ecologists have observed small pondweed exhibiting this excessive growth periodically on other area lakes. However, like on Shishebogama Lake, the growth is isolated to small areas and generally does not cover large areas of the lake. While

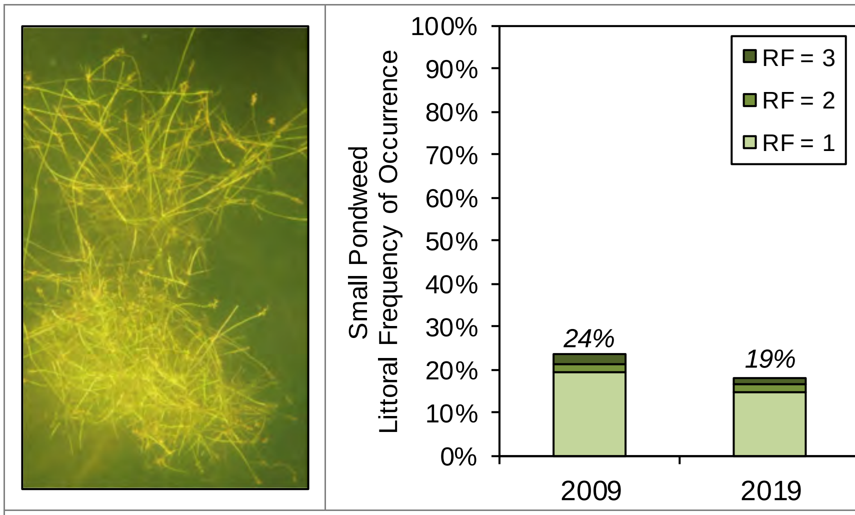
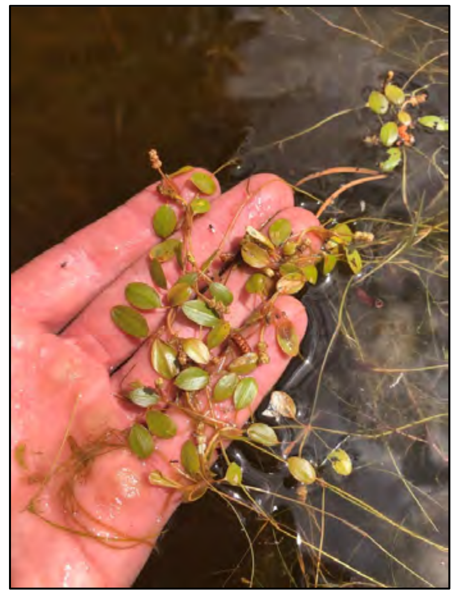


Figure 3.5-5. A large clump of small pondweed (*Potamogeton pusillus*) growing near the surface in Shishebogama Lake (left), and littoral occurrence and rake fullness (RF) ratings (right).. Photograph credit Onterra July 2019.

the conditions which lead to this abundant growth are not understood, this does not occur every year, and SGLA members can likely anticipate that most years will not see this level of growth of small pondweed. Small pondweed is highly beneficial in terms of structural habitat and a food source for wildlife, so if watercraft are able to navigate around colonies which grow near the surface, that would be the most ecologically beneficial solution in years when abundant growth is present.

In both the 2009 and the 2019 survey on Shishebogama Lake, Vasey's pondweed (*Potamogeton vaseyi*), a native species listed as special concern by the Wisconsin National Heritage Inventory, was observed (Photograph 3.5-3). Vasey's pondweed had a littoral frequency of occurrence of just 0.4% in 2009, but in 2019 it increased to a littoral frequency of occurrence of 2.8%. Vasey's pondweed produces very thin and pointed leaves that alternate along a slender stem. In instances when it is able to reach the surface, it frequently produces small oval to oblong floating leaves no larger than a human thumbnail. When floating leaves are produced, they often support a small cluster of flowers on a stalk which are held above the water's surface. In Wisconsin, Vasey's pondweed is generally found in lakes in the northern and central regions of the state. It is currently listed as special concern due to uncertainty about the status of its population in Wisconsin.



Photograph 3.5-3 Vasey's pondweed (*Potamogeton vaseyi*) with floating leaves and flowering stalks present. Photograph credit: Onterra.

Data collected during the aquatic plant surveys was also used to complete a Floristic Quality Assessment (FQA), which incorporates the number of native aquatic plant species recorded on the rake during the point-intercept survey and their average conservatism. The data used for these calculations does not include any incidental species (visual observations) but only considers plants that were sampled on the rake during the survey. For instance, while a total of 64 native species were located in Shishebogama Lake in 2019, 43 were physically encountered on the rake while the remaining 21 species were located incidentally. Figure 3.5-6 displays the species richness, average conservatism, and floristic quality of Shishebogama Lake along with ecoregion and state median values.

Shishebogama Lake's Floristic Quality Analysis components are well above the median values for both the ecoregion and the state (Figure 3.5-6). In 2009, 54 species were recorded on the rake during the point-intercept survey compared to 43 in 2019. The reduction in the number of species recorded on the rake between 2009 and 2019 is likely the result of overall aquatic plant occurrence declining between these two surveys, as discussed earlier. These species did not disappear from Shishebogama Lake as most of them were recorded as incidentals in 2019, rather they were likely present in lower abundance when compared in 2009. As mentioned previously, of the 77 total species recorded between the two surveys, 55 were recorded in both surveys.

Average conservatism is another important measurement that can be calculated from data collected from the point-intercept survey and speaks to the habitat quality of the lake. Both the 2009 and 2019 surveys yielded an average conservatism value of 6.7, identical to the ecoregion median and slightly above the statewide median of 6.3. The high average conservatism values calculated for Shishebogama Lake indicate that the lake maintains a plant community comprised of a high number of environmentally-sensitive species. Using these values to calculate the floristic quality for the lake results in values of 48.9 in 2009 and 44.1 for 2019, once again, well above the ecoregion and state median values. While the floristic quality was lower in 2019 compared to 2009, this was due to the lower number of species recorded on the rake. As discussed previously, the reduction in the overall occurrence of vegetation in Shishebogama Lake in 2019 is due to natural changes in environmental conditions, and not an indication of environmental degradation due to human activity.

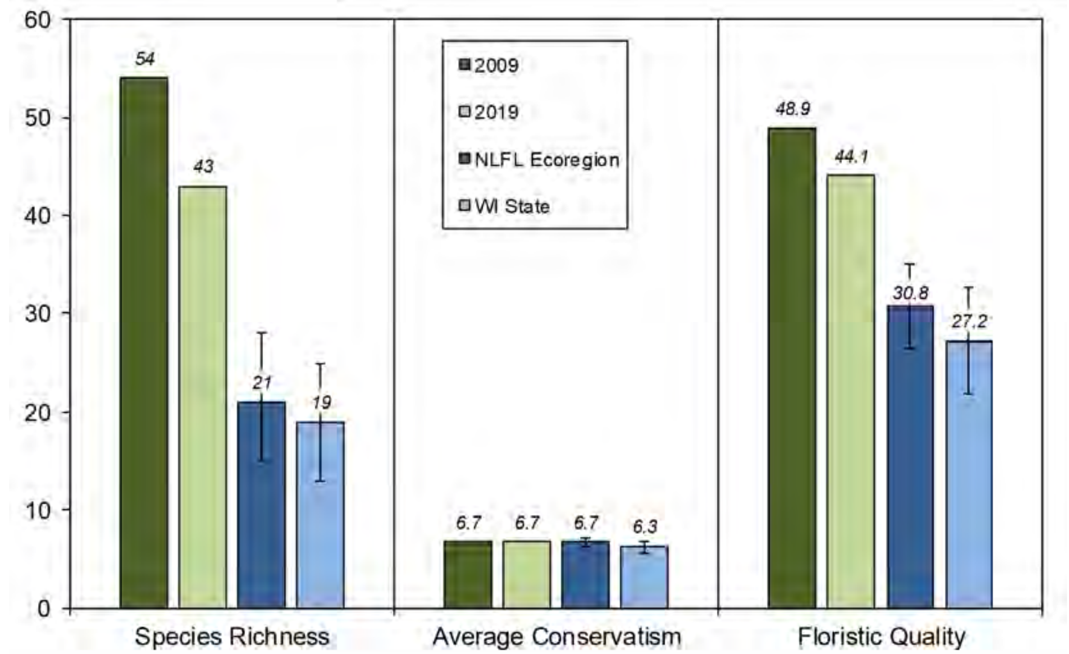


Figure 3.5-6. Floristic Quality Assessment (FQA) of Shishebogama Lake. Includes survey data from 2009 and 2019 point-intercept surveys by Onterra. Analysis follows Nichols (1999).

Simpson's Diversity Index is a measure of both the number of aquatic plant species in a given community and their abundance. This measurement is important because plant communities with higher diversity are believed to be more resilient to disturbances and natural fluctuations that affect plant growth (e.g., changes water clarity, water levels, etc.). Plant communities with higher diversity also provide more diversity in habitat types and food sources for invertebrates, fish, and other wildlife. Higher species diversity leads to a healthier and more adaptive system that is resistant to disturbance and more stable over time. Unlike species richness which is simply the number of aquatic plant species within the community, species diversity considers how evenly those species are distributed throughout the community.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Shishebogama Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.5-7). The Simpson's Diversity Index values were calculated for Shishebogama Lake using the 2009 and 2019 point-intercept survey data. Shishebogama Lake's species diversity was identical in both years at 0.94, falling above the 75th percentile for lakes in the NLFL ecoregion. In other words, if two aquatic plants were randomly sampled from Shishebogama Lake, there would be a 94% probability that they would be two different species.

One way to visualize the diversity of Shishebogama Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species (Figure 3.5-8). Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while coontail was found at 21% of the littoral sampling locations in Shishebogama Lake in 2019 (littoral occurrence), its relative frequency of occurrence was 12%. Explained another way, of 100 plants were randomly sampled from Shishebogama Lake in 2019, 12 of them would have been coontail, 10 small pondweed, 7 fern-leaf pondweed, etc. If only a few species comprised the majority of the lake's plant community, diversity would be lower.

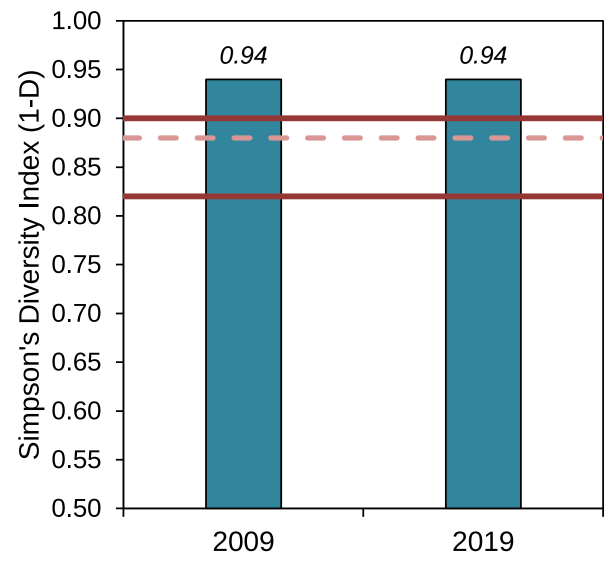


Figure 3.5-7. Simpson's Diversity Index for Shishebogama Lake. Created using data from 2009 and 2019 point-intercept surveys.

In 2019, Onterra ecologists also conducted a survey aimed at re-mapping emergent and floating-leaved plant communities in Shishebogama Lake (Photograph 3.5-4). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies. Like submersed aquatic plat communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosions control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

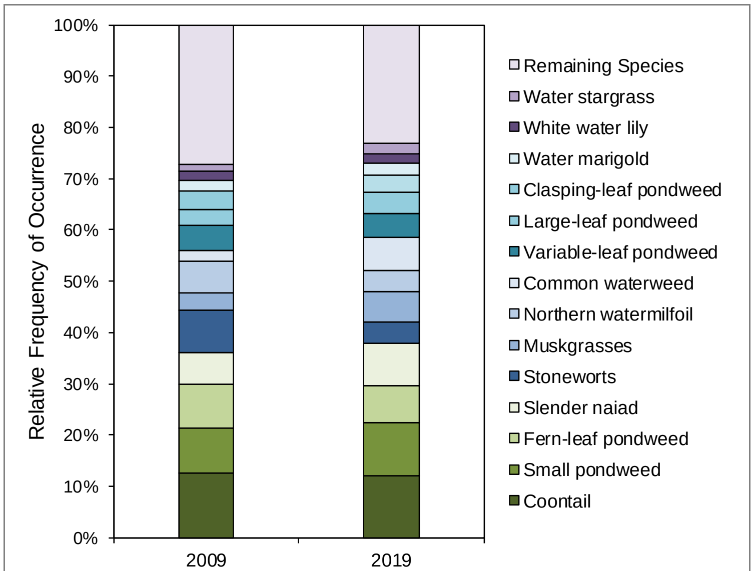


Figure 3.5-8. Relative frequency of occurrence of aquatic vegetation in Shishebogama lake. Created using data from 2009 and 2019 point-intercept surveys.

This is important to note because these communities are often negatively affected by recreational use and shoreland development. Radmoski & Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes.

Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

Photograph 3.5-4. Emergent aquatic plant community on Shishebogama Lake. Photograph credit Onterra 2019.

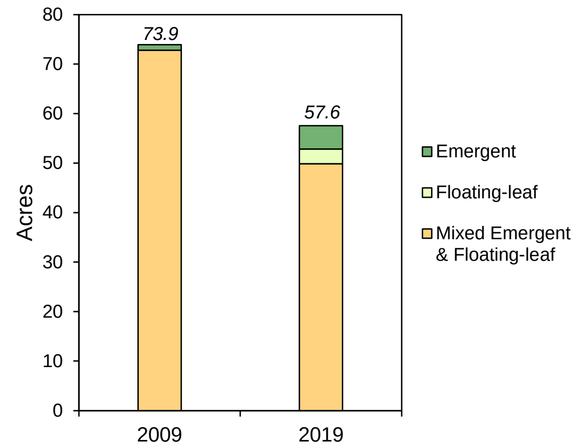


Figure 3.5-9. Acres of floating-leaf and emergent plant communities on Shishebogama lake. Data from 2009 and 2019 community mapping surveys conducted by Onterra.

In 2009, approximately 73.9 acres of emergent and floating-leaf aquatic plant communities were delineated in Shishebogama Lake (Figure 3.5-9 and Maps 9 and 10). In 2019, the acreage of these communities was found to have declined to 57.6 acres, a decline of over 16 acres between the 10-year period. This decline in acreage appears to be distributed amongst communities throughout the lake, and it does not appear that one area of the lake in particular accounts for this loss in acreage.

Examination of the 2009 and 2019 data together shows that many of the emergent and floating-leaf communities contracted shoreward between the two surveys (Figure 3.5-5). Emergent and floating-leaf plant communities often contract shoreward in response to higher water levels. As water levels rise, these communities retract as water at their lakeward extent becomes too deep. In contrast, these communities often expand during periods of lower water levels. Water levels in lakes across Wisconsin have been higher in recent years, and this is the primary factor causing the observed declines in emergent and floating-leaf acreage in Shishebogama Lake between 2009 and 2019.

Figure 3.5-10. Emergent and floating-leaf plant communities in northeast portion of Shishebogama Lake from 2009 (red dashed polygons) and 2019 (green polygons). This image illustrates the shoreward retraction of these communities between 2009 and 2019. This is likely due to water level fluctuations that have occurred over this period.

Gunlock Lake

The first survey completed on Gunlock Lake was an early-season aquatic invasive species (ESAIS) survey completed on June 25, 2019. The goal of this survey was to identify and assess any new or existing occurrences of invasive plant species in the lake, with a particular focus on species that are most likely to be observed at this time of year: curly-leaf pondweed and pale-yellow iris. During this survey, Onterra ecologists did not observe any occurrences of curly-leaf pondweed or Eurasian watermilfoil. While numerous occurrences of pale-yellow iris were located along portions of Shishebogama Lake's shoreline, no occurrences of pale-yellow iris were located along the shorelines of Gunlock Lake. However, a sterile iris species was located later in the summer during the emergent and floating-leaf aquatic plant community mapping survey. Flowers and/or fruits are needed to distinguish between pale-yellow iris and our native blue-flag iris species. This location should be monitored in the future for the development of flowers so a positive identification can be made.

The 2019 whole-lake point-intercept survey on Gunlock Lake was completed LDF NRD staff, and the data were shared with Onterra for analysis and inclusion in this updated management plan. The emergent and floating-leaf community mapping survey was completed by Onterra on August 13, 2019. During the 2019 surveys, a total of 45 aquatic plant species were located in Gunlock Lake, two of which are considered to be non-native, invasive species: purple loosestrife and narrow-leaved cattail (Table 3.5-3 and Table 3.5-4). These non-native plants are discussed in the Non-Native Aquatic Plants Section. Tables 3.5-3 and 3.5-4 also contain the list of the 56 aquatic plant species that were recorded during the 2009 surveys completed by Onterra. Taking both survey years together, a total of 64 aquatic plant species have been identified from Gunlock Lake, with 38 of these species being recorded in both 2009 and 2019.

Lakes in Wisconsin vary in their morphometry, water chemistry, water clarity, substrate composition, management, and recreational use, all factors which influence aquatic plant community composition. Like terrestrial plants, different aquatic plant species are adapted to grow in certain substrate types; some species are only found growing in soft substrates, others only in sandy/rocky areas, and some can be found growing in either. The combination of both soft sediments and areas of harder substrates creates different habitat types for aquatic plants, and generally leads to a higher number of aquatic plant species within the lake.

During the 2019 point-intercept survey on Gunlock Lake, information regarding substrate type was collected at locations sampled with a pole-mounted rake (less than 15 feet). These data indicate that 82% of the point-intercept locations in 15 feet of water or less contained organic sediments, 16% contained sand, and 2% contained rock (Map 7). Sampling locations with sand and/or rock were primarily located in near-shore areas of the lake. The combination of both soft and hard substrates in Gunlock Lake creates habitat types which support different aquatic plant community assemblages.

The maximum depth of aquatic plant growth in Gunlock Lake in 2019 was 17 feet, comparable to the maximum depth of plants recorded in 2009 of 16 feet. The maximum depth of plant growth is largely going to be determined by water clarity. In general, aquatic plants grow to a depth of two to three times the average Secchi disk depth. There has been a slight decline in Gunlock Lake's growing season Secchi disk depths between 2009 and 2019, decreasing from an average of 10.0 feet to 7.7 feet. Despite this decline in water clarity, the maximum depth of aquatic plant growth was not reduced in 2019. However, like Shishebogama Lake, the occurrence of aquatic plants in deeper areas of Gunlock Lake's littoral zone declined in 2019.

Table 3.5-1. Emergent and floating-leaf aquatic plant species located in Gunlock Lake during the 2009 and 2019 aquatic plant surveys by Onterra.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2009	2019
Emergent	*Calla palustris*	Water arum	Native	9	I	I
	Carex comosa	Bristly sedge	Native	5	I	
	Carex lasiocarpa	Narrow-leaved woolly sedge	Native	9	I	
	Carex pseudocyperus	Cypress-like sedge	Native	8		I
	Carex vesicaria	Blister sedge	Native	7	X	
	Dulichium arundinaceum	Three-way sedge	Native	9	X	I
	Eleocharis palustris	Creeping spikerush	Native	6	I	I
	Juncus effusus	Soft rush	Native	4		I
	Lythrum salicaria	Purple loosestrife	Non-Native - Invasive	N/A	I	I
	Pontederia cordata	Pickerelweed	Native	9	X	X
	Sagittaria latifolia	Common arrowhead	Native	3	I	I
	Schoenoplectus acutus	Hardstem bulrush	Native	5	X	I
	Schoenoplectus tabernaemontani	Softstem bulrush	Native	4		X
	Scirpus cyperinus	Wool grass	Native	4		I
	Sparganium eurycarpum	Common bur-reed	Native	5	I	
	Typha angustifolia	Narrow-leaved cattail	Non-Native - Invasive	N/A	X	
	Typha latifolia	Broad-leaved cattail	Native	1	I	
FL	*Brasenia schreberi*	Watershield	Native	7	X	X
	Nuphar variegata	Spatterdock	Native	6	X	X
	Nymphaea odorata	White water lily	Native	6	X	X
	Sparganium angustifolium	Narrow-leaf bur-reed	Native	9	X	I
	Sparganium fluctuans	Floating-leaf bur-reed	Native	10	X	X
FL/E	*Sparganium emersum* var. *acaule*	Short-stemmed bur-reed	Native	8	I	

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

In 2009, 87% of the point-intercept survey sampling locations that fell within the littoral zone contained aquatic vegetation (Figure 3.5-11 and Map 8). In 2019, this percentage declined to 68%, indicating that the littoral frequency of occurrence of aquatic plants in Gunlock Lake had declined by 22%. While total rake fullness (TRF) ratings had not been part of the standard point-intercept survey protocol in 2009, the higher proportion of TRF ratings of 1 in 2019 indicate that the overall biomass of aquatic plants in Gunlock Lake was relatively low. Figure 3.5-12 illustrates that the majority of the vegetation loss in Gunlock Lake between 2009 and 2019 has been in the deepest areas of the littoral zone, between 11 and 17 feet.

The reduction in the occurrence of aquatic plant growth in deeper areas of Gunlock Lake's littoral zone likely indicates reduced light availability at these depths in 2019 when compared to 2009. As discussed in the Water Quality Section (3.1), recent reductions in the lake's water clarity are believed to be due to increases in dissolved organic matter (DOM) which decrease light penetration. Water levels on area lakes have also increased in recent years, and while water level data are not available from Gunlock Lake, it is possible increases in water levels have also resulted in decreased light availability in deeper areas of the littoral zone. While aquatic plant occurrence has declined in Gunlock Lake between 2009 and 2019, these declines are believed to be driven by natural environmental factors and are not the result of human activity.

Table 3.5-2. Submergent and free-floating aquatic plant species located in Gunlock Lake during the 2009 and 2019 aquatic plant surveys by Onterra.

Growth Form	Scientific Name	Common Name	Status in Wisconsin	Coefficient of Conservatism	2009	2019
Submergent	*Bidens beckii*	Water marigold	Native	8	X	X
	Ceratophyllum demersum	Coontail	Native	3	X	X
	Chara spp.	Muskgrasses	Native	7	X	X
	Elatine minima	Waterwort	Native	9	X	
	Elodea canadensis	Common waterweed	Native	3	X	X
	Heteranthera dubia	Water stargrass	Native	6	X	X
	Isoetes lacustris	Lake quillwort	Native	8	X	
	Myriophyllum alterniflorum	Alternate-flowered watermilfoil	Native	10		X
	Myriophyllum sibiricum	Northern watermilfoil	Native	7	X	X
	Myriophyllum tenellum	Dwarf watermilfoil	Native	10	X	X
	Najas flexilis	Slender naiad	Native	6	X	X
	Nitella spp.	Stoneworts	Native	7	X	X
	Potamogeton alpinus	Alpine pondweed	Native	9	X	
	Potamogeton amplifolius	Large-leaf pondweed	Native	7	X	X
	Potamogeton foliosus	Leafy pondweed	Native	6	X	X
	Potamogeton friesii	Fries' pondweed	Native	8	X	X
	Potamogeton gramineus	Variable-leaf pondweed	Native	7	X	X
	Potamogeton praelongus x *P. richardsonii*	White-stem x Clasing-leaf pondweed	Native	N/A	X	
	Potamogeton illinoensis	Illinois pondweed	Native	6	X	
	Potamogeton natans	Floating-leaf pondweed	Native	5	X	
	Potamogeton praelongus	White-stem pondweed	Native	8	X	X
	Potamogeton pusillus	Small pondweed	Native	7	X	X
	Potamogeton richardsonii	Clasping-leaf pondweed	Native	5	X	X
	Potamogeton robbinsii	Fern-leaf pondweed	Native	8	X	X
	Potamogeton vaseyi	Vasey's pondweed	Native - Special Concern	10	X	
	Potamogeton zosteriformis	Flat-stem pondweed	Native	6	X	X
	Ranunculus aquatilis	White water crowfoot	Native	8	X	X
	Ranunculus flammula	Creeping spearwort	Native	9	X	X
	Utricularia gibba	Creeping bladderwort	Native	9		X
	Utricularia intermedia	Flat-leaf bladderwort	Native	9	X	
	Utricularia minor	Small bladderwort	Native	10		X
	Utricularia vulgaris	Common bladderwort	Native	7	X	X
	Vallisneria americana	Wild celery	Native	6	X	X
SE	*Eleocharis acicularis*	Needle spikerush	Native	5	X	
	Juncus pelocarpus	Brown-fruited rush	Native	8	X	X
	Sagittaria cristata	Crested arrowhead	Native	9	X	X
	Sagittaria graminea	Grass-leaved arrowhead	Native	9	I	
FF	*Lemna minor*	Lesser duckweed	Native	5	X	X
	Lemna trisulca	Forked duckweed	Native	6	X	X
	Spirodela polyrhiza	Greater duckweed	Native	5	X	

X = Located on rake during point-intercept survey; I = Incidentally located; not located on rake during point-intercept survey
SE = Submergent or Emergent; FF = Free-floating

The data collected in the 2009 and 2019 point-intercept surveys can also be used to compare how the occurrence of individual species have changed between these two years. Species that had a littoral frequency of occurrence of approximately 5% or higher in at least one of the survey years are included in this analysis (Figure 3.5-13). Of the 20 aquatic plant species in Gunlock Lake that had a littoral frequency of occurrence of approximately 5% or greater, seven exhibited statistically valid declines in their occurrence between the 2009 and 2019 surveys. These include flat-stem pondweed (58% decrease), stoneworts (42% decrease), spatterdock (41% decrease), white water lily (52% decrease), clasping-leaf pondweed (64% decrease), variable-leaf pondweed (67% decrease), and hardstem bulrush (100% decrease).

Four species exhibited statistically valid increases in their littoral occurrence between 2009 and 2019, and include: small pondweed (515% increase), common waterweed (54% increase), wild celery (89% increase), and water marigold (199% increase). The occurrences of the remaining nine species were not statistically different between 2009 and 2019.

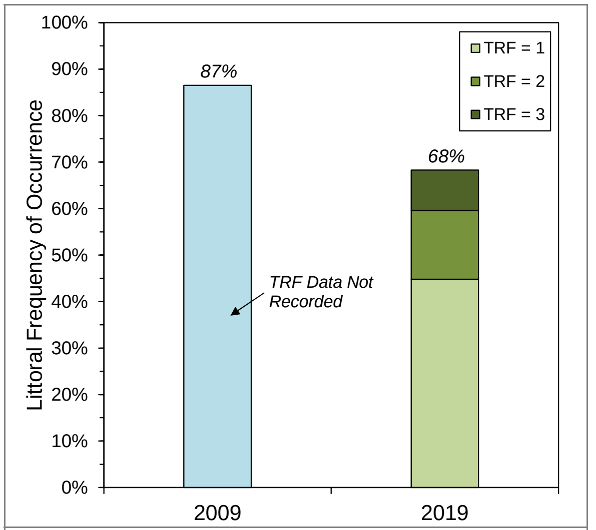


Figure 3.5-11 Gunlock Lake littoral frequency of occurrence of aquatic vegetation and total rake fullness (TRF) ratings.

The data that continues to be collected from Wisconsin lake's is revealing that aquatic plant communities are highly dynamic, and populations of individual species have the capacity to fluctuate, sometimes greatly, in their occurrence from year to year and over longer periods of time. These fluctuations are driven by a combination of interacting natural factors including variations in water levels, temperature, ice and snow cover (winter light availability), nutrient availability, changes in water flow, water clarity, length of the growing season, herbivory, disease, and competition (Lacoul & Freedman, 2006).

Prior to the 2019 surveys, concern was expressed by the SGLA to Onterra ecologists about the excessive growth and surface matting of small pondweed (*Potamogeton pusillus*) in certain areas of Shishebogama Lake and the navigation challenges it was causing. The SGLA also indicated that this type of growth had been observed in areas of Gunlock Lake in the past. The 2019 point-intercept data show that the occurrence of small pondweed in Gunlock Lake increased significantly from an occurrence of 4% in 2009 to 26% in 2019. However, unlike Shishebogama Lake, no areas where small pondweed was matting on the surface were observed in Gunlock Lake in 2019.

Onterra ecologists have observed small pondweed exhibiting this excessive growth periodically on other area lakes. This growth is usually isolated to small areas and generally does not cover large areas of the lake. While the conditions which lead to this abundant growth are not understood, this does not occur every year, and SGLA members can likely anticipate that most years will not see this level of growth of small pondweed. Small pondweed is highly beneficial in terms of structural habitat and a food source for wildlife, so if watercraft are able to navigate around colonies which grow near the surface, that would be the most ecologically beneficial solution in years when abundant growth is present.

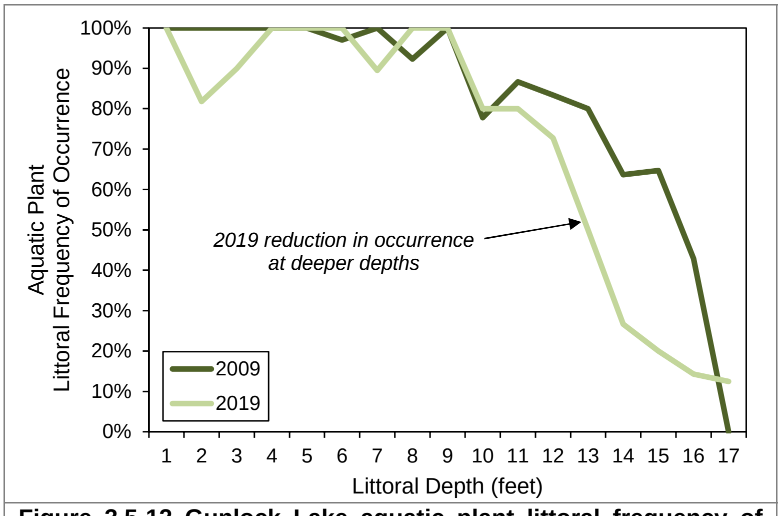


Figure 3.5-12 Gunlock Lake aquatic plant littoral frequency of occurrence across littoral water depth. This figure illustrates the reduction in aquatic plant occurrence in deeper areas of Gunlock Lake's littoral zone between 2009 and 2019.

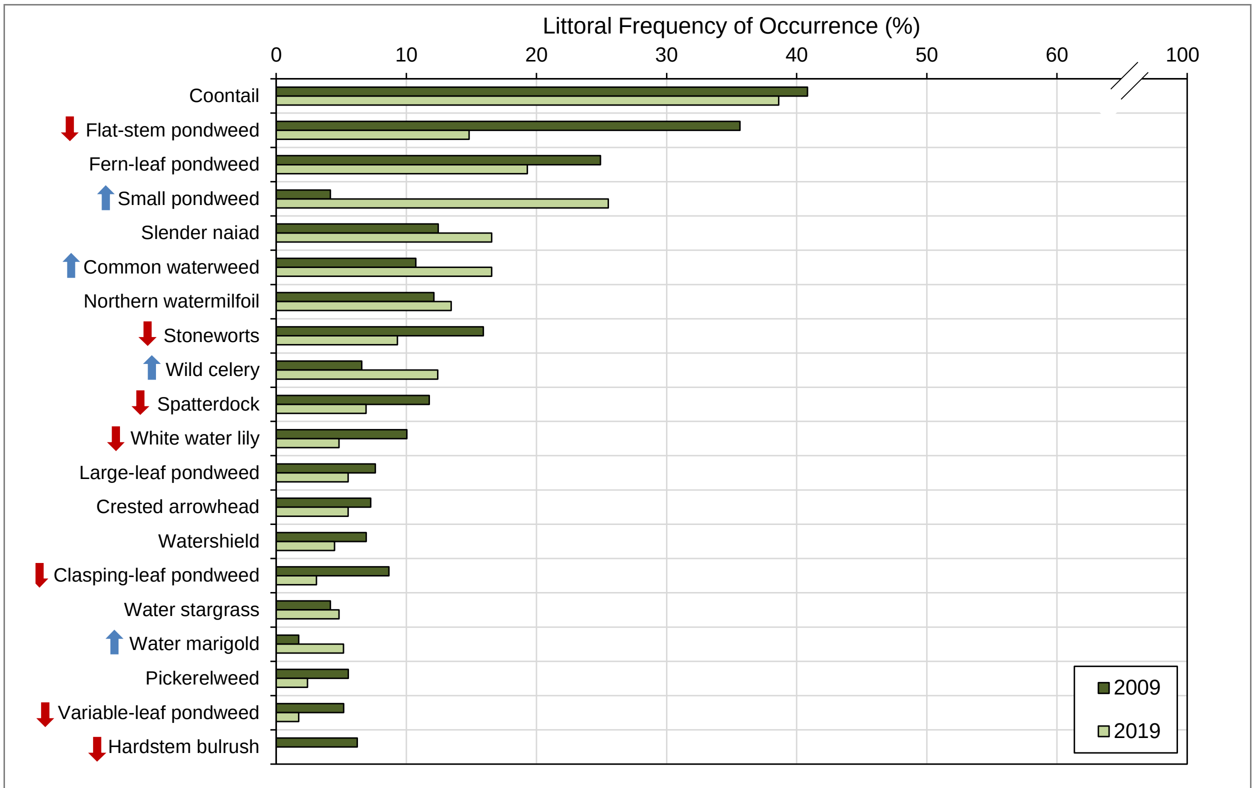


Figure 3.5-13. Littoral frequency of occurrence of most prevalent aquatic plant species in the 2009 and 2019 surveys of Gunlock Lake. Red arrow indicates statistically valid reduction in occurrence, blue arrow indicates statistically valid increase in occurrence, and no arrow indicates occurrence is not statistically different. Chi-square analysis (α = 0.05) used to determine statistical validity. Created using data from Onterra 2009 and LDF NRD 2019 point-intercept surveys.

In the 2009 survey on Gunlock Lake, Vasey's pondweed (*Potamogeton vaseyi*), a native species listed as special concern by the Wisconsin National Heritage Inventory, was observed (Photograph 3.5-3). Vasey's pondweed had a littoral frequency of occurrence of just 0.7% in 2009, and it was not recorded during the point-intercept survey completed in 2019. Vasey's pondweed is likely still present in Gunlock Lake, but its rarity in the community makes the probability of encountering it very low. Vasey's pondweed produces very thin and pointed leaves that alternate along a slender stem. In instances when it is able to reach the surface, it frequently produces small oval to oblong floating leaves no larger than a human thumbnail. When floating leaves are produced, they often support a small cluster of flowers on a stalk which are held above the water's surface. In Wisconsin, Vasey's pondweed is generally found in lakes in the northern and central regions of the state. It is currently listed as special concern due to uncertainty about the status of its population in Wisconsin.

Data collected during the aquatic plant surveys was also used to complete a Floristic Quality Assessment (FQA), which incorporates the number of native aquatic plant species recorded on the rake during the point-intercept survey and their average conservatism. The data used for these calculations does not include any incidental species (visual observations) but only considers plants that were sampled on the rake during the survey. For instance, while a total of 47 native species were located in Gunlock Lake in 2019, 34 were physically encountered on the rake while the remaining 13 species were located incidentally. Figure 3.5-14 displays the species richness, average conservatism, and floristic quality of Gunlock Lake along with ecoregion and state median values.

Gunlock Lake's Floristic Quality Analysis components are well above the median values for both the ecoregion and the state (Figure 3.5-14). In 2009, 46 species were recorded on the rake during the point-intercept survey compared to 34 in 2019. The reduction in the number of species recorded on the rake between 2009 and 2019 may be the result of overall aquatic plant occurrence declining between these two surveys, as discussed earlier. These species did not disappear from Gunlock Lake as most of them were recorded as incidentals in 2019, rather they were likely present in lower abundance when compared in 2009.

Average conservatism is another important measurement that can be calculated from data collected from the point-intercept survey and speaks to the habitat quality of the lake. The average conservatism for Gunlock Lake increased slightly from 6.7 in 2009 to 7.0 in 2019 (Figure 3.5-14). The high average conservatism values calculated for Gunlock Lake indicate that the lake maintains a plant community comprised of a high number of environmentally-sensitive species. Using these values to calculate the floristic quality for the lake results in values of 45.4 in 2009 and 40.8 for 2019, once again, well above the ecoregion and state median values. While the floristic quality was lower in 2019 compared to 2009, this was due to the lower number of species recorded on the rake. As discussed previously, the reduction in the overall occurrence of vegetation in Gunlock Lake in 2019 is due to natural changes in environmental conditions, and not an indication of environmental degradation due to human activity.

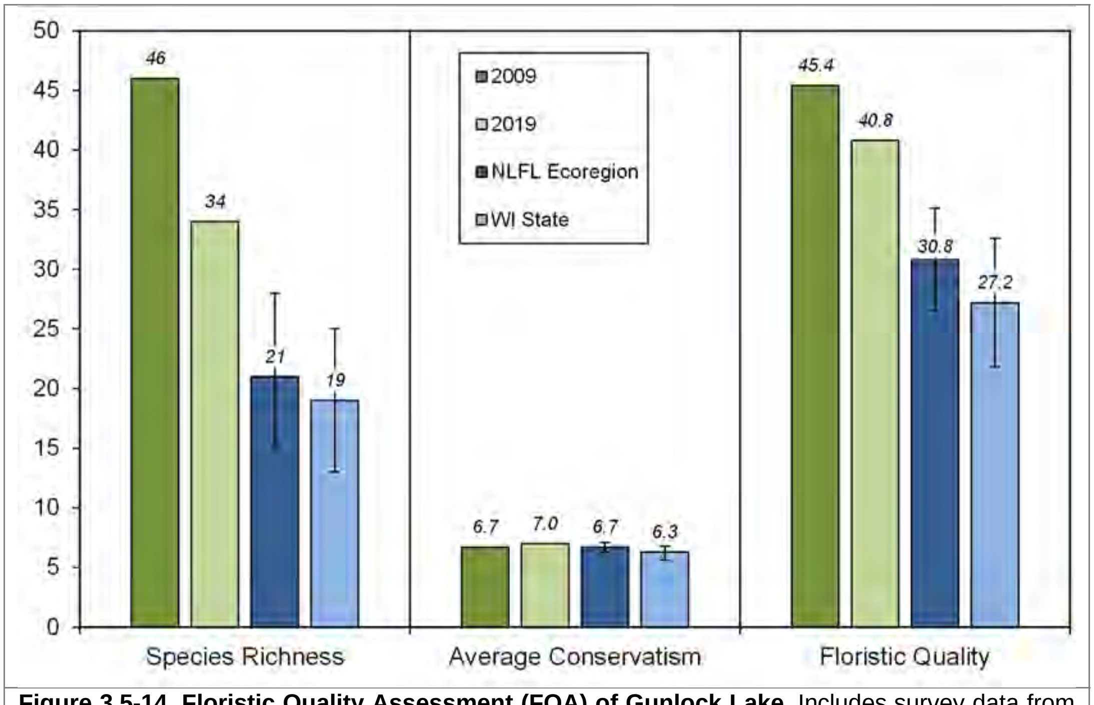


Figure 3.5-14. Floristic Quality Assessment (FQA) of Gunlock Lake. Includes survey data from 2009 and 2019 point-intercept surveys by Onterra. Analysis follows (Nichols, 1999).

Simpson's Diversity Index is a measure of both the number of aquatic plant species in a given community and their abundance. This measurement is important because plant communities with higher diversity are believed to be more resilient to disturbances and natural fluctuations that affect plant growth (e.g., changes water clarity, water levels, etc.). Plant communities with higher diversity also provide more diversity in habitat types and food sources for invertebrates, fish, and other wildlife. Higher species diversity leads to a healthier and more adaptive system that is resistant to disturbance and more stable over time. Unlike species richness which is simply the number of aquatic plant species within the community, species diversity considers how evenly those species are distributed throughout the community.

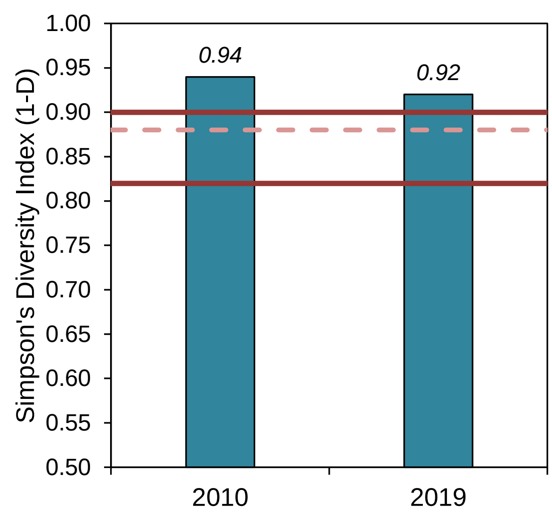


Figure 3.5-15. Simpson's Diversity Index for Gunlock Lake. Created using data from 2009 and 2019 point-intercept surveys.

While a method for characterizing diversity values of fair, poor, etc. does not exist, lakes within the same ecoregion may be compared to provide an idea of how Gunlock Lake's diversity values rank. Using data collected by Onterra and WDNR Science Services, quartiles were calculated for 212 lakes within the NLFL Ecoregion (Figure 3.5-15). The Simpson's Diversity Index values were calculated for Gunlock Lake using the 2009 and 2019 point-intercept survey data. Gunlock Lake's species diversity was high in both years with values of 0.94 in 2009 and 0.92 in 2019, falling above the 75th percentile for lakes in the NLFL ecoregion. In other words, if two aquatic plants were randomly sampled from Gunlock Lake in 2019, there would be a 92% probability that they would be two different species.

One way to visualize the diversity of Gunlock Lake's plant community is to examine the relative frequency of occurrence of aquatic plant species (Figure 3.5-16). Relative frequency of occurrence is used to evaluate how often each plant species is encountered in relation to all the other species found. For example, while coontail was found at 41% of the littoral sampling locations in Gunlock Lake in 2019 (littoral occurrence), its relative frequency of occurrence was 17%. Explained another way, of 100 plants were randomly sampled from Gunlock Lake in 2019, 17 of them would have been coontail, 11 small pondweed, 8 fern-leaf pondweed, etc. If only a few species comprised the majority of the lake's plant community, diversity would be lower.

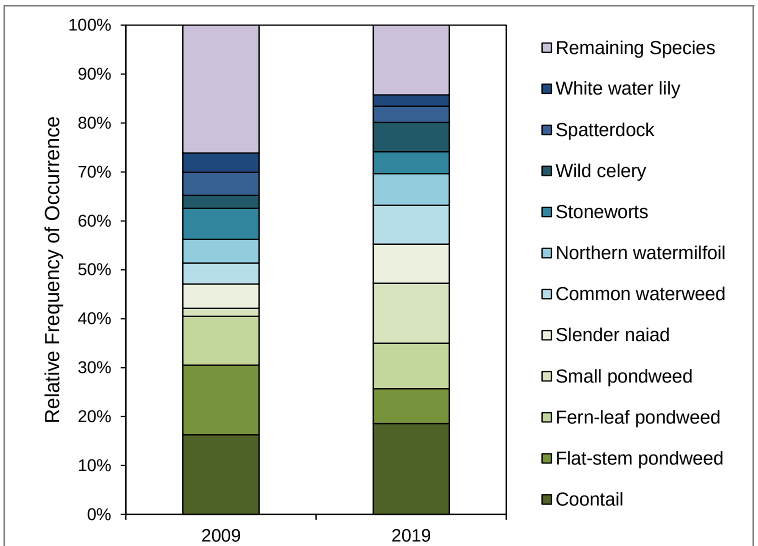


Figure 3.5-16. Relative frequency of occurrence of aquatic vegetation in Gunlock Lake. Created using data from 2009 and 2019 point-intercept surveys.

In 2019, Onterra ecologists also conducted a survey aimed at re-mapping emergent and floating-leaved plant communities in Gunlock Lake (Photograph 3.5-5). Emergent and floating-leaf plant communities are a wetland community type dominated by species such as cattails, bulrushes, and water lilies.

Like submersed aquatic plant communities, these communities also provide valuable habitat, shelter, and food sources for organisms that live in and around the lake. In addition to those functions, floating-leaf and emergent plant communities provide other valuable services such as erosions control and nutrient filtration. These communities also lessen the force of wind and waves before they reach the shoreline which serves to lessen erosion. Their root systems also stabilize bottom sediments and reduce sediment resuspension. In addition, because they often occur in near-shore areas, they act as a buffer against nutrients and other pollutants in runoff from upland areas.

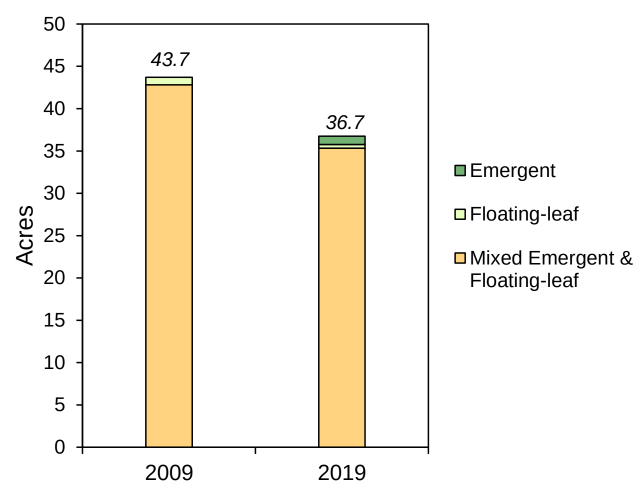


Figure 3.5-17. Acres of floating-leaf and emergent plant communities on Gunlock Lake. Data from 2009 and 2019 community mapping surveys conducted by Onterra.

This is important to note because these communities are often negatively affected by recreational use and shoreland development. Radmoski & Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelands when compared to the undeveloped shorelands in Minnesota lakes. Furthermore, they also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelands.

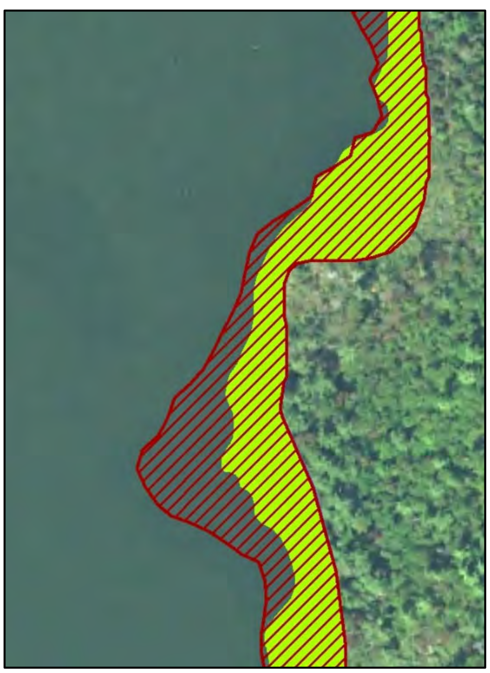


Figure 3.5-18. Emergent and floating-leaf plant communities along northeastern shore of Gunlock Lake from 2009 (red dashed polygons) and 2019 (green polygons). This image illustrates the shoreward retraction of these communities between 2009 and 2019. This is likely due to water level fluctuations that have occurred over this period.

In 2009, approximately 43.7 acres of emergent and floating-leaf aquatic plant communities were delineated in Gunlock Lake (Figure 3.5-9 and Map 11). As in Shishebogama Lake, the acreage of these communities was found to have declined in 2019 to 36.7 acres, likely in response to higher water levels.

Non-Native Aquatic Plants in Shishebogama and Gunlock Lakes

Narrow-leaved Cattail (Typha angustifolia)

Narrow-leaved cattail is a perennial invasive wetland plant which invades shallow marshes and other wet areas. Like Wisconsin's native broad-leaved cattail (*T. latifolia*), narrow-leaved cattail produces tall, erect, sword-like leaves that can grow nearly 10 feet tall (Photograph 3.5-6). The leaves are generally narrower than broad-leaf cattail, typically 0.15-0.5 inches wide. Unlike broad-leaf cattail in which the male and female flowers are typically touching, there is typically a gap of 0.5-4.0 inches between the male and female flowers of narrow-leaved cattail. Hybrid cattail (*Typha* x *glauca*), a cross between narrow-leaved cattail and the native broad-leaved cattail, is also found in Wisconsin and considered invasive. It is not clear if the plants found in 2019 are pure narrow-leaved cattail, hybrid, or a combination of both.

Photograph 3.5-6. Onterra ecologist amongst a colony of narrow-leaved cattail on Shishebogama Lake. Photograph credit: Onterra.

Narrow-leaved cattail was first observed in Gunlock Lake during the 2009 aquatic plant studies. In 2019, colonies of narrow-leaved cattail were marked in three locations in near-shore areas of Shishebogama Lake's western basin (Maps 9 and 10; GPS coordinates in Appendix D). There is also a presumed colony in Gunlock Lake along the margins of the channel leading into Shishebogama Lake. However, Onterra ecologists could not get close enough to this colony to verify its identity. Given the isolated nature of these colonies, the best method of control is likely the cutting of stems (both green and dead) in mid- to late-summer or early fall to below the water line. The following growing season, continually cut-back emerging stems to maintain them below the water for the remainder of the growing season. This process should be repeated until the plants do not reemerge.

Purple Loosestrife (Lythrum salicaria)

Purple loosestrife is a perennial, herbaceous wetland plant native to Europe and was likely brought over to North America as a garden ornamental (Photograph 3.5-7). This plant escaped from its garden landscape into wetland environments where it is able to out-compete our native plants for space and resources. First detected in Wisconsin in the 1930's, it is now widespread across Wisconsin. Purple loosestrife largely spreads by seed but can also spread from root or stem fragments.

In 2019, a single purple loosestrife plant was located on the shoreline of Shishebogama Lake (Map 9; GPS coordinates in Appendix D), while numerous purple loosestrife occurrences were mapped within emergent plant communities in Gunlock Lake within the channel leading into Shishebogama Lake (Map 11; GPS coordinates in Appendix D).

Photograph 3.5-7. The non-native weltand plant purple loosestrife. Photograph credit: Onterra.

Pale-yellow Iris (Iris pseudacorus)

Pale-yellow iris is a large, showy iris with bright yellow flowers (Photograph 3.5-8). Native to Europe and Asia, this species was sold commercially in the United States for ornamental use and has since escaped into Wisconsin's wetland areas forming large monotypic colonies and displacing valuable native wetland species. Numerous occurrences of pale-yellow iris were mapped along Shishebogama Lake's southern shoreline in 2019 (Map 9; GPS coordinates in Appendix D). The pale-yellow iris population on Shishebogama Lake is at present relatively isolated, making eradication possible. Control efforts include digging, cutting, and herbicide application on larger colonies.

Photograph 3.5-8. The non-native weltand plant pale-yellow iris. Photograph credit: Onterra.

3.6 Aquatic Invasive Species in Shishebogama and Gunlock Lakes

As is discussed in section 2.0 Stakeholder Participation, the lake stakeholders were asked about aquatic invasive species (AIS) and their presence in Shishebogama and Gunlock Lakes within the anonymous stakeholder survey. Onterra and the WDNR have confirmed that there are four aquatic invasive species that have been confirmed in these lakes as of 2019.

Table 3.6-1. Aquatic invasive species documented in Shishebogama and Gunlock lakes. List represents species documented as of 2019.

Type	Scientific Name	Common Name	Shishebogama	Gunlock	Location in Report
Plants	*Iris pseudacorus*	Pale-yellow iris	X	X	Section 3.5: Aquatic Plants
	Lythrum salicaria	Purple loosestrife	X		
	Typha angustifolia	Narrow-leaved cattail	X		
Invertebrates	*Cipangopaludina chinensis*	Chinese mystery snail	X	X	Section 3.6: Other AIS

Aquatic Animals

Mystery snails

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

Stakeholder Survey Responses to Shishebogama & Gunlock Lakes Aquatic Invasive Species

Figure 3.6-1 displays the aquatic invasive species that Shishebogama and Gunlock lakes stakeholders believe to be present in these lakes. While nearly 20% of lake stakeholders believe that Eurasian watermilfoil are present in these lakes, and 10% believe curly-leaf pondweed is present, neither of these species have been located to date in Shishebogama or Gunlock lakes. More information on these invasive species or any other AIS can be found at the following links:

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

When asked if they use watercraft on waters other than Shishebogama and Gunlock lakes, 69% of survey respondents indicated that they did not use watercraft on other waters, while 31% indicated they did use their watercraft on other waters. Of the 75 respondents who answered the question of what their typical cleaning routine after using their watercraft on Shishebogama and Gunlock lakes, 80% indicated the removed aquatic hitch-hikers, 71% indicated they drain the bilge, 52% indicated they air dry the boat for more than five days, 36% indicated the rinse their boar, 9%

indicated they power wash their boat, 5% indicated they apply bleach, and 0% indicated that they do not clean their boat at all.

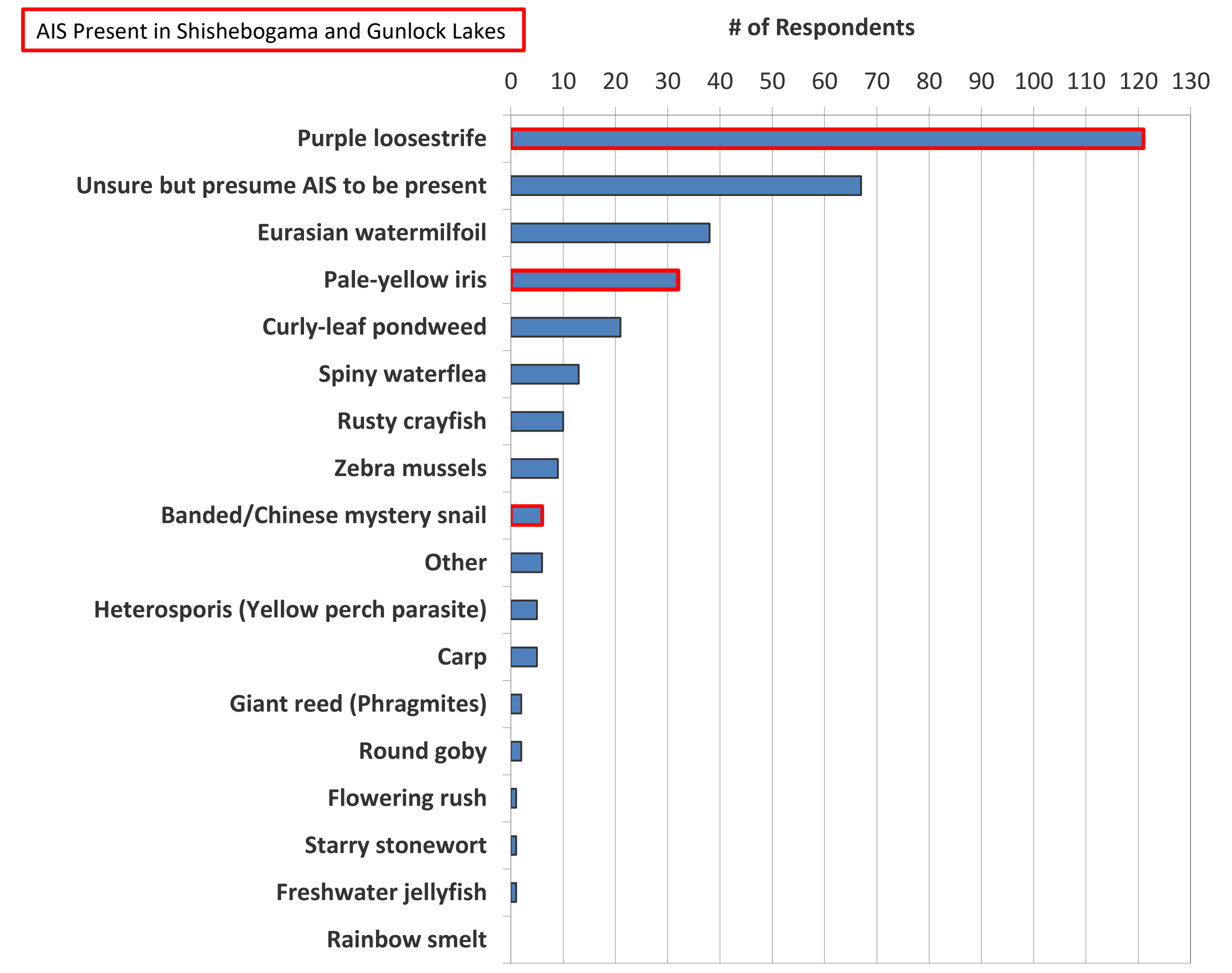


Figure 3.6-1. Stakeholder survey response Question #27. *Which aquatic invasive species do you believe are in Shishebogama and Gunlock Lakes?* Red bars indicate species has been confirmed in Shishebogama and Gunlock lakes. Created using data from 272 survey respondents.

3.7 Fisheries Data Integration

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

Shishebogama and Gunlock Lakes Fishery

Energy Flow of a Fishery

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

A concept called energy flow describes how the biomass of piscivores is determined within a lake. Because algae and plant matter are generally small in energy content, it takes an incredible amount of this food type to support a sufficient biomass of zooplankton and insects. In turn, it takes a large biomass of zooplankton and insects to support planktivorous fish species. And finally, there must be a large planktivorous fish community to support a modest piscivorous fish community. Studies have shown that in natural ecosystems, it is largely the amount of primary productivity (algae and plant matter) that drives the rest of the producers and consumers in the aquatic food chain. This relationship is illustrated in Figure 3.7-1.

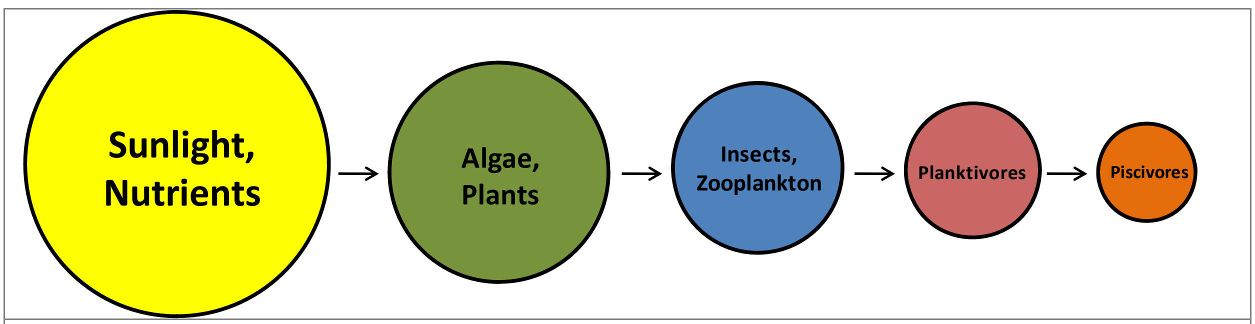


Figure 3.7-1. Aquatic food chain. Adapted from Carpenter et. al 1985.

As discussed in the Water Quality section, Shishebogama and Gunlock Lakes are a eutrophic system, meaning they have a high nutrient content and thus relatively high primary productivity. Simply put, this means Shishebogama and Gunlock Lakes should be able to support sizable populations of predatory fish (piscivores) because the supporting food chain is relatively robust.

Table 3.7-1 shows the popular game fish present in the system. Although not an exhaustive list of fish species in the lake, additional fish species found in past WDNR surveys of Shishebogama and Gunlock Lakes include bluntnose minnow (*Pimephales notatus*), common shiner (*Luxilus cornutus*), golden shiner (*Notemigonus crysoleucas*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris*), white sucker (*Catostomus commersonii*), and the yellow bullhead (*Ameiurus natalis*).

Table 3.7-1. Gamefish present in Shishebogama Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie *(Pomoxis nigromaculatus)*	5	April - June	Matted vegetation, woody debris, overhanging banks	Amphipods, insect larvae and adults, fish, detritus, algae
Bluegill *(Lepomis macrochirus)*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Grass Pickerel *(Esox amerianus)*	7	March - April	Shallow, flooded marshes with emergent vegetation with dense submergent vegetation	Insect larvae, crayfish, smaller fish, aquatic insects
Largemouth bass *(micropterus salmoides)*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge *(Esox masquinongy)*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike *(Esox lucius)*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Smallmouth Bass *(micropterus dolomieu)*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch *(Perca flavescens)*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Table 3.7-2. Gamefish present in Gunlock Lake with corresponding biological information (Becker, 1983).

Common Name (*Scientific Name*)	Max Age (yrs)	Spawning Period	Spawning Habitat Requirements	Food Source
Black Crappie *(Pomoxis nigromaculat*	7	May - June	Near Chara or other vegetation, over sand or fine gravel	Fish, cladocera, insect larvae, other invertebrates
Bluegill *(Lepmis macrochirus)*	11	Late May - Early August	Shallow water with sand or gravel bottom	Fish, crayfish, aquatic insects and other invertebrates
Largemouth Bass *(Micropterus salmo*	13	Late April - Early July	Shallow, quiet bays with emergent vegetation	Fish, amphipods, algae, crayfish and other invertebrates
Muskellunge *(Esox masquinongy)*	30	Mid April - Mid May	Shallow bays over muck bottom with dead vegetation, 6 - 30 in.	Fish including other muskies, small mammals, shore birds, frogs
Northern Pike *(Esox lucius)*	25	Late March - Early April	Shallow, flooded marshes with emergent vegetation with fine leaves	Fish including other pike, crayfish, small mammals, water fowl, frogs
Smallmouth Bass *(Micropterus dolom*	13	Mid May - June	Nests more common on north and west shorelines over gravel	Small fish including other bass, crayfish, insects (aquatic and terrestrial)
Walleye *(Sander vitreus)*	18	Mid April - Early May	Rocky, wavewashed shallows, inlet streams on gravel bottoms	Fish, fly and other insect larvae, crayfish
Yellow Perch *(Perca flavescens)*	13	April - Early May	Sheltered areas, emergent and submergent veg	Small fish, aquatic invertebrates

Survey Methods

In order to keep the fishery of a lake healthy and stable, fisheries biologists must assess the current fish populations and trends. To begin this process, the correct sampling technique(s) must be selected to efficiently capture the desired fish species. A commonly used passive trap is a fyke net (Photograph 3.7-1). Fish swimming towards this net along the shore or bottom will encounter the lead of the net, be diverted into the trap and through a series of funnels which direct the fish further into the net. Once reaching the end, the fisheries technicians can open the net, record biological characteristics, mark (usually with a fin clip), and then release the captured fish.

The other commonly used sampling method is electrofishing (Photograph 3.7-1). This is done, often at night, by using a specialized boat fit with a generator and two electrodes installed on the front touching the water. Once a fish comes in contact with the electrical current produced, the fish involuntarily swims toward the electrodes. When the fish is in the vicinity of the electrodes, they become stunned making them easier to net and place into a livewell to recover. Contrary to what some may believe, electrofishing does not kill the fish and after being placed in the livewell fish generally recover within minutes. As with a fyke net survey, biological characteristics are recorded and any fish that has a mark (considered a recapture from the earlier fyke net survey) are also documented before the fish is released.

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

Photograph 3.7-1. Fyke net positioned in the littoral zone of a Wisconsin Lake (left) and an electroshocking boat (right).

Fish Stocking

To assist in meeting fisheries management goals, the WDNR may permit the stocking of fingerling or adult fish in a waterbody that were raised in permitted hatcheries (Photograph 3.7-2). Stocking a lake may be done to assist the population of a species due to a lack of natural reproduction in the system, or to otherwise enhance angling opportunities. Shishebogama Lake has received consistent stocking of both muskellunge and walleye dating back to the 1970's (Tables 3.7-3 and 3.7-4). A handful of WDNR stocking events occurred on Gunlock lake as well. The SGLA has provided significant efforts and funds in recent years to stock fingerling walleye. Between 2013 and 2016, approximately $35,000 was spent by the association to stock over 17,000 extended growth walleyes (Table 3.7-5). The walleyes were raised

Photograph 3.7-2. Muskellunge fingerlings.

and provided by Central Wisconsin Fish Farm. Additional funds have also been set aside to help grow and improve the walleye fishery in Shishebogama and Gunlock Lakes. The Lac Du Flambeau Tribe has contributed numerous walleye fingerlings and fry in recent years as well (Table 3.7-4 and 3.7-6).

Table 3.7-3. WDNR stocking data available for muskellunge in Shishebogama Lake (1972-2017).

Lake	Year	Species	Source	Age Class	# Fish Stocked	Avg Fish Length (in)
Shishebogama Lake	1972	Muskellunge	WDNR	Fingerling	1,150	11
Shishebogama Lake	1976	Muskellunge	WDNR	Fingerling	700	11
Shishebogama Lake	1977	Muskellunge	WDNR	Fingerling	1,412	12
Shishebogama Lake	1979	Muskellunge	WDNR	Fingerling	750	10
Shishebogama Lake	1980	Muskellunge	WDNR	Fingerling	676	11.5
Shishebogama Lake	1983	Muskellunge	WDNR	Fingerling	1,400	10
Shishebogama Lake	2007	Muskellunge	WDNR	Large Fingerling	239	12.3
Shishebogama Lake	2009	Muskellunge	WDNR	Large Fingerling	349	9.9
Shishebogama Lake	2011	Muskellunge	WDNR	Large Fingerling	358	9.3
Shishebogama Lake	2013	Muskellunge	WDNR	Large Fingerling	358	9.2
Shishebogama Lake	2015	Muskellunge	WDNR	Large Fingerling	356	11.7
Shishebogama Lake	2017	Muskellunge	WDNR	Large Fingerling	220	10.8

Table 3.7-4. WDNR and LDF stocking data available for walleye in Shishebogama Lake (1981-2020).

Lake	Year	Species	Source	Age Class	# Fish Stocked	Avg Fish Length (in)
Shishebogama Lake	1981	Walleye	WDNR	Fingerling	35,000	2.0
Shishebogama Lake	1982	Walleye	WDNR	Fingerling	35,000	3.0
Shishebogama Lake	1984	Walleye	WDNR	Fingerling	17,000	3.0
Shishebogama Lake	1985	Walleye	WDNR	Fingerling	35,700	2.0
Shishebogama Lake	1999	Walleye	WDNR	Small Fingerling	71,602	1.7
Shishebogama Lake	2001	Walleye	WDNR	Small Fingerling	71,687	2.0
Shishebogama Lake	2003	Walleye	WDNR	Small Fingerling	71,575	1.2
Shishebogama Lake	2005	Walleye	WDNR	Small Fingerling	35,947	1.3
Shishebogama Lake	2009	Walleye	WDNR	Small Fingerling	23,426	1.6
Shishebogama Lake	2017	Walleye	LDF	Fingerling	3,173	5.4
Shishebogama Lake	2018	Walleye	LDF	Fry	250,000	-
Shishebogama Lake	2019	Walleye	LDF	Fingerling	1,756	6.5
Shishebogama Lake	2020	Walleye	LDF	Fingerling	2,000	6.0

Table 3.7-5. SGLA stocking data for walleye in Shishebogama and Gunlock Lakes (2013-2016).

Lake	Year	Species	Source	Age Class	# Fish Stocked	Avg Fish Length (in)
Shishebogama Lake	2013	Walleye	SGLA	Extended Growth	3,377	-
Shishebogama Lake	2014	Walleye	SGLA	Extended Growth	5,000	11.0
Shishebogama Lake	2015	Walleye	SGLA	Extended Growth	4,660	10.0
Shishebogama Lake	2016	Walleye	SGLA	Extended Growth	3,840	8.0
Gunlock Lake	2016	Walleye	SGLA	Extended Growth	960	8.0

Table 3.7-6. WDNR and LDF stocking data available for walleye and muskellunge in Gunlock Lake (1972-2020).

Lake	Year	Species	Source	Age Class	# Fish Stocked	Avg Fish Length (in)
Gunlock Lake	1972	Muskellunge	WDNR	Fingerling	1,500	7.0
Gunlock Lake	1975	Muskellunge	WDNR	Fingerling	319	9.0
Gunlock Lake	1972	Walleye	WDNR	Fry	500,000	1.0
Gunlock Lake	1973	Walleye	WDNR	Fry	440,000	-
Gunlock Lake	1974	Walleye	WDNR	Fry	500,000	-
Gunlock Lake	2016	Walleye	LDF	Fry	250000	-
Gunlock Lake	2017	Walleye	LDF	Fingerling	3173	5.4
Gunlock Lake	2018	Walleye	LDF	Fry	500,00	-
Gunlock Lake	2019	Walleye	LDF	Fingerling	1604	6.5
Gunlock Lake	2020	Walleye	LDF	Fingerling	1000	5.8

Fishing Activity

Based on data collected from the stakeholder survey (Appendix B), fishing (open-water and ice) was the second important reason for owning property on or near Shishebogama and Gunlock Lakes (Question #9). Figure 3.7-2 displays the fish that Shishebogama and Gunlock Lakes stakeholders enjoy catching the most, with bluegill/sunfish, crappie and yellow perch being the most popular. Approximately 80% of these same respondents believed that the quality of fishing on the lake was either good or fair (Figure 3.7-3). Approximately 59% of respondents who fish Shishebogama and Gunlock Lakes believe the quality of fishing has remained the same or is somewhat worse since they first started to fish the lake (Figure 3.7-4).

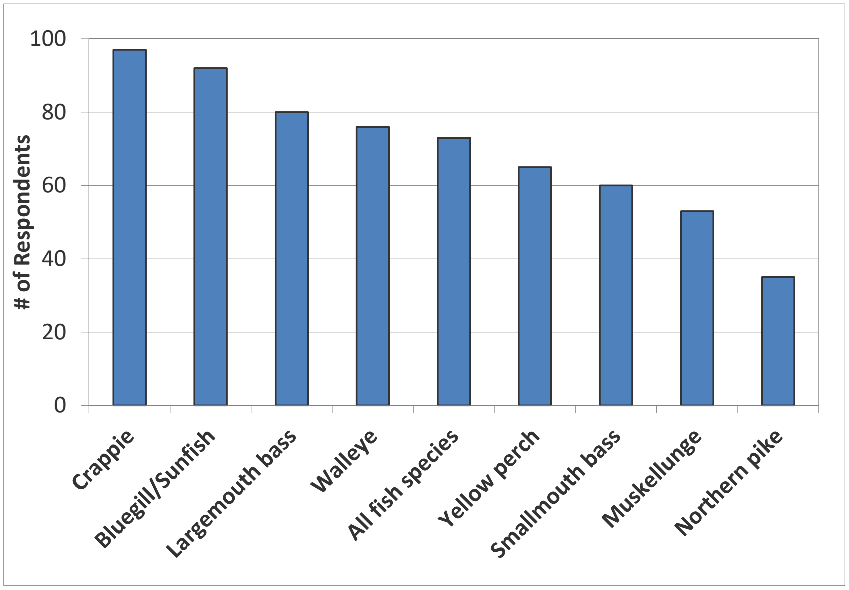


Figure 3.7-2. Stakeholder survey response Question #14. What species of fish do you like to catch on Shishebogama and Gunlock Lakes?

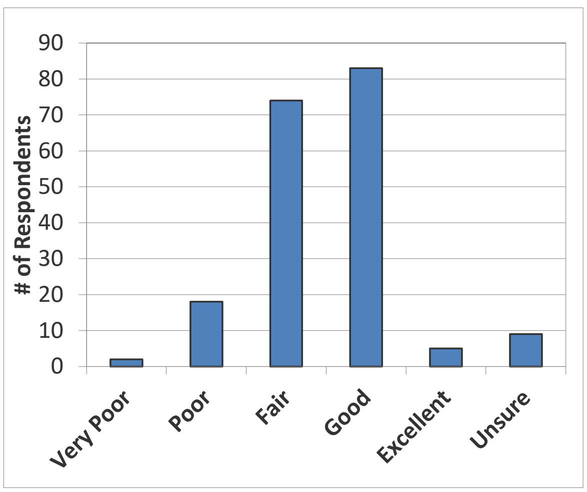


Figure 3.7-3. Stakeholder survey response Question #15. How would you describe the current quality of fishing on Shishebogama and Gunlock Lakes?

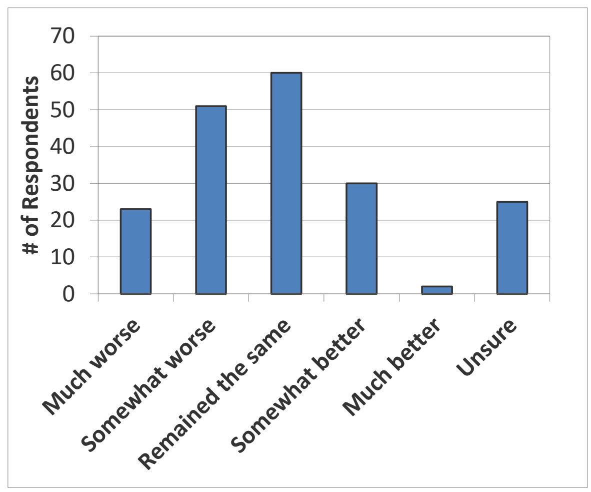


Figure 3.7-4. Stakeholder survey response Question #16. How has the quality of fishing changed on Shishebogama and Gunlock Lakes since you started fishing the lake?

The WDNR measures sport fishing harvest by conducting creel surveys. A Creel Survey Clerk will count the number of anglers present on a lake and interview anglers who have completed fishing for the day. Data collected from the interviews include targeted fish species, harvest, lengths of harvested fish and hours of fishing effort. Creel clerks will work on randomly-selected days and shifts to achieve a randomized census of the fish being harvested. A creel survey was completed on both Shishebogama and Gunlock Lakes during the 1993-1994 and 2002-2003 fishing seasons (Table 3.7-7 and Table 3.7-8).

Total angler effort saw an increase in 2002-2003 (40 hours/acre) compared to the 1993-1994 season (29.7 hours/acre). Anglers directed the largest amount of effort towards largemouth bass during the 20002-2003 season compared to the 1993-1994 season, where the majority of effort directed at northern pike and walleye.

Table 3.7-7. Creel Survey for Gunlock Lake in 1993 and 2002.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth Bass	1993	29.7	3.8	3.3	0.4
	2002	40.3	11.1	17.2	0.1
Muskellunge	1993	29.7	4.8	0.1	0
	2002	40.3	4.1	0.1	0
Northern Pike	1993	29.7	8	1.5	0.6
	2002	40.3	6.2	0.7	0.3
Smallmouth Bass	1993	29.7	2.6	0.2	0
	2002	40.3	6.3	1.8	0
Walleye	1993	29.7	1.1	0	0
	2002	40.3	5.8	1.8	0.1

Table 3.7-8. Creel Survey for Shishebogama Lake in 1993 and 2002.

Species	Year	Total Angler Effort / Acre (Hours)	Directed Effort / Acre (Hours)	Catch / Acre	Harvest / Acre
Largemouth Bass	1993	30.8	3.9	2.3	0.3
	2002	44.9	13	22.6	0.2
Muskellunge	1993	30.8	8.2	0.2	0.1
	2002	44.9	4.2	0.2	0
Northern Pike	1993	30.8	2.4	0.5	0.2
	2002	44.9	8.6	1.8	0.2
Smallmouth Bass	1993	30.8	2.4	0.5	0.1
	2002	44.9	6.8	4.6	0
Walleye	1993	30.8	3.2	0.2	0.1
	2002	44.9	11.6	2.5	0.1

Fish Populations and Trends

Utilizing the above-mentioned fish sampling techniques and specialized formulas, WDNR fisheries biologists can estimate populations and determine trends of captured fish species. These numbers provide a standardized way to compare fish caught in different sampling years depending on gear used (fyke net or electrofishing). Data is analyzed in many ways by fisheries biologists to better understand the fishery and how it should be managed.

Gamefish

The gamefish present on Shishebogama and Gunlock Lakes represent different population dynamics depending on the species. The results for the stakeholder survey show landowners prefer to catch largemouth bass and walleye on Shishebogama and Gunlock Lakes (Figure 3.7-2). Brief summaries of gamefish with fishable populations in Shishebogama and Gunlock Lakes are provided based off of the report submitted by WDNR fisheries biologist John Kubisiak following the fisheries survey completed in 2012.

Walleyes are a valued sportfish in Wisconsin. While common in Shishebogama Lake, walleyes were a bycatch of the 2012 survey and were not the primary target. Six fish were captured, the largest being a 24.4-inch fish.

Largemouth bass were the most abundant gamefish and the primary target in the 2012 survey. Many of these fish were less than 14 inches. DNR biologists noted that growth rates for largemouth bass in Shishebogama Lake appear to be 1-2 years behind the regional average. The largest largemouth captured was a 19.5-inch fish, however.

Northern Pike, while present in Shishebogama Lake, were not found in high numbers in the 2012 survey and were not a primary target. Only four individuals were captured, all between 18.0-19.5 inches.

Muskellunge, like walleye, are also considered a valued sportfish of Shishebogama and Gunlock Lakes. Eight fish were captured, in which two appeared to be from a 2011 stocking event. Muskellunge stocking has been steady in Shishebogama Lake.

Smallmouth bass are present in Shishebogama and Gunlock Lakes but in low numbers. No population estimate was attempted and 40% of the captured fish were 14 inches or greater in length.

Panfish

Yellow perch, black crappie and bluegill were common during the 2012 WDNR fisheries survey (WDNR 2012). The results for the stakeholder survey show anglers prefer to catch crappie on Shishebogama and Gunlock Lakes (Figure 3.7-2). During the 2012 electrofishing survey, panfish species were only collected from three, half-mile long stretches of shoreline.

Bluegill are the most abundant panfish in Shishebogama Lake. Good numbers of fish were recorded up to 7.5 inches. A sharp decline in numbers of fish greater than 7.5 inches can be seen, most likely due to angler harvest. The largest fish measured was 8.4 inches. In June 2019, a number of dead panfish, mostly bluegills, were found in Shishebogama Lake. A bluegill was sent to the WDNR in Woodruff for testing. The cause of death was determined to be natural and did not pose a threat to the health of the fishery.

Black crappie were not found in as high abundance as bluegill. Nineteen fish were captured, with size ranging from 2.5-10.9 inches.

Yellow perch were also not found in high abundance during this survey. It has been noted that the timing of the survey may be the cause of this. In total, 20 perch were captured. A majority of the fish captured measured less than three inches, indicating a strong 2011-year class. The largest fish specimen was a 9.9-inch fish.

Shishebogama and Gunlock Lakes Spear Harvest Records

Approximately 22,400 square miles of northern Wisconsin was ceded to the United States by the Lake Superior Chippewa tribes in 1837 and 1842 (Figure 3.7-5). Shishebogama and Gunlock lakes fall within the ceded territory based on the Treaty of 1842. This allows for a regulated open water spear fishery by Native Americans on lakes located within the Ceded Territory. Determining how many fish are able to be taken from a lake by tribal harvest is a highly regimented and dictated process.

Figure 3.7-5. Location of Shishebogama and Gunlock Lakes within the Native American Ceded Territory (GLIFWC, 2017)**.** This map was digitized by Onterra; therefore, it is a representation and not legally binding.

This highly structured procedure begins with bi-annual meetings between tribal and state management authorities. Reviews of population estimates are made for ceded territory lakes, and then a *total allowable catch* (TAC) is established, based upon estimates of a sustainable harvest of the fishing stock. The TAC is the number of adult walleye or muskellunge that can be harvested from a lake by tribal and recreational anglers without endangering the population.

A *safe harvest* value is calculated as a percentage of the TAC each year for all walleye lakes in the ceded territory. The safe harvest represents the number of fish that can be harvested by tribal members through the use of high efficiency gear such as spearing or netting without influencing the sustainability of the population. This does not apply to angling harvest which is considered a low-efficiency harvest regulated statewide by season length, size and bag limits. The safe harvest limits are set through either recent population estimates or a statistical model that ensure there is less than a 1 in 40 chance that more than 35% of the adult walleye population will be harvested in a lake through high efficiency methods.

By March 15th of each year the relevant Native American communities may declare a proportion of the total safe harvest on each lake; this declaration represents the maximum number of fish that can be harvested by tribal members annually. Prior to 2015, annual walleye bag limits for anglers were adjusted in all Ceded Territory lakes based upon the percent of the safe harvest levels determined for the Native American spearfishing season. Beginning in 2015, new regulations for walleye were created to stabilize regional walleye angler bag limits. The daily bag limits for walleye in lakes located partially or wholly within the ceded territory is three. The statewide bag limit for walleye is five. Anglers may only remove three walleye from any individual lake in the ceded territory but may fish other waters to full-fill the state bag limit (WDNR 2017).

Tribal members may harvest muskellunge, walleye, northern pike, and bass during the open water season; however, in practice walleye and muskellunge are the only species harvested in significant numbers, so conservative quotas are set for other species. The spear harvest is monitored through a nightly permit system and a complete monitoring of the harvest (GLIFWC, 2017). Creel clerks and tribal wardens are assigned to each lake at the designated boat landing. A catch report is completed for each boating party upon return to the boat landing. In addition to counting every fish harvested, the first 100 walleye (plus all those in the last boat) are measured and sexed.

Tribal spearers may only take two walleyes over twenty inches per nightly permit; one between 20 and 24 inches and one of any size over 20 inches (GLIFWC, 2017). This regulation limits the harvest of the larger, spawning female walleye. An updated nightly declaration is determined each morning by 9 a.m. based on the data collected from the successful spearers. Spearfishing of a particular species ends once the declared harvest is reached in a given lake. In 2011, a new reporting requirement went into effect on lakes with smaller declarations. Starting with the 2011 spear harvest season, on lakes with a harvestable declaration of 75 or fewer fish, reporting of harvests may take place at a location other than the landing of the speared lake.

Walleye open water spear harvest records are provided in Figure 3.7-6 from 2000 to 2019. 2019 saw the most walleye harvested over the indicated years, with 40 walleyes being harvested. Between 2000 and 2019, spear harvesters on average have taken 13% of the declared quota. Since 2016, however, Shishebogama Lake has seen an increase in spear fishing pressure. During this span, spear harvesters have harvested approximately 57% of the declared quota. Muskellunge open water spear harvest records are provided in Figure 3.7-7 from 2000-2019. 2018 was the only year where muskellunge harvest occurred, with two fish being taken.

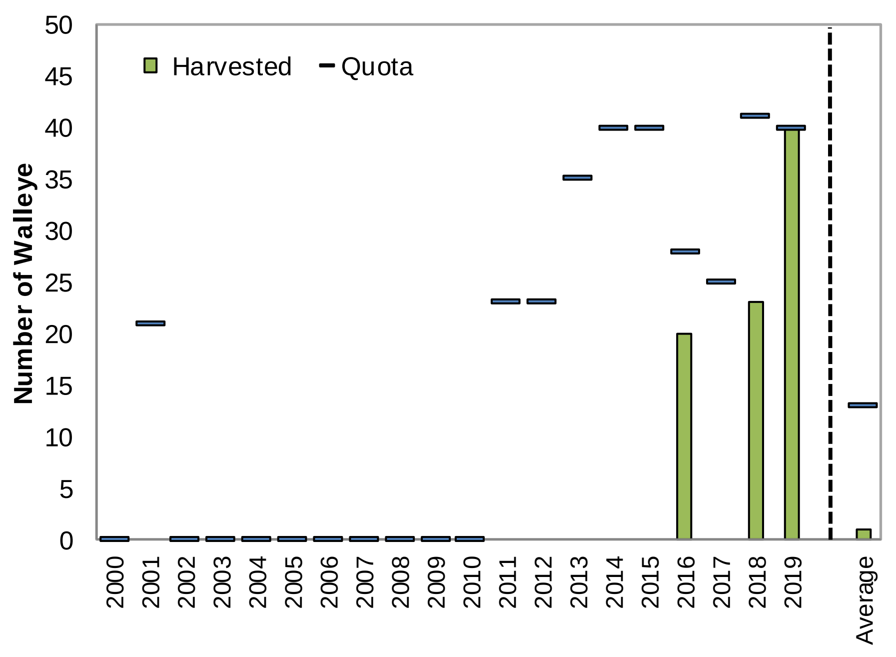


Figure 3.7-6. Shishebogama Lake walleye spear harvest data. (GLIFWC 2000-2019).

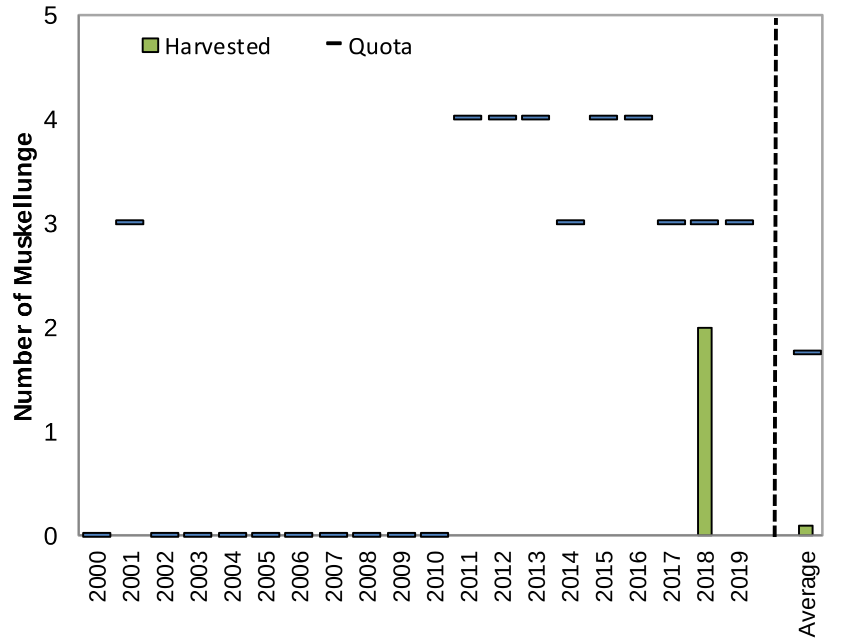


Figure 3.7-7. Shishebogama Lake muskellunge spear harvest data. (GLIFWC 2000-2019).

Shishebogama and Gunlock Lakes Fish Habitat

Substrate Composition

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

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

According to the point-intercept survey conducted by Onterra on Shishebogama Lake in 2019, 69% of the substrate sampled in the littoral zone were soft sediments, 24% was composed of sand sediments, and 7% were composed of rock sediments.

Woody Habitat

As discussed in the Shoreland Condition Section, the presence of coarse woody habitat is important for many stages of a fish's life cycle, including nesting or spawning, escaping predation as a juvenile, and hunting insects or smaller fish as an adult. Unfortunately, as development has increased on Wisconsin lake shorelines in the past century, this beneficial habitat has often been the first to be removed from the natural shoreland zone. Leaving these shoreland zones barrens of coarse woody habitat can lead to decreased abundances and slower growth rates in fish (Sass, 2009). A fall 2019 survey documented 280 pieces of coarse woody along the shores of Shishebogama, resulting in a ratio of approximately 26 pieces per mile of shoreline. A fall 2019 survey documented 69 pieces of coarse woody along the of shores on Gunlock Lake, resulting in in a ratio of 14 pieces per mile of shoreline. Fisheries biologists do not suggest a specific number of fish sticks for a lake but rather highly encourage their installation wherever possible. To learn how Shishebogama and Gunlock Lakes' coarse woody habitat is compared to other lakes in its region please refer to section 3.3.

Fish Habitat Structures

Some fisheries managers may look to incorporate fish habitat structures on the lakebed or littoral areas extending to shore for the purpose of improving fish habitats and spawning areas. These projects are typically conducted on lakes lacking significant coarse woody habitat in the shoreland zone. The "Fish sticks" program, outlined in the WDNR best practices manual, adds trees to the shoreland zone restoring fish habitat to critical near shore areas. Typically, every site has 3 – 5 trees which are partially or fully submerged in the water and anchored to shore (Photograph 3.7-3). The WDNR recommends placement of the fish sticks during the winter on ice when possible to prevent adverse impacts on fish spawning or egg incubation periods. The program requires a WDNR permit and can be funded through many different sources including the WDNR, County Land & Water Conservation Departments or partner contributions.

Photograph 3.7-3. Examples of fish sticks (left) and half-log habitat structures. (Photographs by WDNR)

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

Half-logs are another form of fish spawning habitat placed on the bottom of the lakebed (Photograph 3.7-3). Smallmouth bass specifically have shown an affinity for overhead cover when creating spawning nests, which half-logs provide (Wills, Bremigan, & Haynes, 2004). If the waterbody is exempt from a permit or a permit has been received, information related to the construction, placement and maintenance of half-log structures are available online.

An additional form of fish habitat structure is spawning reefs. Spawning reefs typically consist of small rubble in a shallow area near the shoreline for mainly walleye habitat. Rock reefs are sometimes utilized by fisheries managers when attempting to enhance spawning habitats for some fish species. However, a 2004 WDNR study of rock habitat projects on 20 northern Wisconsin lakes offers little hope the addition of rock substrate will improve walleye reproduction (WDNR, 2004).

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

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

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

If interested, the Shishebogama & Gunlock Lake Association, Inc, may work with the local WDNR fisheries biologist to determine if the installation of fish habitat structures should be considered in aiding fisheries management goals for Shishebogama and Gunlock Lakes.

Shishebogama and Gunlock Lakes were chosen, along with 110 other lakes, to participate in an experimental daily bag limit on panfish. Below are the three different daily bag limits selected to determine which is best at improving panfish size.

- 25/5 over 7" – A total of 25 panfish may be kept but no more than five of the sunfish (bluegill and pumpkinseed) may be over 7"
- 25/10 – A total of 25 panfish may be kept but no more than ten of any one species.
- 15/5 – A total of 15 panfish may be kept but only five of any one species.

Shishebogama and Gunlock Lakes are currently under the 25/5 over 7" experimental regulation. The efficacy of the regulations as well as anglers support of the changes will be evaluated in the next few years (WDNR personal comms, 2020).

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

Table 3.7-9. WDNR fishing regulations for Shishebogama and Gunlock Lakes (As of March 2020).

Species	Daily bag limit	Length Restrictions	Season
Panfish (bluegill, pumpkinseed, sunfish, crappie and yellow perch)	25	Only 5 fish or fewer can be over 7"	Open All Year
Largemouth bass and smallmouth bass	5	Only fish less than 14" may be kept, except one fish over 18" may be kept	June 20, 2020 to March 7, 2021
Smallmouth bass	5	Only fish less than 14" may be kept, except one fish over 18" may be kept	June 20, 2020 to March 7, 2021
Largemouth bass	5	Only fish less than 14" may be kept, except one fish over 18" may be kept	May 2, 2020 to March 7, 2021
Muskellunge and hybrids	1	40"	May 23, 2020 to December 31, 2020
Northern pike	5	None	May 5, 2018 to March 3, 2019
Walleye, sauger, and hybrids	3	The minimum length is 18"	May 2, 2020 to March 7, 2021
Bullheads	Unlimited	None	Open All Year
Cisco and whitefish	10 fish	None	Open All Year

General Waterbody Restrictions: Motor Trolling is allowed with 1 hook, bait, or lure per angler, and 2 hooks, baits, or lures maximum per boat.

Mercury Contamination and Fish Consumption Advisories

Freshwater fish are amongst the healthiest of choices you can make for a home-cooked meal. Unfortunately, fish in some regions of Wisconsin are known to hold levels of contaminants that are harmful to human health when consumed in great abundance. The two most common contaminants are polychlorinated biphenyls (PCBs) and mercury. These contaminants may be found in very small amounts within a single fish, but their concentration may build up in your body over time if you consume many fish. Health concerns linked to these contaminants range from poor balance and problems with memory to more serious conditions such as diabetes or cancer. These contaminants, particularly mercury, may be found naturally to some degree.

However, the majority of fish contamination has come from industrial practices such as coal-burning facilities, waste incinerators, paper industry effluent and others. Though environmental regulations have reduced emissions over the past few decades, these contaminants are greatly resistant to breakdown and may persist in the environment for a long time. Fortunately, the human body is able to eliminate contaminants that are consumed however this can take a long time depending upon the type of contaminant, rate of consumption, and overall diet. Therefore, guidelines are set upon the consumption of fish as a means of regulating how much contaminant could be consumed over time.

General fish consumption guidelines for Wisconsin inland waterways are presented in Figure 3.7-8. There is an elevated risk for children as they are in a stage of life where cognitive development is rapidly occurring. As mercury and PCB both locate to and impact the brain, there are greater restrictions on women who may have children or are nursing children, and also for children under 15.

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

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

Figure 3.7-8. Wisconsin statewide safe fish consumption guidelines. Graphic displays consumption guidance for most Wisconsin waterways. Figure adapted from WDNR website graphic (http://dnr.wi.gov/topic/fishing/consumption/)

Fishery Management & Conclusions

Shishebogama and Gunlock Lakes are both part of the WDNR statewide panfish study, a survey will be performed on each lake within the next few years to assess the experimental panfish regulation.

4.0 SUMMARY AND CONCLUSIONS

The design of this project was intended to fulfill two primary objectives:

1) Collect and analyze baseline data to reassess Shishebogama and Gunlock lakes' water quality, watershed, aquatic plant community, immediate shoreland zone, and stakeholder perceptions.
2) Develop an updated comprehensive management plan with realistic and implementable management goals and actions to protect and enhance the Shishebogama and Gunlock lake ecosystem for current and future generations.

These objectives were fulfilled during the project and have led to a greater understanding of the Shishebogama and Gunlock lakes ecosystem, the occurrence of shoreland invasive plant species, the concerns of lake stakeholders, and the actions that need to be taken to continue to conserve and enhance these lakes. The studies completed in 2019 found that both of these lakes continue to support high water quality. While there has been a measurable decline in water clarity in recent years, this is believed to be the result of increased precipitation and input of dissolved organic matter which darkens or stains the water. This has been a trend observed in lakes across northern Wisconsin. Analysis of water quality data also showed that both lakes likely experience the internal loading of phosphorus during summer stratification, which can become mobilized to surface waters later in the summer. This can lead to increased algal production and reductions in water clarity, and occurs to a more significant extent in Gunlock Lake.

The slight decrease in water clarity in combination with higher water levels also resulted in changes in the lakes' aquatic plant communities between the 2009 and 2019 surveys. One of the major changes observed was an overall reduction in aquatic plant occurrence in deeper areas of each lakes' littoral zone, likely the result of reduced light availability to these areas. Despite this reduction in occurrence, the aquatic plant communities of both lakes remain high, and each contain a number of native species which are considered sensitive to environmental degradation. Non-native plant species located included small, isolated populations of shoreland plants including pale-yellow iris, purple loosestrife, and narrow-leaved cattail. The Implementation Plan which follows, outlines ongoing monitoring and control strategies for each of these species.

Reassessment of Shishebogama and Gunlock lakes' watersheds showed that the majority of their watersheds remain undeveloped, comprised of intact forests and wetlands. The conservation of these natural land cover types is essential for maintaining the lakes' water quality. The shoreland assessment found that approximately 20% of each lakes' shoreline has been completely developed, with little to no natural habitat remaining. Approximately 70% of each lakes' shoreline was found to contain all or nearly all of its natural habitat intact (no development), while the remaining 10% contained moderate levels of development. The Implementation Plan outlines management actions for restoring highly developed shorelands on these lakes and also protecting natural shorelands.

Like all lakes, Shishebogama and Gunlock lakes face a number of ongoing threats and challenges, from the introduction of invasive species to changing climate patterns, but the SGLA and LDR NRD among other dedicated lake stakeholders are taking proactive action to meet these challenges to ensure the conservation and enhancement of these lakes for current and future generations.

5.0 IMPLEMENTATION PLAN

The Implementation Plan presented in this section was created through the collaborative efforts of the Shishebogama and Gunlock Lakes Planning Committee, Onterra ecologists, and Lac du Flambeau Tribal Natural Resources Department (LDF NRD) and Wisconsin Department of Natural Resources (WDNR) staff. The goals detailed within the plan are realistic and based upon the findings of the studies completed in conjunction with this planning project and the needs of the Shishebogama and Gunlock lakes stakeholders as portrayed by the members of the Planning Committee and the communications between Planning Committee members and the lake stakeholders. The Implementation Plan is a living document in that it will be under constant review and adjustment depending on the condition of the lakes, the availability of funds, level of volunteer involvement, and the needs of the stakeholders. Please note that the listing order of these management goals is not indicative of priority.

Management Goal 1: Protect Current Water Quality Conditions

Management Action 1a:	Continue monitoring of Shishebogama and Gunlock lakes' water quality through the WDNR Citizens Lake Monitoring Network (CLMN) program and develop a water quality sampling plan with LDR NRD to address water quality sampling needs and available resources.
Timeframe:	Continuation of current effort with collaboration with LDR NRD.
Facilitators:	Robert Schulz (current Shishebogama volunteer), Patrick Hayes (current Gunlock volunteer), and SGLA board of directors.
Description:	Monitoring water quality is an import aspect of every lake management planning activity. Collection of water quality data at regular intervals aids in the management of the lake by building a database that can be used for long-term trend analysis. The Citizen Lake Monitoring Network (CLMN) is a WDNR program in which volunteers are trained to collect water quality information on their lake. Volunteers from the SGLA have been collecting water quality data nearly every year since 1990. The data collected by these volunteers allowed for a determination that Shishebogama and Gunlock lakes' current water quality parameters range from *good* to *excellent* for each respective lake type. The data also revealed that the internal loading of phosphorus occurs periodically in these lakes and that water clarity has declined slightly in recent years. As is discussed in the Water Quality Section, this decline is believed to be the result increased dissolved organic matter (DOM) entering the lake from the watershed as a result of increased rainfall. Dissolved organic matter darkens, or stains the water, reducing light penetration. Continued monitoring of these lakes' water quality will continue to increase managers' understanding of how changes in precipitation and

other environmental factors such as increasing temperatures influence water clarity and nutrient dynamics over time.

When a change in the collection volunteer occurs, Sandy Wickman (715.365.8951) or the appropriate WDNR/UW-Extension staff will need to be contacted to ensure the proper training occurs and the necessary sampling materials are received by the new volunteer. It is also important to note that as a part of this program, the data collected are automatically added to the WDNR database and available through their Surface Water Integrated Monitoring System (SWIMS) by the volunteer.

The SGLA should also work with LDF NRD staff to develop a water quality sampling plan to ensure that efforts are not being duplicated and resources being allocated appropriately.

Action Steps:

1. Rob Schulz for Shishebogama Lake and Patrick Hayes for Gunlock Lake and/or SGLA board of directors appoints/recruits new water quality monitoring volunteer(s) as needed. SGLA should notify LDF NRD Celeste Hockings when change in volunteer occurs.
2. New volunteer(s) contact Sandy Wickman (715.365.8951) with the WDNR as needed.
3. Volunteer(s) report annual monitoring results to WDNR SWIMS database.
4. Work with LDF NRD staff to develop a water quality sampling plan.

Management Goal 2: Protect and Enhance Immediate Shoreland Zone Habitat and Reduce Shoreland Erosion on Shishebogama & Gunlock Lakes

Management Action 2a: Establish SGLA Shoreland Protection Committee to educate lake stakeholders, provide informational resources, and investigate financial opportunities to protect and restore shoreland areas on Shishebogama and Gunlock lakes.

Timeframe: Initiate 2021

Facilitator: SGLA Board of Directors

Description: Stakeholder input through planning meetings and the stakeholder survey revealed that shoreland erosion and development were one of the top concerns that stakeholders believe are negatively impacting Shishebogama and Gunlock lakes. In an effort to increase stakeholder awareness of the importance of maintaining a natural shoreline and to provide riparian property owners with opportunities to restore and/or protect their shoreline, the SGLA will be creating a Shoreland Protection Committee.

The goal of the Shoreland Protection Committee will be to increase communication and outreach to riparian property owners on the benefits of natural shorelines, provide informational resources to riparian property owners on how to initiate restoration and/or shoreland protection projects, and investigate financial opportunities for shoreland restoration/projects on Shishebogama and Gunlock lakes. The committee will report their activities and suggestions to the SGLA Board of Directors.

Action Steps:

1. See description above.

Management Action 2b: Educate and promote restoration of highly developed shoreline areas to protect and enhance natural habitat, reduce erosion, and protect water quality.

Timeframe: Initiate in 2021

Facilitator: Property owner with assistance from SGLA Shoreland Protection Committee

Potential Funding: Healthy Lakes Grants; Surface Water Restoration Grants

Description: The Shoreland Protection Committee will explore project opportunities and make recommendations on best management practices along lakeshore properties of Shishebogama and Gunlock lakes to the SGLA Board of Directors. Projects approved by the SGLA Board through recommendation by the Shoreland Protection Committee will receive assistance from the Committee as property owners apply for grant applications. Educational materials for healthy shorelines and watercraft safety will be created to inform and educate property owners.

The 2019 shoreland condition assessment completed by Onterra on Shishebogama and Gunlock lakes found that approximately 2.9 miles or 18% of the lakes' combined shoreline of 15.8 miles contained a higher degree of development, categorized as either *developed-unnatural* or *urbanized* (Maps 3 and 4). These developed shorelands contain little to no natural vegetation and habitat. Approximately 11.4 miles or 72% of the combined shoreline was found to have minimal human development with most of the native vegetation intact, categorized as either *develop-semi-natural* or *developed-natural* (Maps 3 and 4). In addition, these lakes support over 94 acres of near-shore emergent and floating-leaf marsh communities found primarily adjacent to minimally-developed shorelands.

Approximately 2.0 miles (13%) of Shishebogama and Gunlock lakes' shoreline is under ownership by the LDF Tribe while the remaining 13.8 miles (87%) is under private ownership. The Shoreland Protection Committee with LDF NRD staff will provide riparian property owners with little to no shoreland development on their property information about how important the benefits of their shoreland are to the lakes in terms of habitat, stabilizing shoreland soils, protecting water quality, and maintaining the lake's aesthetic appeal. The Shoreland Protection Committee along with LDF NRD staff will also provide riparian properties with developed shorelands information as to how developed shorelands lack healthy lake benefits and the possible negative affects their shoreland imparts on Shishebogama-Gunlock lake system. It should be noted that the LDF Tribe has a Land Use Application (LUA) that the LDF NRD is utilizing for any work that takes place below the ordinary high water mark in waters residing within the LDF Reservation boundary. Some activities will require a permit from the LDF NRD.

The Shoreland Protection Committee will begin working with Shishebogama and Gunlock lake property owners to pursue projects that would qualify for Healthy Lakes grants to restore developed shorelands and implement best management practices (e.g., rain gardens and native plantings) on their property. The SGLA is also highly concerned with recent shoreland erosion on shoreland areas, believed to be due to the combination of higher water levels and large waves produced by motorized watercraft. Maintaining natural shorelands and restoring developed shorelands will reduce the rate of this erosion.

The WDNR's Healthy Lakes grants allow partial cost coverage for native plantings in transition areas. This reimbursable grant program is intended for relatively straightforward and simple projects. More advanced projects that require advanced engineering design may seek alternative funding opportunities, potentially through the county and the WDNR Lake Protection Grant Program. For a larger project that may include a number of properties, it may be more appropriate to seek funding through a WDNR Lake Protection Grant. While more funding can be provided through a Lake Protection Grant and there are no limits to where that funding is utilized (e.g., technical, installation, etc.). However, the grant does require that the restored shorelines remain undeveloped in perpetuity.

The Committee should work with the WDNR's Kevin Gauthier (715.356.5211) and Scott Van Egeren (715.471.0007) to initiate new Healthy Lake projects and research ideas for larger-scale projects to address shoreland erosion if needed. The SGLA should also work with the LDF Tribe and Oneida and Vilas counties land and water conservation departments to research other grant programs, shoreland restoration/preservation techniques, and other pertinent information that will aid the SGLA.

In addition, in an effort to reduce shoreland erosion and damage from waves generated by watercraft, the SGLA will consider installing signage at public access locations to inform lake users of watercraft regulations, including slow-no-wake zones designated by the Town of Lac du Flambeau and the LDF Tribe within and within the designated setback from the shoreline (100 feet for boats and 200 feet for personal watercraft). Please see Management Action 3 for a detailed description of this action.

Action Steps:

1. The Shoreland Protection Committee gathers appropriate information from entities listed in description.
2. The Shoreland Protection Committee provides Shishebogama and Gunlock lakes property owners with informational resources on shoreland protection and restoration. Interested property owners may contact the committee or WDNR for more information on shoreland restoration plans, financial assistance, and benefits of implementation.
3. Complete shoreland condition assessment as part of next management plan update.

Management Goal 3: Increase Navigation Safety on Shishebogama & Gunlock Lakes

Management Action 3a: SGLA to form a Watercraft Safety Education Committee.

Timeframe: Initiate 2021

Facilitator: SGLA Board of Directors

Description: During meetings with the Planning Committee and in the results from the 2020 stakeholder survey, excessive watercraft traffic, unsafe boating practices, and resulting wave action and shoreland erosion were one of the top concerns regarding Shishebogama and Gunlock lakes. During the planning meetings, members of the Planning Committee expressed concern about motorboats and personal watercraft operating above slow, no wake speed within the designated setback from the shoreline and docks (100 feet for boats and 200 feet for personal watercraft). The Planning Committee is concerned not only about recreational safety but about the impact to shoreland areas from watercraft operating above slow-no-wake too close to shore.

In an effort to increase navigational and recreational safety on Shishebogama and Gunlock lakes, the SGLA will form a Watercraft Safety Education Committee to initiate an educational endeavor to promote boating safety on the lakes. The goal of the committee will be to gather and disseminate information on Wisconsin's watercraft regulations, Shishebogama and Gunlock lakes' slow-no-wake ordinances, and responsible boating practices. To reach as many lake stakeholders and users as possible, this information can be routinely disseminated through the association's webpage and Facebook page, the association's quarterly newsletter, email (Eblast), and outreach at the public boat landing (see next management action). The committee will also investigate the creation of brochures or informational card for rental property owners to provide to renters who may not be familiar with boating regulations and safety.

Action Steps:

1. SGLA forms Watercraft Safety Education Committee.
2. Watercraft Safety Education Committee compiles information discussed in description by working with local law enforcement and routinely disseminates information through SGLA communication channels.

Management Action 3b: Watercraft Safety Education Committee investigates boater safety educational campaign at the public landing to reach non-SGLA members.

Timeframe: Initiate 2021

Facilitator: Watercraft Safety Education Committee

Description: In an effort to reach out to non-SGLA members, boat renters, and occasional users of Shishebogama and Gunlock lakes, the Watercraft Safety Education Committee (WSEC) will investigate updating signage and/or creating an informational kiosk at the public boat landing which would provide watercraft regulation and lake hazard information to those launching from the public landing. This signage would provide lake users with a map of the lakes displaying slow-no-wake areas (including the 100 and 200 ft setbacks) as well as navigational hazards (rock bars, etc.).

The WSEC will investigate signage and other materials available at the boat landings that may include maps, QR codes, handouts, placards, Twitter messages and more as multiple means of providing lake users with the watercraft regulation and hazards map. This would allow lake users to have a visual reference of the lakes while out on the water. Similarly, the WSEC will also investigate the creation of informational cards that can be made available at the boat landing for lake users. This informational card could contain a watercraft regulation and hazards map of the lakes along with SGLA contact information. The WSEC will also consider the creation of a SGLA Twitter account, which may be able to provide lake users with more frequent and current updates on lake conditions and educational topics.

The WSEC can also consider contacting and developing relationships with local boat rental companies to discuss their procedures for informing renters on Wisconsin's watercraft regulations. In addition, information can be provided to rental property owners around Shishebogama and Gunlock lakes in the form of a brochure, informational card, refrigerator magnet, etc. that could provide rentals on watercraft safety and hazards in Shishebogama and Gunlock lakes. The SGLA will also provide information on AIS to watercraft renters.

Action Steps:

1. Establish Water Safety and Education Committee.
2. Onterra provides SGLA with watercraft regulation and hazards map.
3. The Watercraft Safety Education Committee investigates sign/graphic design companies to create signage for the Gunlock Lake public boat landing.
4. The Watercraft Safety Education Committee investigates creation access to map via QR Code and/or informational cards at the public boat landing.
5. The Watercraft Safety Education Committee contacts WDNR Recreational Safety Warden Justin Bender (715.293.3363) for feedback on proposed activities and signage.

Management Goal 4: Increase SGLA's Capacity to Communicate with Lake Stakeholders and Facilitate Partnerships with Other Management Entities

Management Action 4a:	Promote the conservation and enjoyment of Shishebogama and Gunlock lakes through stakeholder education.
Timeframe:	Continuation and expansion of current efforts.
Facilitator:	SGLA Board or Directors
Description:	Education represents an effective tool to address many lake challenges. The SGLA regularly publishes and distributes a quarterly newsletter, maintains and association website and Facebook, and uses Eblast to maintain contact and provide information to SGLA members and interested stakeholders. These modes of communication provide members and non-members with association-related information including current projects and updates, meeting times, and educational topics. In the 2020 stakeholder survey, approximately 89% of survey respondents had indicated that they have heard of the SGLA, indicating the SGLA's outreach efforts are highly effective at reaching their membership.

The SGLA would like to maintain its capacity to reach out to and educate association and non-association members regarding Shishebogama and Gunlock lakes and their conservation. Education of lake stakeholders on all matters is important, and a list of educational topics that were discussed during the planning meetings along with others can be found below. These topics can be included within the association's newsletter, distributed as separate educational materials, or posted on the association's Facebook page and/or website. The SGLA can also invite speakers to discuss lake-related topics or hold workshops for their members at their annual meetings. The SGLA should also reach out to professionals from the LDF NRD, WDNR, Oneida and Vilas counties land and water conservation departments, etc. to obtain educational pieces for their newsletter.

Example Educational Topics

- Aquatic invasive species identification, prevention, and management
- Boating regulations and responsible use
- Lake property and shoreland conservation and restoration
- Native aquatic plant conservation and importance in the aquatic community
- Importance of maintaining coarse woody habitat (CWH)
- Basic lake ecology (water quality, plants, fisheries, etc.)
- Effect of lawn fertilizers/pesticides on lakes
- Respect to and maintaining a safe distance from wildlife in the lake

- Water quality updates from Shishebogama and Gunlock lakes
- Fishing rules and regulations
- Catch-and-release fishing
- Septic system maintenance
- Noise, air, and light pollution
- Fireworks
- Minimizing disturbance to spawning fish
- Loon monitoring

Action Steps:

1. SGLA appoints officer to maintain email contact list.
2. SGLA Board of Directors communicates lake-related information and educational materials to lake stakeholders through methods discussed in description.

Management Action 4b: Continue and enhance SGLA's involvement with other entities that manage aspects of Shishebogama and Gunlock lakes and other conservation groups.

Timeframe: Continuation of current effort

Facilitator: SGLA Board of Directors

Description: The SGLA is dedicated to enhancing, preserving and protecting the quality of Shishebogama and Gunlock lakes for future generations through effective environmental and education policies. The SGLA promotes policies and practices that protect the interests of Shishebogama and Gunlock lakes stakeholders and enhance their ability to maximize enjoyment of their shared resource.

The waters of Wisconsin belong to everyone and therefore this goal of protecting and enhancing these shared resources is also held by other entities. Some of these entities are tribal and governmental while other organizations rely on voluntary participation.

It is important that the SGLA actively engage with all management entities to enhance the association's understanding of common management goals and to participate in the development of those goals. This also helps all management entities understand the actions that others are taking to reduce the duplication of efforts. Each entity will be specifically addressed in the table on the next pages:

Action Steps:

1. See table guidelines on the next pages.

Partner	Contact Person	Role	Contact Frequency	Contact Basis
Lac du Flambeau Band of Lake Superior Chippewa Indians	Celeste Hockings (chockings@ldftribe.com)	Water Resource Program Manager/Aquatic Ecologist. Northern portion of Shishebogama and all of Gunlock Lake fall within the LDF Reservation.	As needed (watercraft inspections, invasive species control, water quality monitoring, slow-no-wake ordinances, etc.)	Ensure there is not a duplication of water quality, watershed monitoring, watercraft inspection programs, etc. Collaborate on conservation efforts and address tribal regulatory concerns/questions.
Lac du Flambeau Band of Lake Superior Chippewa Indians	Larry Wawronowicz (lwawronoicz@ldftribe.com)	Natural Resource Director/Fisheries Biologist	As needed for fisheries management-related topics.	For projects relating to fisheries: stocking, surveys, habitat enhancement, regulations, etc.
Minocqua Township	Lynn Wildes, Town Secretary (715.356.5296)	Southern portion of Shishebogama Lake falls within the Minocqua Township.	Once a year, or more as needed. May check website (https://www.townofmintowno.org) for updates.	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Lac du Flambeau Township	Mathew Gaulke, Chairman (715-588.3358)	Northern portion of Shishebogama and all of Gunlock Lake fall within the LDF Township.	Once a year, or more as needed. May check website (http://www.tn.lacduflambeau.wi.gov/)	Town staff may be contacted regarding ordinance reviews or questions, and for information on community events.
Oneida County Land and Water Conservation	Michele Saduaskas, County Conservationist (715.369.7835)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements and AIS.
Oneida County Land and Water Conservation	Stephanie Boismenue, sboismenue@co.oneida.wi.us	Coordinator of the Oneida County AIS Program	As needed for AIS-related topics.	Can provide assistance with AIS outreach, monitoring, control, identification, training, workshops, etc.

Vilas County Land and Water Conservation	Carolyn Scholl, County Conservationist (715.479.3682)	Oversees conservation efforts for land and water projects.	As needed	Can provide assistance with shoreland restorations and habitat improvements and AIS.
Vilas County Land and Water Conservation	Catherine Higley, Lake Conservation Specialist (715.479.3738)	Lake monitoring, AIS, shoreland restoration, outreach efforts.	As needed	Can provide assistance with shoreland restoration initiatives, AIS surveys, monitoring, etc.
Vilas County Land and Water Conservation	Marquita Sheehan, Conservation Specialist (715.479.3747)	Lake monitoring, AIS, shoreland restoration, outreach efforts.	As needed	Can provide assistance with shoreland restoration initiatives, AIS surveys, monitoring, etc.
Wisconsin Department of Natural Resources	Scott Van Egeren, Oneida County Lakes Coordinator (715.471.0007)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Kevin Gauthier, Vilas County Lakes Coordinator (715.356.5211)	Oversees management plans, grants, all lake activities.	Every 5 years, or more as necessary.	Information on updating a lake management plan (every 5 years) or to seek advice on other lake issues.
	Audrey Royce, Conservation Warden (715.614.3288)	Oversees regulations handed down by the state in Vilas and Oneida counties.	As needed. May call the WDNR violation tip hotline for anonymous reporting (1-800-847-9367)	Contact regarding suspected violations pertaining to recreational activity on Shishebogama and Gunlock lakes, include fishing, boating safety, ordinance violations, etc.
	Citizens Lake Monitoring Network contact (Sandy Wickman – Sandy.Wickman@wisconsin.gov)	Provides training and assistance on CLMN monitoring, methods, and data entry.	Twice a year or more as needed.	Late winter: arrange for training as needed, in addition to planning out monitoring for the open water season. Late fall: report monitoring activities.

	Jeanne Scherer (Purple Loosestrife Coordinator) jeannes.scherer@wisconsin.gov	Provides assistance on purple loosestrife control and monitoring.	As needed.	
	WDNR Fisheries Biologists (Eric Wegleitner, Vilas County, Eric.Wegleitner@wiwiscons.gov, Zach Woiak, Oneida County, Zach.Woiak@wisconsni.gov)	Oversee fishery management activities no Shishebogama and Gunlock lakes.	Once a year or more as needed.	Stocking activities, scheduled surveys, survey results, volunteer opportunities for improving fishery.
Wisconsin Lakes	General staff (800.542.5253)	Facilitates education, networking and assistance on all matters involving WI lakes.	As needed. May check website (www.wisconsinlakes.org) often for updates.	SGLA members may attend WL's annual conference to keep up-to-date on lake issues. WL reps can assist on grant issues, AIS training, habitat enhancement techniques, etc.
Wisconsin Headwaters Invasives Partnership	Tracy Beckmann, Secretary (715.369.9886)	Cooperative Invasive Species Management Area for Vilas, Oneida, and Lincoln counties comprised of representatives from various agencies to manage invasive species in northern Wisconsin.	Once per year and as needed.	SGLA members can work with WHIP for resources for invasive species control and collaboration.

Vilas County Sherriff's Office	General contact: 715.479.4441	Primary law enforcement agency in Vilas County.	As needed. May call to report watercraft violations on Shishebogama and Gunlock lakes.	Contact regarding suspected violations pertaining to recreational activity on Shishebogama and Gunlock lakes, boating safety, ordinance violations, etc.
Oneida County Sherriff's Office	General contact: 715.361.5100	Primary law enforcement agency in Oneida County.	As needed. May call to report watercraft violations on Shishebogama and Gunlock lakes.	Contact regarding suspected violations pertaining to recreational activity on Shishebogama and Gunlock lakes, boating safety, ordinance violations, etc.
Wisconsin Lakes	Michael Engleson, Executive Director at Wisconsin Lakes (mengleson@wisconsinlakes.org)	Non-profit organization working to protect and enhance Wisconsin's lakes.	As needed.	Contact to obtain updates and information on news and policy information for Wisconsin's lakes and how SGLA can participate in the WI Lakes Partnership.
Extension Lakes	Eric Olson, Director and Lake Specialist (715.346.2192)	Works with lake professionals and citizens across the state.	As needed.	Can help SGLA foster communication and collaboration.
Extension Lakes	Patrick Goggin, Lake Specialist (715-365-8943)	Works with lake professionals and citizens across the state.	As needed.	Can help SGLA bolster existing efforts, lakeshore habitat restoration, native plant ideas, working with tribal communities.

Extension Lakes	Paul Skawinski, Citizen Lake Monitoring Network Educator (715.346.4853)	Develops protocols used by volunteers when assessing lake water quality and their environment.	As needed.	Can help with ongoing lake monitoring and associated training.

Management Goal 5: Manage Existing Invasive Plant Species in Shishebogama & Gunlock Lakes' Shoreland Zone

Management Action 5a: Monitor and control pale-yellow iris within the immediate shoreland zone of Shishebogama and Gunlock lakes.

Timeframe: Continuation of current effort.

Facilitator: SGLA Board of Directors and Mike Rooney

Description: In 2019, numerous occurrences of the invasive pale-yellow iris were located along the southern shore of Shishebogama Lake (Map 9). Currently, the SGLA has 17 active volunteer invasive species monitors which search designated shoreline areas around the lakes three times per year. Volunteers have hand-removed nearly 1,500 pounds of pale-yellow iris.

Volunteer monitoring and control of pale-yellow iris should continue to prevent this plant from establishing in new areas around the lake. The ideal time to identify this plant is in early summer, likely June, during the peak blooming period. Volunteers will then cut flowers and/or seed pods or dig out plants where applicable as a means for control. If larger colonies are located that are beyond control by digging, the SGLA should work with LDF NRD staff their local WDNR staff (Kevin Gauthier [Kevin.Gauthier@wisconsin.gov], Scott Van Egeren [Scott.VanEgeren@wisconsin.gov]) to apply for a chemical control permit if herbicides are warranted. The LDF Tribe does not allow any chemical control methods within exterior boundaries of the reservation. The applicant will need to seek Tribal consultation along with the WDNR.

The SGLA will communicate with lake property owners through their annual meetings, newsletters, email, Facebook page, and website to educate and recruit property owners on how to identify pale-yellow iris on their property and effective methods for control.

Action Steps:

1. Continue volunteer-based monitoring and control of pale-yellow iris along the shorelines of Shishebogama and Gunlock lakes.
2. Document and monitor all pale-yellow iris occurrences with GPS coordinates and maintain database (e.g., Excel spreadsheet) to keep and update records.
3. Work with WDNR, LDF NRD, and county partners to develop a long-term pale-yellow iris monitoring and control strategy.
4. Continue to educate property owners on pale-yellow iris identification and control via methods discussed above, recruit volunteers as needed to maintain annual monitoring and control of these plants within the shoreland zone.

5. Discuss with WDNR and LDF consideration of replacing removed pale-yellow iris plants (and other subsequently discussed shoreline invasive plants) with native plants to decrease erosion and improve habitat (e.g., pollinator benefits). Plantings could be covered as part of an AIS or other Surface Water grant.

<u>Management Action 5b:</u> Monitor and control purple loosestrife within the immediate shoreland zone of Shishebogama and Gunlock lakes.

Timeframe: Continuation of current effort.

Facilitator: SGLA Board of Directors and Mike Rooney

Description: In 2019, the non-native, invasive purple loosestrife was scattered in areas in the channel between Gunlock and Shishebogama lakes, while only one plant was located on the shores of Shishebogama Lake (Map 9). While the SGLA has raised *Galericella* beetles in the past to control purple loosestrife, no beetles were raised in 2020 and all plants that were found were hand-pulled or their flowers were cut off. Due to the SGLA's ongoing control efforts, purple loosestrife has been reduced over the years. The SGLA should continue their volunteer-based monitoring and control of purple loosestrife, and work with WDNR, LDF RD, and county partners in this effort.

Action Steps:

1. Continue volunteer-based monitoring and control of purple loosestrife along the shorelines of Shishebogama and Gunlock lakes.
2. Document and monitor all purple loosestrife occurrences with GPS coordinates and maintain database (e.g., Excel spreadsheet) to keep and update records.
3. Work with WDNR, LDF NRD, and county partners to develop a long-term purple loosestrife monitoring and control strategy.
4. Continue to educate property owners on purple loosestrife identification and control via methods discussed above, and recruit volunteers as needed to maintain annual monitoring and control of these plants within the shoreland zone.

<u>Management Action 5c:</u> Monitor and control narrow-leaved/hybrid cattail within the immediate shoreland zone of Shishebogama and Gunlock lakes.

Timeframe: Initiate 2021.

Facilitator: SGLA Board of Directors and Mike Rooney

Description: Narrow-leaved/hybrid cattail, a non-native, invasive wetland plant that has the capacity to create large, monotypic colonies and displace native wetland vegetation. Narrow-leaved cattail was first located in Gunlock Lake in 2009, and in 2019, a few colonies of narrow-leaved cattail and/or hybrid cattail were located along the shorelines of Shishebogama and Gunlock lakes (Maps 9-11). Given the isolated nature of these colonies, the best method of control is likely the cutting of stems (both green and dead) in mid- to late-summer or early fall to below the water line. The following growing season, continually cut-back emerging stems to maintain them below the water for the remainder of the growing season. This process should be repeated until the plants do not reemerge. The SGLA should work with WDNR, LDF NRD, and county partners to discuss control and monitoring options for narrow-leaved cattail.

Action Steps:

1. Initiate volunteer-based monitoring and control of narrow-leaved cattail along the shorelines of Shishebogama and Gunlock lakes.
2. Document and monitor all narrow-leaved cattail occurrences with GPS coordinates and maintain database (e.g., Excel spreadsheet) to keep and update records.
3. Work with WDNR, LDF NRD, and county partners to develop a long-term narrow-leaved cattail monitoring and control strategy.
4. Educate property owners on narrow-leaved cattail identification and control via methods discussed above, and recruit volunteers as needed to maintain annual monitoring and control of these plants within the shoreland zone.

Management Goal 6: Prevent the Introduction of New Invasive Species to Shishebogama & Gunlock Lakes

Management Action 6a: Continue volunteer-based monitoring for aquatic invasive species in Shishebogama and Gunlock lakes.

Timeframe: Continuation of current effort.

Facilitator: SGLA Board of Directors and Mike Rooney

Description: The SGLA currently has 17 volunteers who actively monitor designated areas of Shishebogama and Gunlock lakes shoreline and littoral zone for aquatic invasive species. This monitoring is conducted three times per year. These volunteers use GPS to mark invasive plant species such as pale-yellow iris, purple loosestrife along the shoreline. The monitoring of narrow-leaved cattail will be added to the current monitoring effort. They also search shallow areas for potential occurrences of submersed invasive species like Eurasian watermilfoil and curly-leaf pondweed. The SGLA will actively recruit new volunteer monitors as needed and designate a member (currently Mike Rooney) to coordinate the volunteer monitoring efforts.

Action Steps:

1. See description above.

Management Action 6b: Continue Clean Boats Clean Waters watercraft inspections at the public boat landing on Gunlock Lake and investigate increasing monitoring strategies and efforts.

Timeframe: Continuation of current effort.

Facilitator: SGLA Board of Directors and LDF NRD staff

Potential Funding: WDNR AIS-Clean Boats Clean Waters Grant

Description: The public landing on Gunlock Lake sees the highest use in terms of boats entering and leaving this two-lake system. Given the higher use rate, this landing is the most likely entry point for new AIS into Gunlock and Shishebogama lakes. The SGLA and LDF NRD currently partner to monitor the public boat landing on Gunlock Lake to complete watercraft inspections and lake user education. Staff from the LDF NRD manage the Clean Boats Clean Waters (CBCW) grant which funds 216 paid inspection hours. Volunteers are used to cover additional monitoring or a total of approximately 350 monitoring hours per year. The SGLA currently has a three-year agreement with the LDF NRD for funding, and 2021 will be the second year in the agreement.

Shishebogama and Gunlock lakes are a popular destination for recreationalists and anglers, making these lakes vulnerable to new infestations of exotic species. The fact that Eurasian watermilfoil nor curly-leaf pondweed have been located in either of these high-use lakes do date is testament to watercraft inspection efforts undertaken by the SGLA and LDF NRD. Continuation of this monitoring will be essential to minimize the probability of future invasive species introduction. The goal is to cover the landing during the busiest times in order to maximize contact with lake users, spreading the word about the negative impacts of AIS on lakes and educating people about how they are the primary vector of their spread. The SGLA will investigate additional boat landing monitoring strategies (e.g., cameras) and also discuss possibilities of increasing monitoring efforts.

Action Steps:

1. Continue in-person watercraft inspections at Gunlock Lake boat landing at levels outlined above.
2. Monitor WDNR, Vilas and Oneida counties', LDF NRD, and local news reports and resources on new discoveries of IAS in nearby lakes and alert boat landing monitors.
3. Monitor any additional lake access points as necessary for risks of AIS introduction.
4. Investigate new monitoring technologies such as boat landing camera systems and more to reduce the risks of uninspected watercraft introducing AIS to the lakes during periods when in-person monitoring is not occurring.

<u>Management Action 6c:</u> Activate aquatic invasive species rapid response plan upon discovery of a new infestation.

Timeframe: Review current Rapid Response Plan

Facilitator: SGLA and/or appropriate lake stakeholder(s)

Description: The SGLA currently has a response plan in place with monies put aside for control and monitoring in the event that a new invasive species is discovered in either lake (see Appendix G). It is recognized that aggressive aquatic invasive species such as Eurasian watermilfoil are in nearby lakes and represent an increased risk to Shishebogama and Gunlock lakes. In the event that a new aquatic invasive species, such as Eurasian watermilfoil, is located in Shishebogama or Gunlock lakes by trained volunteers, the areas would be marked using GPS and the SGLA should contact resource managers immediately. The areas marked by volunteers would serve as focus areas for professional ecologists, and these areas would be surveyed by professionals during the plant's peak growth phase. The results would be used to develop potential control strategies. The SGLA will continue to educate lake stakeholders on how to identify Eurasian watermilfoil, curly-leaf pondweed, and other invasive species so they may recognize potential occurrences while out on the lake.

Action Steps:

1. SGLA Board of Directors contacts WDNR and LDF NRD upon discovery of new aquatic invasive species in Shishebogama and Gunlock lakes.
2. SGLA works with WDNR, LDF NRD, and/or qualified professionals to develop management strategy for newly discovered invasive species.
3. The SGLA board currently maintains and will potentially grow the SGLA ear-marked funding for emergency aquatic invasive species control. The SGLA Board will actively study the current AIS Remediation Fund levels and will determine if sufficient funds exist to do both an initial remediation and support ongoing management activities of a new invasive species. The Board will also estimate what funds would be required for on-going remediation of an aggressive infestation in the lakes and make recommendations on how to accomplish future funding requirements.
4. Communicate and advise riparian property owners and lake stakeholders immediately with new invasive species discovery and information.

Management Goal 7: Protect Native Aquatic Plant Communities in Shishebogama & Gunlock Lakes

Management Action 7a: Coordinate periodic, quantitative aquatic plant monitoring on Shishebogama and Gunlock lakes.

Timeframe: Whole-lake point-intercept and emergent/floating-leaf community mapping surveys every 5 years.

Facilitator: SGLA Board of Directors in collaboration with LDF NRD

Description: Aquatic plants are a critical component to a properly functioning lake ecosystem. The Shishebogama-Gunlock lake system harbors a species-rich plant community. In the surveys completed on Shishebogama and Gunlock lakes in 2009 and 2019, a total of 77 native aquatic plant species have been documented to date, a number of which are considered to be rare or environmentally sensitive. In addition, these lakes support a number of distinct aquatic plant communities, including isoetid-dominated, elodeid-dominated, and floating-leaf and emergent marshes.

Conservation of these valuable native aquatic plant communities is not only important for the ecological function of these lakes, but aids in regional and statewide efforts to conserve these valuable aquatic plant communities. The isoetid communities found in these lakes are relatively rare, restricted to the northern portion of the state, and are sensitive to degradation. In addition to conserving water quality and immediate shoreland areas, the SGLA could also distribute materials on how boating can impact aquatic plants in terms of direct cutting, propwash, and wave action. In an effort to maintain the integrity of these communities, it is recommended that comprehensive surveys (whole-lake point-intercept and emergent/floating-leaf community mapping surveys) be completed on these lakes every 5 years.

Action Steps:

1. Collaborate with LDF NRD and retain qualified professional to complete whole-lake point-intercept and emergent/floating-leaf mapping surveys every 5 years.
2. Work with qualified professional to develop protection/restoration strategies if warranted.
3. Update management plan to reflect changes in aquatic plant communities and aquatic plant management/monitoring needs and those of the lake ecosystem.

Management Goal 8: Conserve and Enhance Shishebogama & Gunlock Lakes as a Fishery Resource

Management Action 8a: Work with LDF NRD and WDNR fisheries managers to conserve and enhance the fishery of Shishebogama and Gunlock lakes.

Timeframe: Continuation of current effort.

Facilitator: SGLA Fisheries Committee and Board of Directors

Description: Respondents to the 2020 stakeholder survey listed fishing as the top activity for lake stakeholders of Shishebogama and Gunlock lakes. SGLA stakeholders must realize the complexities and capabilities of this ecosystem with respect to the fishery it can produce. The SGLA currently collaborates with WDNR and LDF NRD staff to enhance the fishery of Shishebogama and Gunlock lakes through stocking and habitat improvements. The SGLA currently supports a Fisheries Committee that has and will continue to support a strong fisheries program for Shishebogama and Gunlock lakes.

Following a survey in 2015, stocking of walleye was conducted in an effort to increase the population. In addition, efforts were made to determine if there were opportunities to improve spawning habitat and increase natural reproduction. However, ongoing research is indicating that increasing water temperatures may be the primary factor limiting natural walleye reproduction. While the Fisheries Committee will continue to work with WDNR and LDF NRD biologists to determine if habitat improvements have the capacity to increase natural reproduction, stocking of walleye will continue as the primary means of sustaining the population. The SGLA provides financial support to the LDF Tribe to aid in stocking efforts, and the quantity of fish stocked is determined by LDF NRD or WDNR biologists. If fish are not stocked by the LDF Tribe, the SGLA will have to seek a WDNR permit to continue regular stocking. The Fisheries Committee will also continue to work with WDNR and LFD NRD staff in an effort to complete another fisheries survey to determine if population goals are being met.

The SGLA Fisheries Committee will also work with WDNR and LDR NRD fisheries biologists to enhance fisheries habitat in Shishebogama and Gunlock lakes. The 2019 survey found that the amount of course woody habitat in Shishebogama and Gunlock lakes on a per shoreline mile basis fell in the 50^{th} and 18^{th} percentile, respectively. The SGLA Fisheries Committee will work with local fisheries biologists to determine if course woody habitat enhancements would be beneficial to the fisheries of one or both of these lakes.

Action Steps:

1. SGLA Fisheries Committee contact LDF NRD Larry Wawronowicz (715.588.4203) and WDNR Fisheries Biologists (Eric Wegleitner,

Vilas County, Eric.Wegleitner@wiwiscons.gov, Zach Woiak, Oneida County, Zach.Woiak@wisconsni.gov) at least once per year to inquire about ongoing fisheries management in Shishebogama and Gunlock lakes.

2. SGLA works with LDF NRD and WDNR fisheries biologists to continue walleye stocking in the absence of natural reproduction and will continue to work to improve fisheries spawning and foraging habitat.
3. SGLA continues to educate and communicate with stakeholders about the lake's fishery, shocking and creel surveys, regulations, catch-and-release fishing, habitat, and other fisheries-related topics.
4. SGLA will file the appropriate Tribal (and WDNR) permits for installation of fish cribs, fish sticks, etc., when these items are placed on a lakebed within the boundary of the Reservation. The LDF NRD staff will assist with these permit submissions.

6.0 METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Shishebogama and Gunlock lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point on each lake. Samples were collected using WDNR Citizen Lake Monitoring Network (CLMN) protocols which occurred twice during the summer. In addition to the samples collected by SGLA members, professional water quality samples were collected at subsurface (S) and near bottom (B) depths once in spring, summer, fall and winter. Winter dissolved oxygen was determined with a calibrated probe and all samples were collected with a 3-liter Van Dorn bottle. Secchi disk transparency was also included during each visit. All samples that required laboratory analysis were processed through the Wisconsin State Laboratory of Hygiene (SLOH). The parameters measured, sample collection timing, and designated collector are contained in the table below.

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

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

Watershed Analysis

The watershed analysis began with an accurate delineation of Shishebogama and Gunlock lakes' drainage area using Vilas and Oneida county LiDAR data. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the National Land Cover Database (NLCD) (Fry, et al., 2011) were then combined to determine the watershed land cover classifications. These data were modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska & Kreider, 2003).

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on Shishebogama and Gunlock lakes during a June 2019 field visit, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat.

Comprehensive Macrophyte Surveys

Comprehensive surveys of aquatic macrophytes were conducted on Shishebogama and Gunlock lakes to characterize the existing communities within the lake and include inventories of emergent, submergent, and floating-leaved aquatic plants within them. The point-intercept method as described in the Wisconsin Department of Natural Resource document, Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry, and Analysis, and Applications (WDNR PUB-SS-1068 2010) was used to complete this study on Gunlock Lake by LDR NRD on July 24, 2019 and by Onterra on Shishebogama Lake on July 24, 2019.

Community Mapping

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

Representatives of all plant species located during the point-intercept and community mapping survey were collected, vouchered, and sent to the University of Wisconsin – Steven's Point Herbarium.

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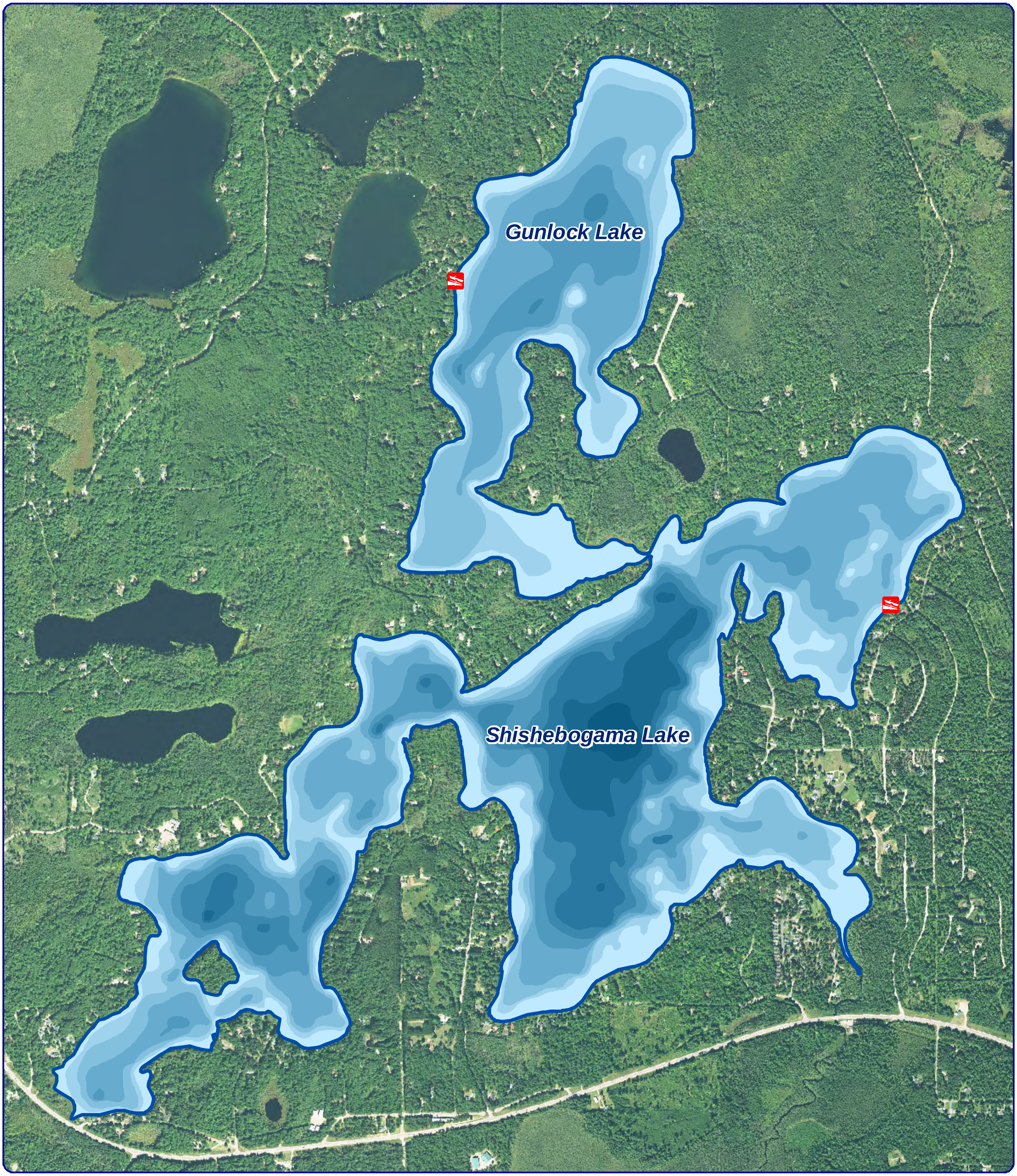

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Sources:
Orthophotography: NAIP 2018
Bathymetry: WDNR, digitized by Onterra
Map Date: August 10, 2020
Filename: Map1_Shish-Gun_Location.mxd

Project Location in Wisconsin

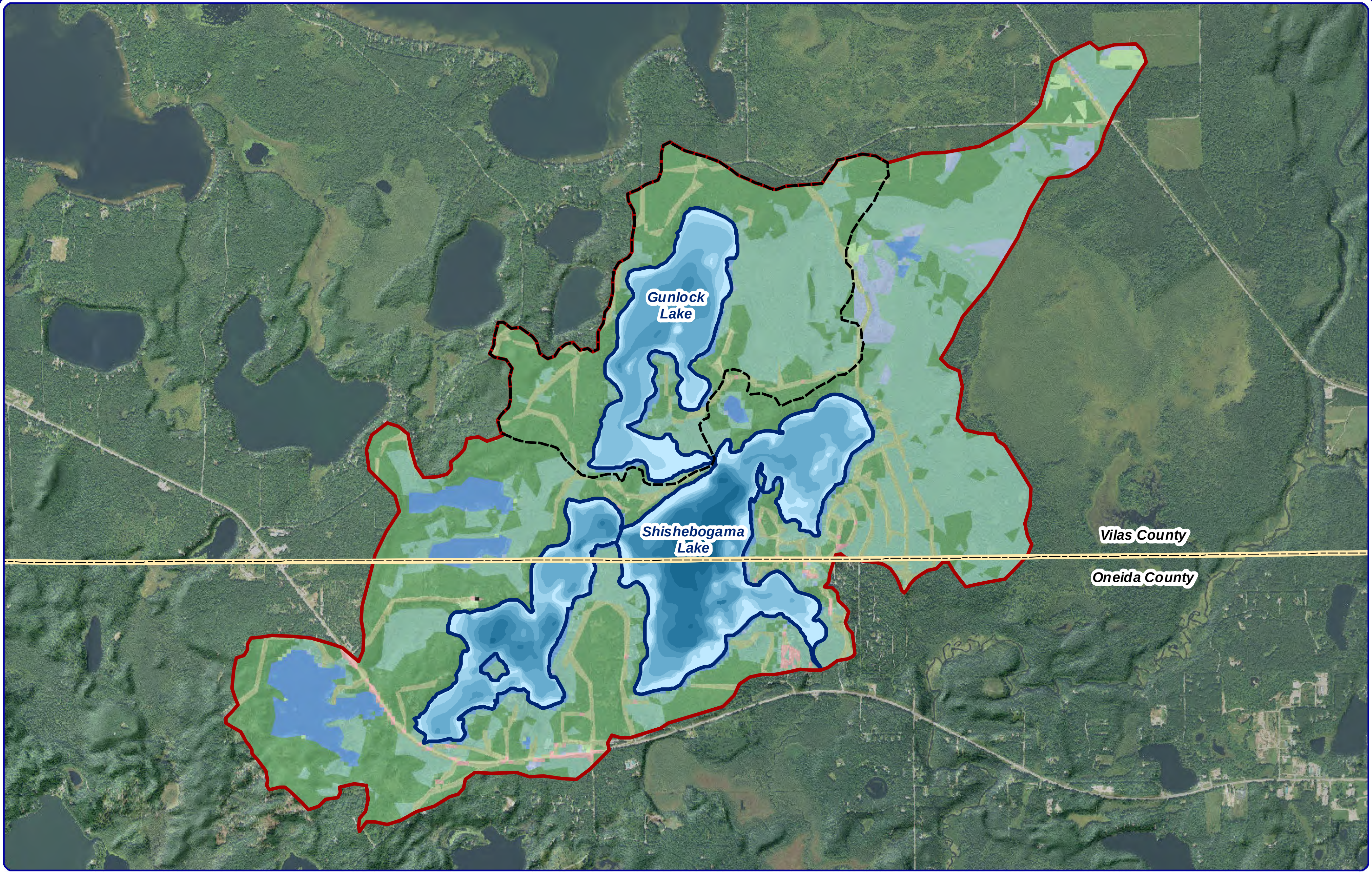
Legend

Shishebogama & Gunlock Lakes

Public Boat Launch

Map 1
Shishebogama & Gunlock Lakes
Oneida & Vilas Counties, Wisconsin

Project Location & Lake Boundaries



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Sources:
Hydro: WDNR
Watershed: Onterra 2020
Orthophotography: 2018 NAIP
Map Date: August 10, 2020 BTB
File Name Map2_Shish-Gun_WS.mxd

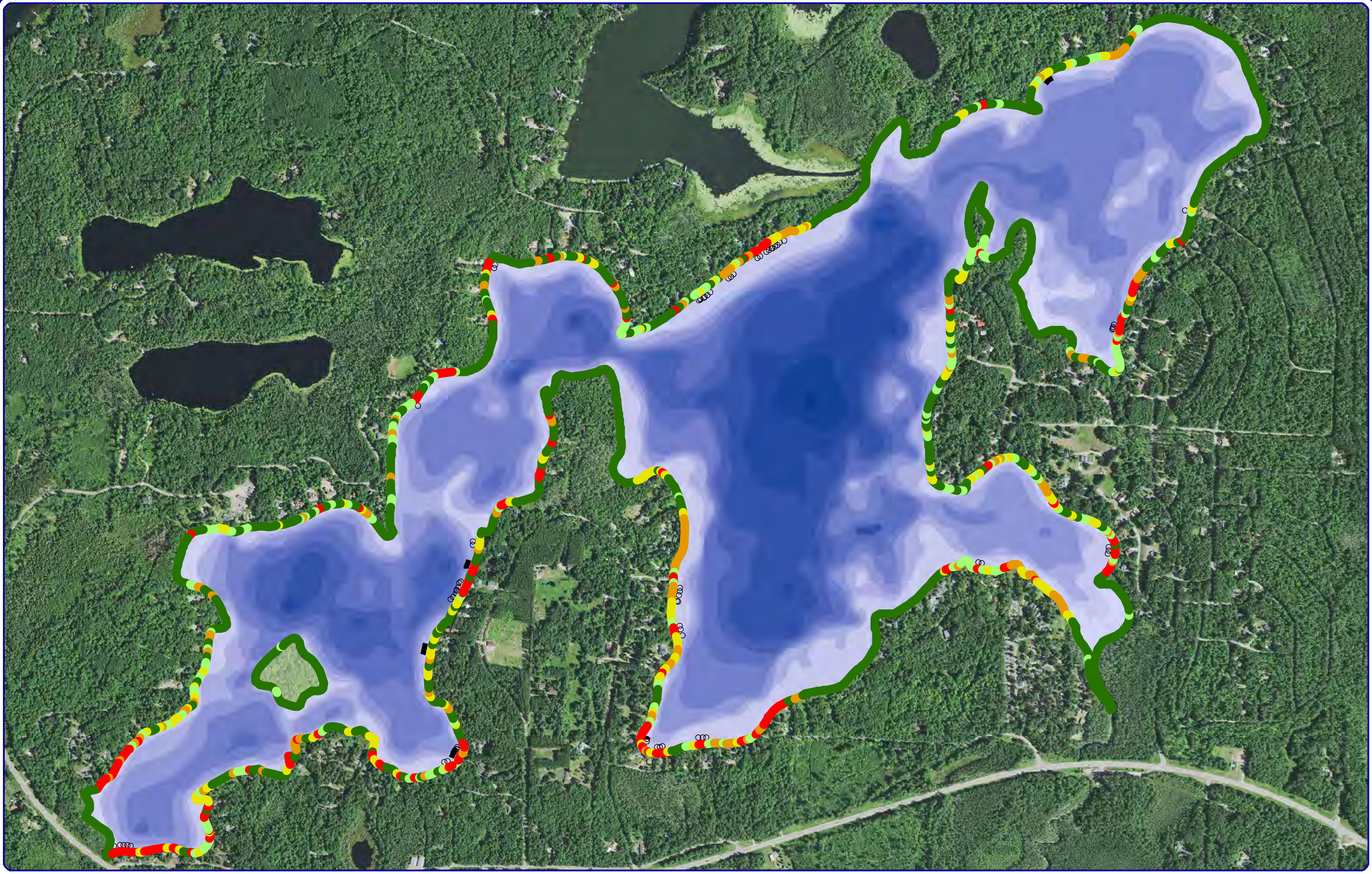
Project Location in Wisconsin

Legend

- Gunlock Lake Watershed Boundary
- Shishebogama Lake Watershed Boundary
- Forest
- Forested Wetlands
- Pasture/Grass (None)
- Rural Open Space
- Rural Residential
- Non-Forested Wetlands
- Open Water

Map 2
Shishebogama & Gunlock Lakes
Oneida & Vilas Counties, Wisconsin

Watershed Boundaries & Land Cover Types



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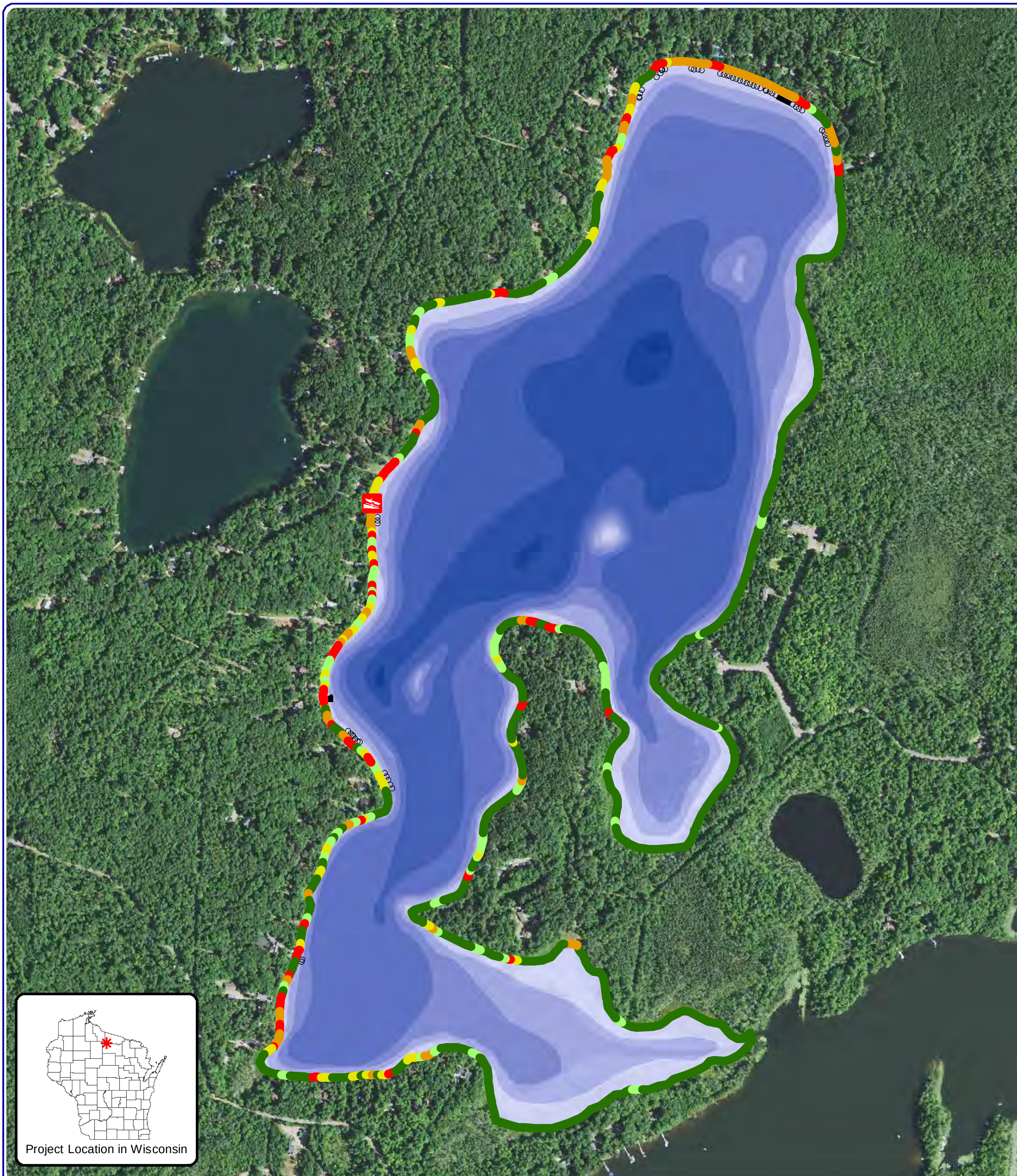
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 10/22/2019
Orthophotography: NAIP, 2015
Map date: November 6, 2019 JMB
Filename: Shish_SA_2019.mxd

Legend

Natural/Undeveloped
Developed-Natural
Developed-Semi-Natural
Developed-Unnatural
Urbanized

Seawall Modifier
Masonary/Metal/Wood
Rip-Rap

Map 3
Shishebogama Lake
Oneida & Vilas Counties, Wisconsin
2019 Shoreland Condition Assessment



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Legend

- Natural/Undeveloped
- Developed-Natural
- Developed-Semi-Natural
- Developed-Unnatural
- Urbanized

Seawall Modifier

- Masonary/Wood Seawall
- Rip-Rap

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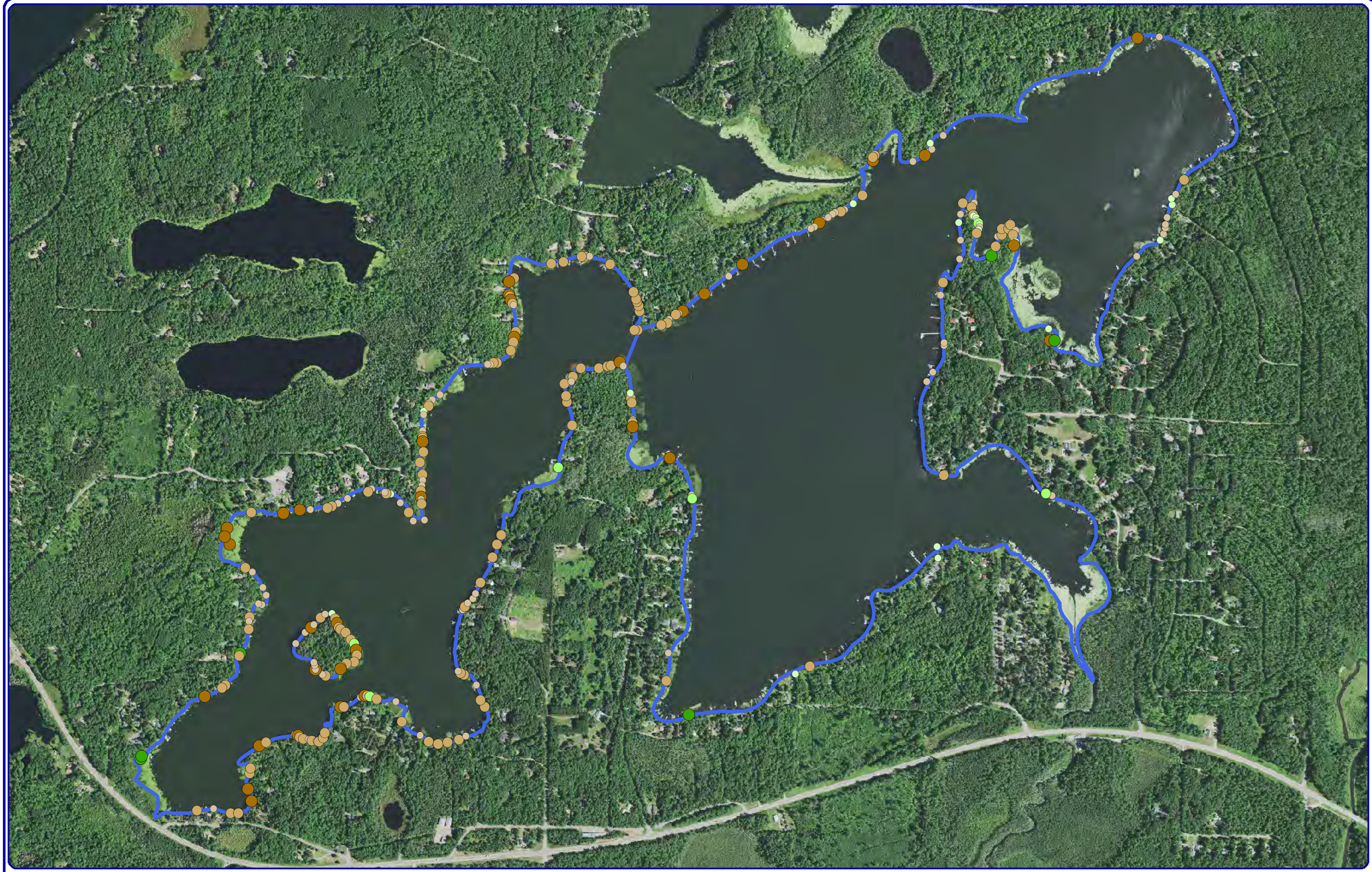
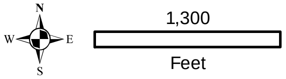
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 10/22/2019
Orthophotography: NAIP, 2015
Map date: November 7, 2019 JMB
Filename: Gunlock_SA_2019.mxd

Map 4
Gunlock Lake
Vilas County, Wisconsin
2019 Shoreland Condition Assessment





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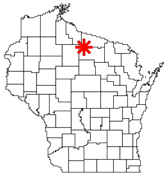
Sources
Hydro: WDNR
CWH Survey: Onterra, 10/22/2019
Orthophotography: NAIP, 2015
Map date: November 6, 2019 JMB
Filename: Shish_CWH_2019.mxd

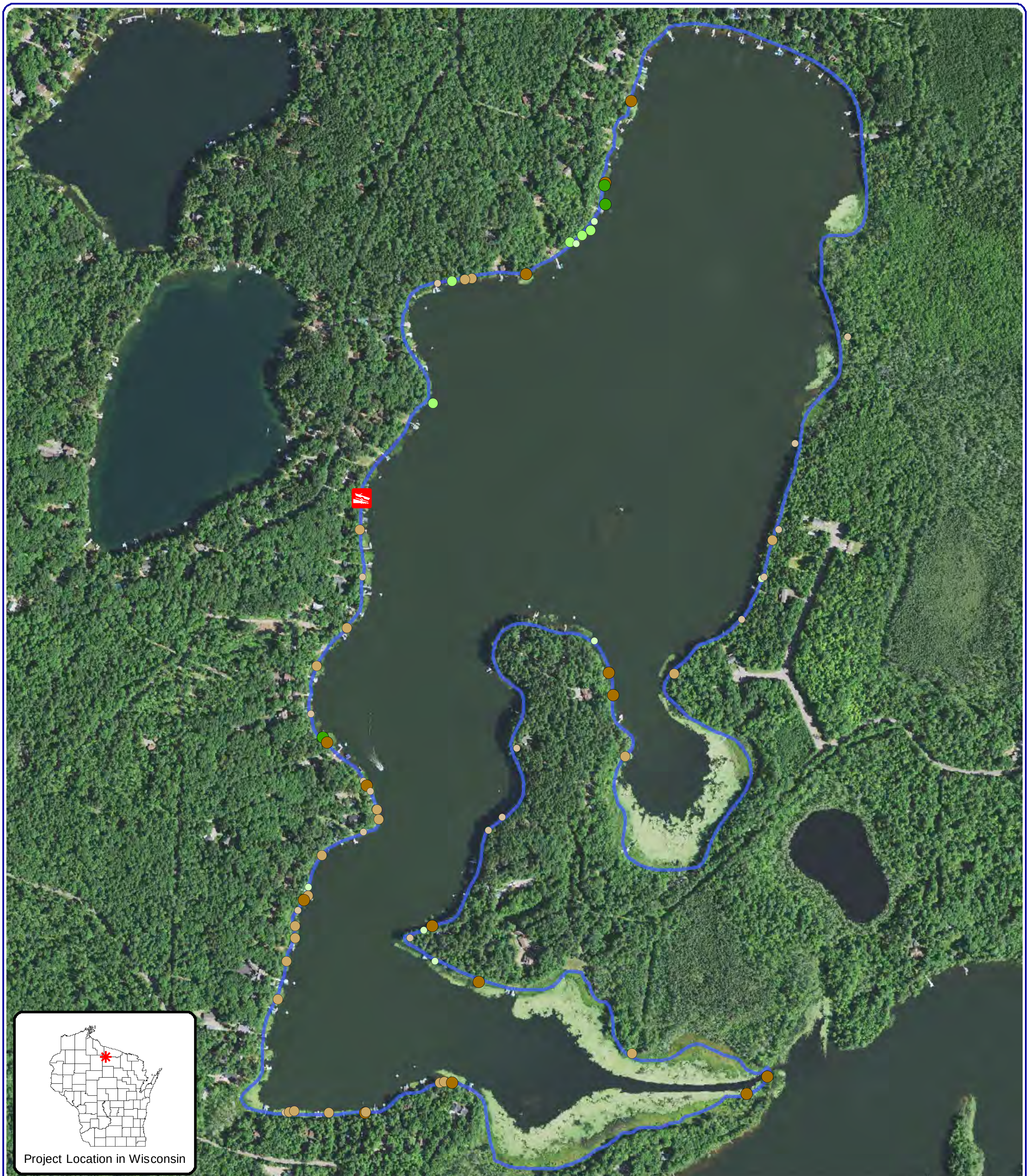


Project Location in Wisconsin

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

Map 5
Shishebogama Lake
Oneida & Vilas Counties, Wisconsin
2019 Coarse Woody Habitat



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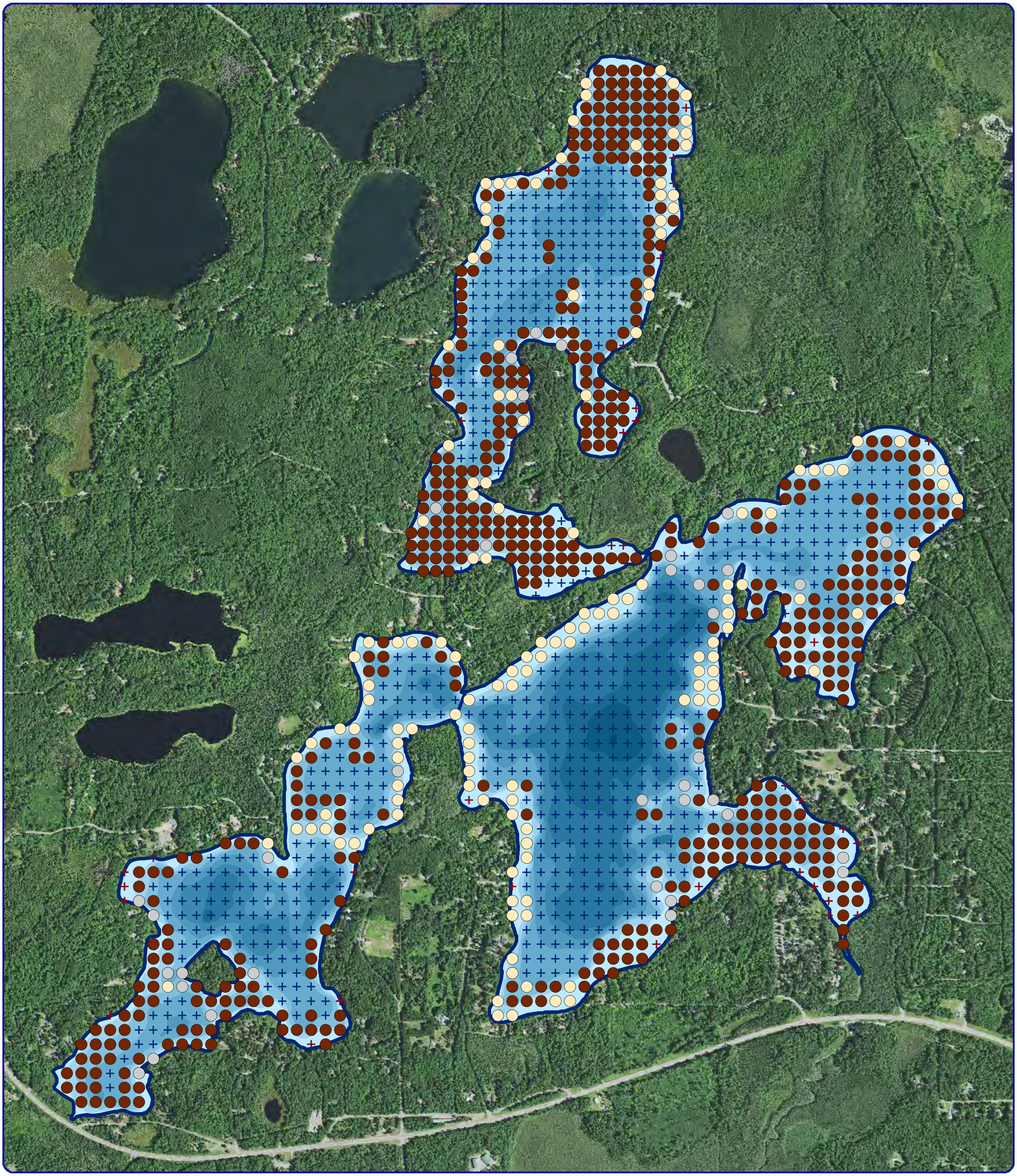
Sources
Hydro: WDNR
CWH Survey: Onterra, 10/22/2019
Orthophotography: NAIP, 2015
Map date: November 7, 2019 JMB
Filename: Gunlock_CWH_2019.mxd

Legend

2-8 Inch Pieces	8+ Inch Pieces	Cluster of Pieces
No Branches	No Branches	No Branches
Minimal Branches	Minimal Branches	Minimal Branches
Moderate Branches	Moderate Branches	Moderate Branches
Full Canopy	Full Canopy	Full Canopy

Map 6
Gunlock Lake
Vilas County, Wisconsin
2019 Coarse Woody Habitat



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Feet

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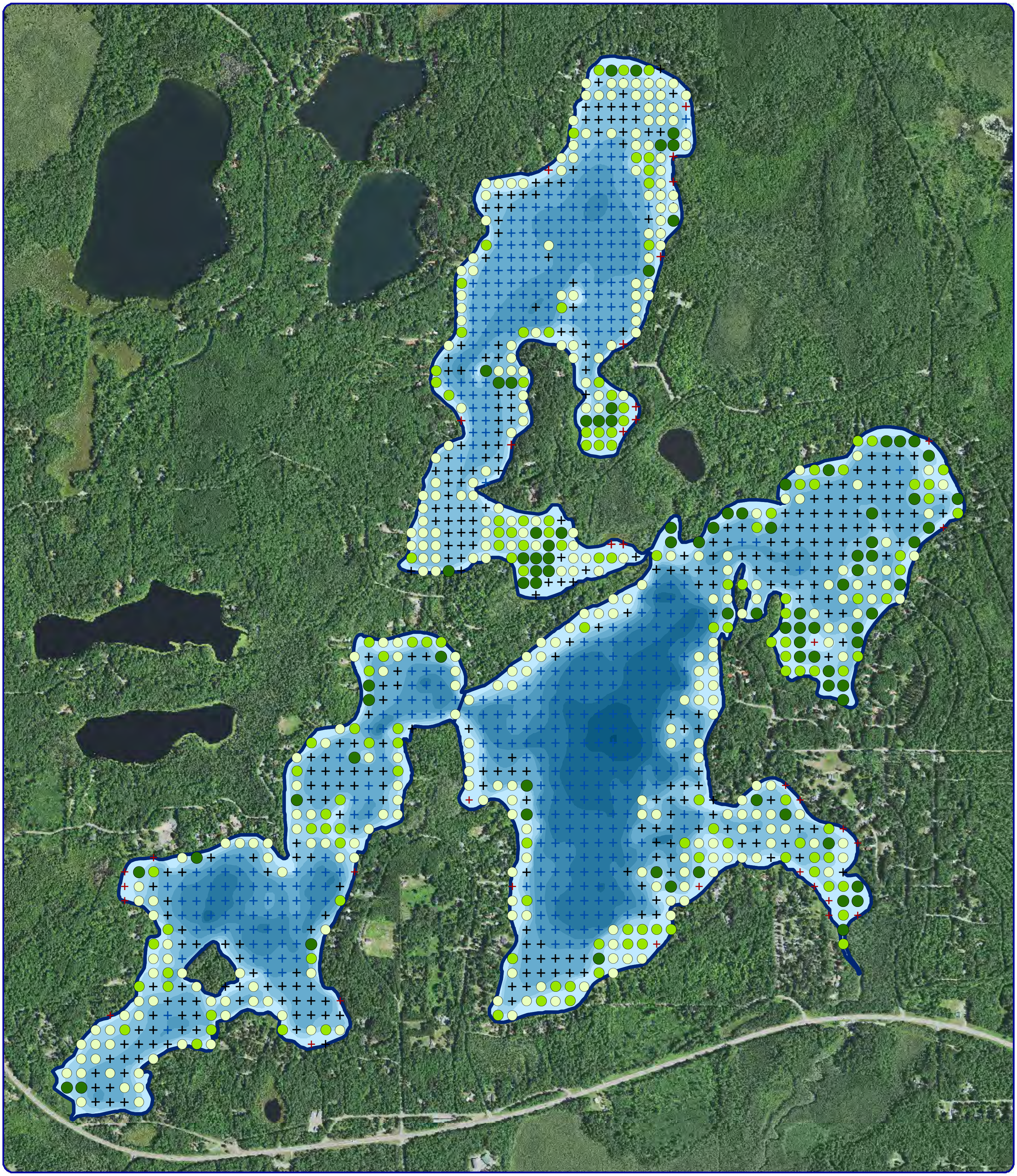
Sources:
Gunlock PI Data: LDF 7/24/2019
Shishebogama PI Data: Onterra 7/24/2019
Orthophotography: NAIP 2018
Map Date: August 14, 2020 BTB
Filename: Map7_Shish-Gun_SubstratePI.mxd

● Soft/Organic Sediment
● Rock
● Sand
+ Too Deep - No Data
+ Non-Navigable, Obstacle, etc. - No Data

Map 7
Shishebogama & Gunlock Lakes
Oneida & Vilas Counties

2019 Point-Intercept Survey: Substrate Types



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Feet

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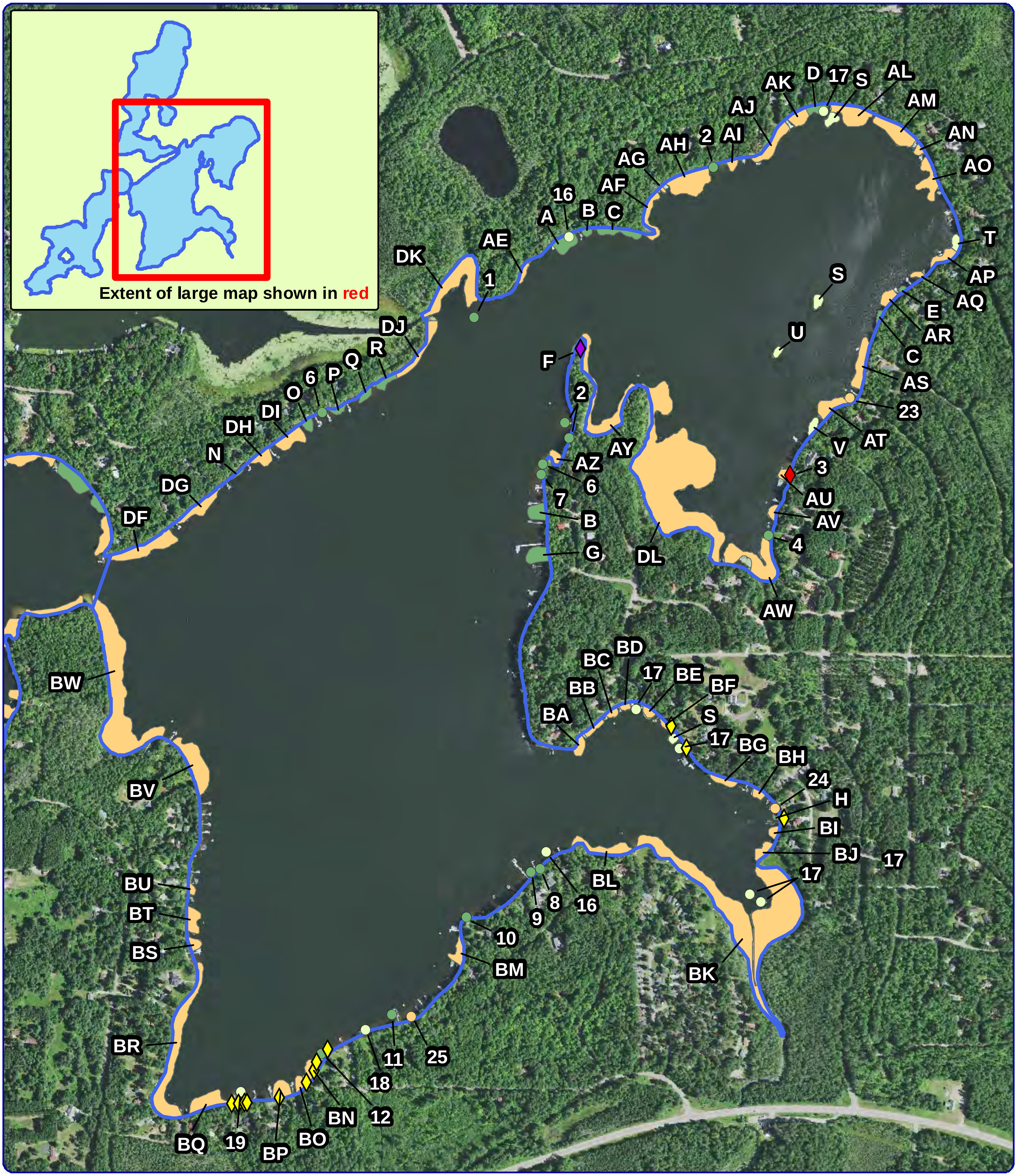
Sources:
Gunlock PI Data: LDF 7/24/2019
Shishebogama PI Data: Onterra 7/24/2019
Orthophotography: NAIP 2018
Map Date: August 14, 2020 BTB
Filename: Map8_Shish-Gun_TRFPI.mxd

+ No Vegetation - Littoral Zone
Total Rake Fullness = 1
Total Rake Fullness = 2
Total Rake Fullness = 3
+ No Vegetation - Profundal Zone
+ Non-Navigable, Obstacle, etc. - No Data

Map 8
Shishebogama & Gunlock Lakes
Oneida & Vilas Counties

2019 Point-Intercept Survey:
Vegetation Distribution



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Small Naitve Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Native Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Non-Native Plant Communities
- Narrow-leaved cattail
- Pale yellow iris
- Purple loosestrife

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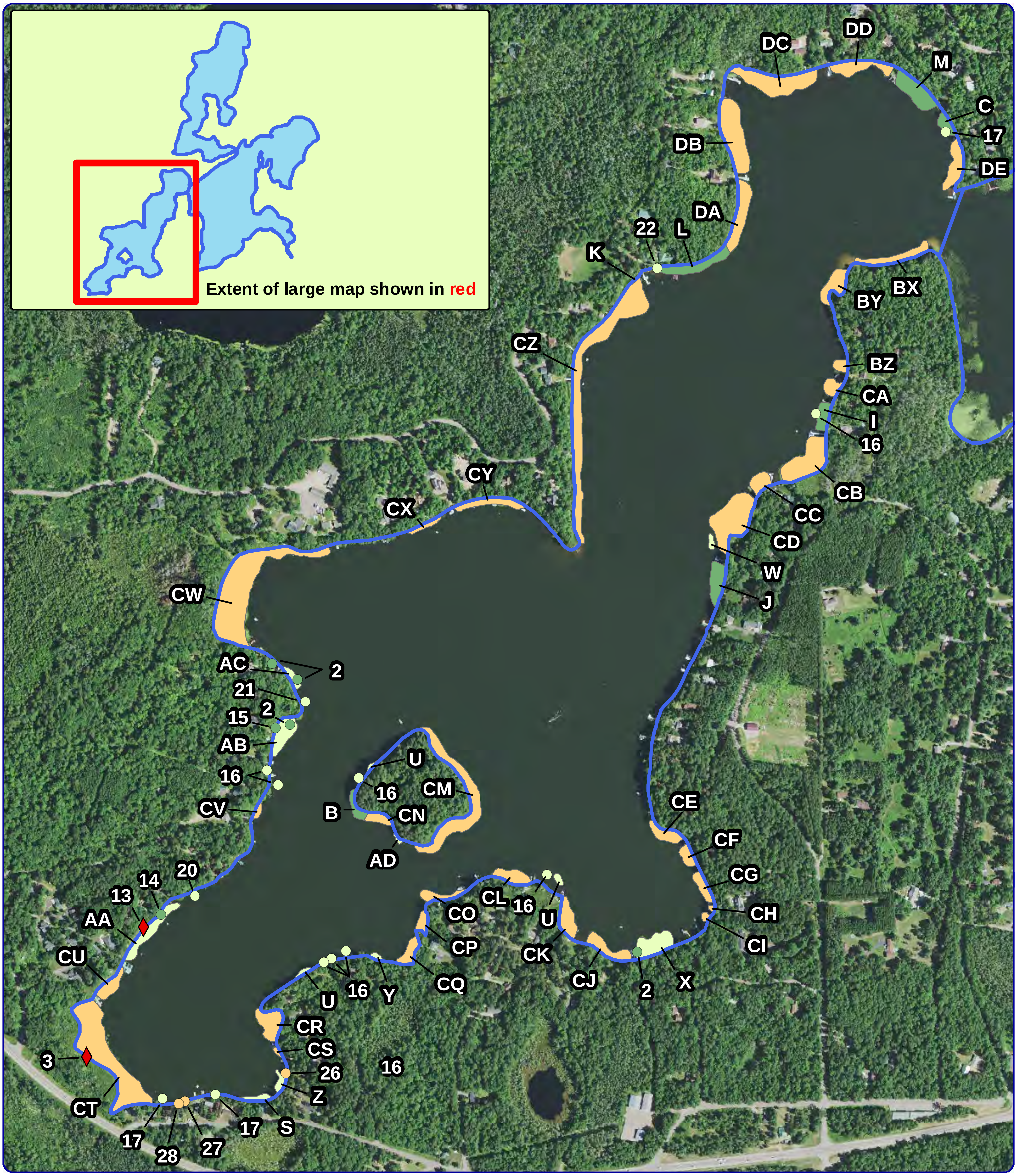
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 8/14/19
Orthophotography: NAIP, 2017
Map date: January 8, 2020 AMS
Filename: Map9_Shish_Comm_East_2019.mxd

Map 9
Shishebogama Lake
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities East



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Feet

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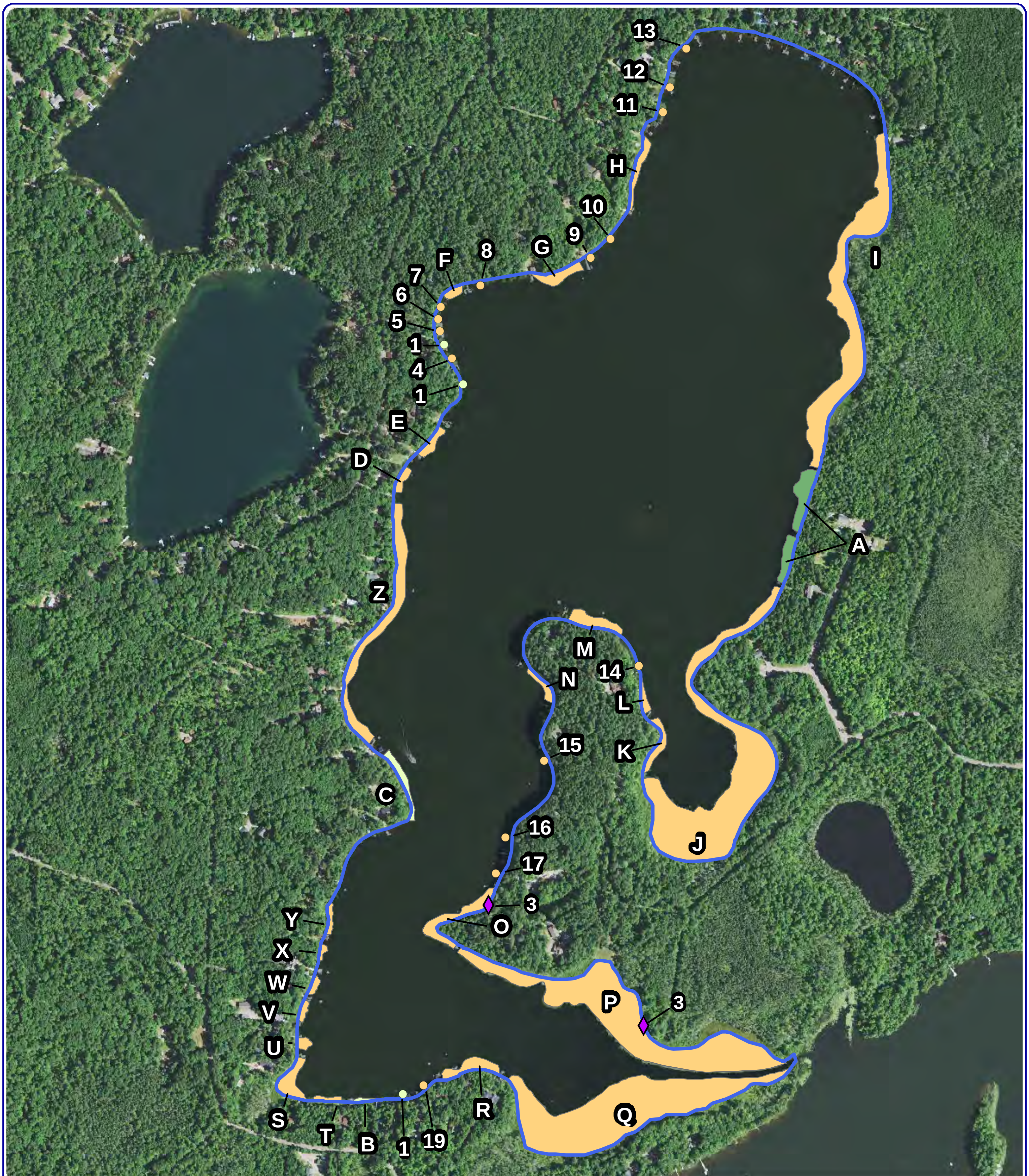
Sources
Hydro: WDNR
Aquatic Plants: Onterra, 8/14/2019
Orthophotography: NAIP, 2017
Map date: January 9, 2020 AMS
Filename: Map10_Shish_Comm_West_2019.mxd

Small Naitve Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Native Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Non-Native Plant Communities
- Narrow-leaved cattail
- Pale yellow iris
- Purple loosestrife

Map 10
Shishebogama Lake
Vilas County, Wisconsin
Emergent & Floating-leaf Aquatic Plant Communities West



N W E S

760
Feet

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Sources
Hydro: WDNR
Plant Survey: Onterra, 8/13/2019
Orthophotography: NAIP, 2017

Map date: January 7, 2020 AMS

Filename: Map11_Gunlock_Comm_2019.mxd

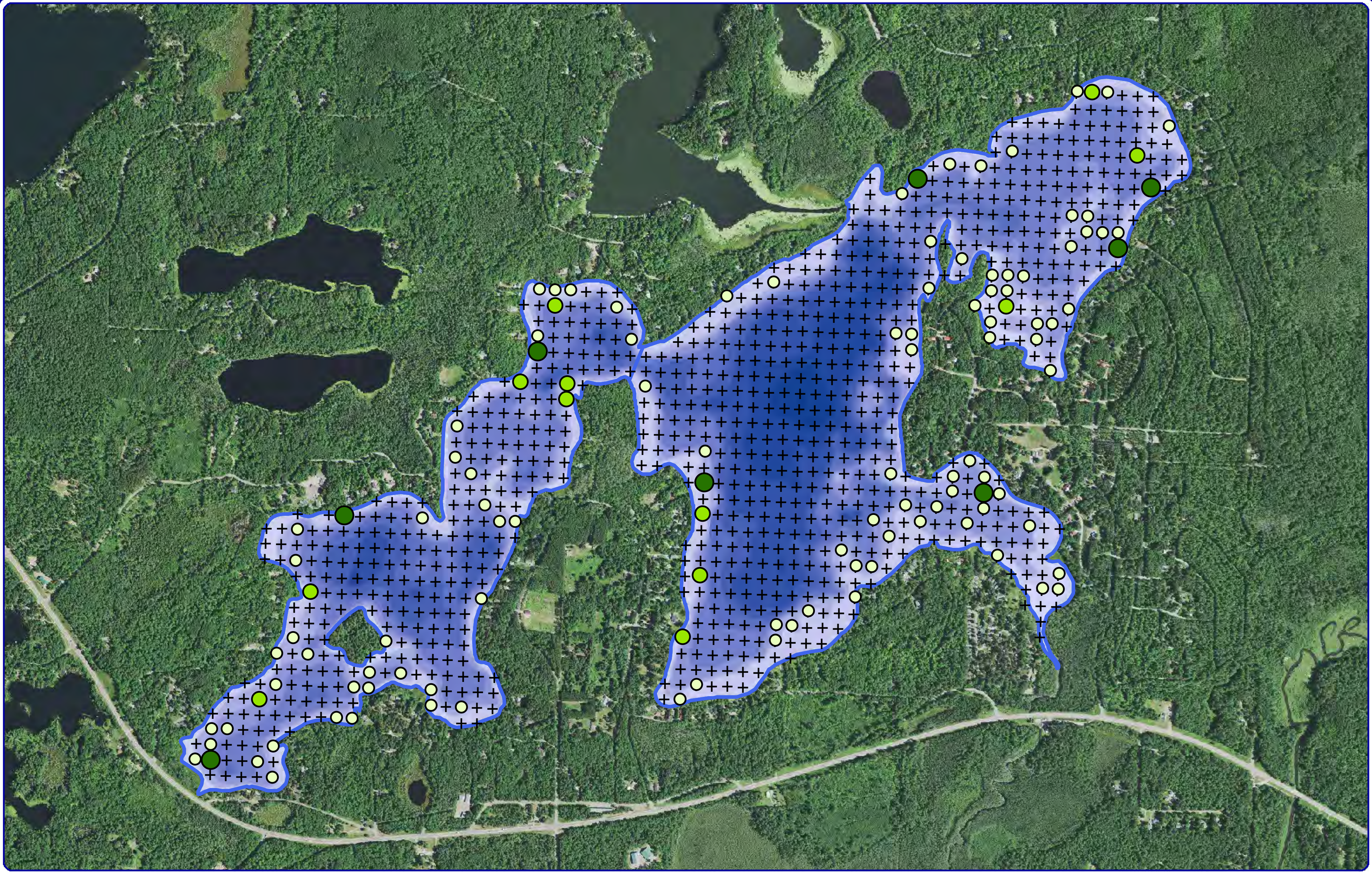
Small Naitve Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Large Native Plant Communities
- Emergent
- Floating-leaf
- Mixed Floating-leaf & Emergent

Non-Native Plant Communities
- Purple loosestrife

Map 11
Gunlock Lake
Vilas County, Wisconsin

Emergent & Floating-leaf Aquatic Plant Communities



1,400

Feet

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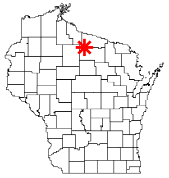
Sources
Hydro: WDNR
Shoreland Assessment: Onterra, 7/24/2019
Orthophotography: NAIP, 2015
Map date: November 6, 2019 JMB
Filename: Shish_SA_2019.mxd



Project Location in Wisconsin

Small Pondweed
Total Rake Fullness Ratings

- + No Small Pondweed Recorded
- Total Rake Fullness = 1
- Total Rake Fullness = 2
- Total Rake Fullness = 3

Map 12

Shishebogama Lake

Oneida & Vilas Counties, Wisconsin

2019 Locations of Small Pondweed
(*Potamogeton berchtoldii/pusillus*)